AutoCAD Civil 3D Hydraflow Hydrographs Extension

User's Guide

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Getting Started

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Introduction

AutoCAD Civil 3D Hydraflow Hydrographs Extension is an application for urban hydro systems engineering. You can use it for:

- Analyzing the hydrologic properties of simple and complex watersheds.
- Determining runoff from historical and synthetic storms.
- Planning or modeling flood control measures, such as detention ponds.

You can perform the following manipulations with hydrographs:

- Model entire drainage basins and detention ponds. See Using Detention Ponds on page 31.
- Instantly create a hydrograph and place it on the routing diagram, which enables you to access it at any time while you work on other tasks. See Creating Runoff Hydrographs on page 18 and Creating SCS Hydrographs on page 18.
- Edit, delete, insert, cut, copy, paste, plot, and print hydrographs. See Editing Hydrographs on page 60, Deleting Hydrographs on page 61, and Using Cut, Copy, and Paste with Hydrographs on page 61.
- Import or export any generated hydrograph. See Exporting Hydrographs on page 69.
- Add a generated hydrograph to any other previously generated hydrograph, or route it through a channel or detention pond. See Routing Channels on page 29 and Pond Routing on page 52.
- Automatically display your model in the Model or the Hydrographs view. See Plotting Hydrographs on page 68.
- Print reports on any or all of your hydrographs at any time during the session. See Printing Reports on page 62.

Help and Documentation

Use the *AutoCAD Civil 3D Hydraflow Hydrographs Extension User's Guide* and the online help to learn how to use the application.

You can access both resources from the Help menu.

- For online help, click Help menu ➤ Contents.
- For the *AutoCAD Civil 3D Hydraflow Hydrographs Extension User's Guide*, click Help menu ➤ User's Guide (PDF).

You can also open the online help from the application. Press *F1* or click the Help button in any dialog box.

Support and Sample File Locations

Hydraflow Hydrographs Extension Support and Sample Files

The following Hydraflow Hydrographs Extension support and sample files are installed with the product:

- Hydrographs.ini
- Interconnected.gpw
- NJWaterQuality.cds
- PondToolsExample.gpw
- PreandPostDevelopment2007.gpw
- Sample.cds
- Sample.pcp
- Sample2007.gpw
- TypeIIAsCustom.cds
- WatershedBasics2007.gpw

These files are installed to the following locations:

Microsoft Vista

C:\Users\<username>\AppData\Local\Autodesk\C3D2011\enu\HHApps\Hydrographs

C:\Program Files\Autodesk\AutoCAD Civil 3D 2011\UserDataCache\HHApps\Hydrographs

Microsoft XP

C:\Program Files\Autodesk\AutoCAD Civil 3D 2011\UserDataCache\HHApps

C:\Documents and Settings\<username>\Local Settings\Application Data\Autodesk\C3D2011\enu\HHApps

Sample .IDF curve files are installed to the following locations:

Microsoft Vista

C:\ProgramData\Autodesk\C3D2011\enu\HHApps\IDF

Microsoft XP

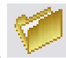
C:\Documents and Settings\All Users\Application Data\Autodesk\2011\enu\HHApps\IDF

Using Files From Previous Versions

AutoCAD Civil 3D Hydraflow Hydrographs Extension reads your legacy project files with the *.gpw* extension. After you saved the files in the Hydraflow Hydrographs Extension format, the files cannot be reloaded in earlier versions of the application. Your existing files are not backward compatible.

To open IDF (intensity-duration-frequency) curves, created with previous versions of Hydraflow Hydrographs Extension

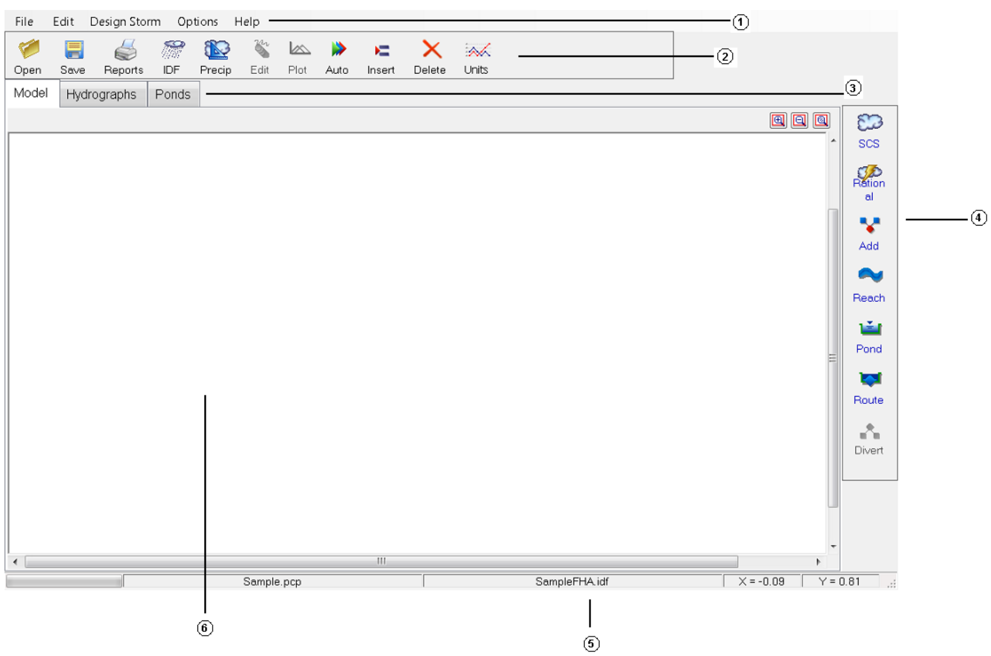
1 From the toolbar, click  (View/Edit IDF Curves).

2 In the Rainfall IDF Curve dialog box, click  (Open) and select the IDF file.

The User Interface

You perform most tasks in the main workspace, which consists of:

- Menu bar that gives you access to the full functionality of the application.
- Toolbar that contains icons that give access to the most common application commands.
- Toolbox that contains icons that give access to the hydrograph-related commands.
- Status bar that displays the progress bar, the rainfall IDF file name, and the Event Manager file name.



(1) Menu bar	(3) Workspace view tabs	(5) Status bar
(2) Toolbar	(4) Toolbox	(6) Workspace

Choose from the following workspace views:

- Model view - displays the routing diagram and the connectivity of the individual hydrographs.
- Hydrographs view - displays the same information as the Model view, but in a numeric or a spreadsheet format. This view is used most often.
- Ponds view - displays a list of existing ponds and gives you access to the pond creation tools, settings, and editing controls.

Hydrograph Creating Workflow

You add or create hydrographs, one at a time, starting from the highest upstream basin and working downstream. You can use both Model and Hydrographs views.

To create a hydrograph

1. In the Hydrographs view, click an empty row.
2. On the toolbox, click  (Create SCS Hydrograph) or  (Create Rational Method Hydrograph).
3. Enter the required data.

In the Model view, follow steps 2 to 3. Hydraflow Hydrographs Extension automatically increments the number for each hydrograph you create.

You can generate a maximum of 99 hydrographs. Each hydrograph can contain up to eight return periods for a total of 792. Each hydrograph is identified by a number between 1 and 99. Hydrograph numbers increase as you work downstream. Hydraflow Hydrographs Extension maintains this numbering system in order to properly construct the routing diagram.

See also:

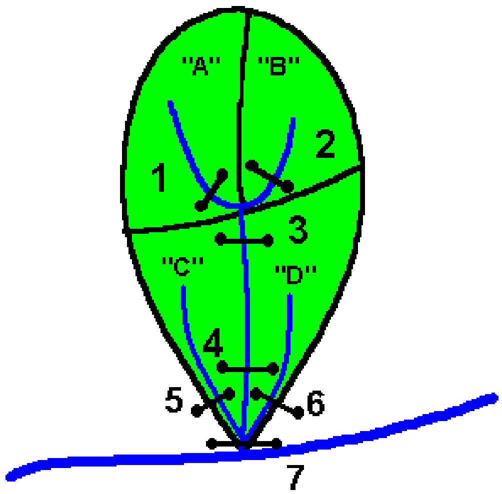
- Creating Runoff Hydrographs on page 18
- Creating SCS Hydrographs on page 18
- Creating Rational Method Hydrographs on page 22

Automatic Batch Processing

Since each hydrograph can hold up to eight return periods, you do not have to create additional hydrographs to account for the two-, ten-, and 100-year frequencies. Hydraflow Hydrographs Extension does this automatically, each time you create a new hydrograph. You can activate or deactivate desired frequencies from the Hydraflow Hydrographs Extension Event Manager. See Setting Up the Event Manager on page 17.

Watershed Modeling Workflow

You simulate watersheds by selecting the appropriate functions from the toolbar in the order of the subbasin connectivity. Begin at the uppermost subbasin and work downstream. You must have a basic understanding of hydrology and how to delineate the various subbasins. The following illustration shows a simple watershed. It consists of four subbasins (A, B, C, and D), and an intermediate channel.



The following procedure contains the high-level steps involved in developing a watershed model. The objective is to develop the downstream hydrograph which outfalls into the lower horizontal channel (7). For details on the particular data input, such as drainage areas and runoff curve numbers (CNs), see Running Hydraflow Hydrographs Extension on page 13.

To model a watershed

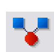
1. On the toolbox, click  (Create SCS Hydrograph) or  (Create Rational Method Hydrograph).
2. In the SCS Runoff Hydrograph or Rational Method Hydrograph dialog box, enter the required data for hydrograph 1 and click OK.
3. Click Results to display a hydrograph plot.
4. Click Exit and then click the Model tab.

   The hydrograph 1 icon appears in the workspace.

   NOTE Hydraflow Hydrographs Extension automatically updates the model as you add hydrographs.

5. Click anywhere on the white space to increment the hydrograph number and repeat steps 1-4.

   The hydrograph 2 icon appears in the workspace.

6. On the toolbox, click  (Combine Multiple Hydrographs).
7. In the Combine Hydrographs dialog box, select hydrographs 1 and 2 and click OK.
8. Click Exit.

   Hydraflow Hydrographs Extension combines hydrographs 1 and 2 and displays the updated model.

9. Click anywhere in the white space to increment the hydrograph number and then click  (Route Hydrograph Through Channel).
10. In the Reach dialog box, enter the required data for hydrograph 4, specify hydrograph 3 as Inflow Hyd. No. and click OK.
11. Click Exit to return to the Model view.

    Hydraflow Hydrographs Extension adds hydrograph 4 to the model.

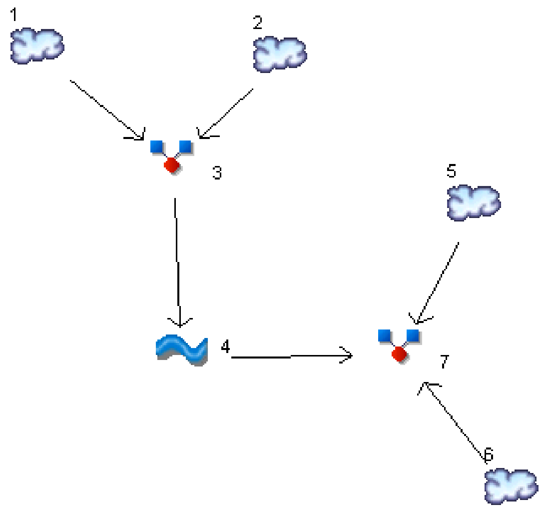
12. Follow steps 1 to 5 to create hydrographs 5 and 6 for subbasins C and D.

AutoCAD Civil 3D Hydraflow Hydrographs Extension adds hydrographs 5 and 6 to the model.

NOTE You can rearrange the icons in the Model view by dragging them with your right mouse button.

13 Follow steps 6 to 8 to combine hydrographs 4, 5, and 6.

The following illustration shows the final model (with minor layout modifications):



NOTE You can set up a hydrograph using the Hydrographs view. Follow the same steps as in the model view, but click in an empty table row to assign a number to your hydrograph. In the Hydrographs view, you can select any row as long as each consecutive hydrograph number is greater than the previous one.

Setting Up Pre- and Post-Development Models

Most often, you use Hydraflow Hydrographs Extension to create and model watersheds in connection with urban land development. Generally, you will have the task of designing a detention pond in order to attenuate the flows from the post-developed state to that of the pre-developed. Hydraflow Hydrographs Extension has many options to accomplish these tasks, including the interactive pond tools. There are four basic steps:

1. Create a pre-developed hydrograph.
2. Create a post-developed hydrograph.
3. Set up a detention pond.
4. Route the post-developed hydrograph through the pond to create the outflow hydrograph.

Try to limit the peak outflow (Qp) to that of the hydrograph developed in step 1.

Use the sample project file, *PreandPostDevelopment2007.gpw*in the following procedure that demonstrates a high-level overview of creating pre- and post-development models. For sample file locations, see Support and Sample File Locations on page 2. For details on refining the pre- and post-development models, see Refining Pre- and Post-Development Models on page 49.

Given:

Drainage area = 4.5 acres

Pre-developed

C = 0.55 (the Rational method is used)

Tc = 35 minutes

Post-developed

C = 0.85

Tc = 20 minutes

To create a pre- and post-development model

1 On the toolbox, click  (Create Rational Method Hydrograph).

2 In the Rational Method Hydrograph dialog box, enter the required data.

3 Click OK and then Exit.

4 Optionally, you can click Results to view the plotted hydrograph.

5 Follow steps 1-4 to create a post-developed hydrograph.

NOTE If the toolbox icons are unavailable, click anywhere in the workspace to increment the hydrograph number.

The following table shows the values for pre- and post-developed peak flow (Qp). The goal is to create a detention pond that reduces the post-developed flows to that of the pre-developed condition:

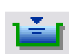
Return Period	2	10	100
Pre Qp	6.05	8.49	12.24
Post Qp	12.91	17.57	24.86

Consider the following data given based on the physical site conditions:

Outflow culvert length = 25 ft @ 0.50 % slope.

Pond side slopes = 2:1.

Allowable pond depth = 5 feet with 2-ft freeboard.

6 On the toolbox, click  (Add/Edit Detention Pond).

7 To develop the stage-storage relationship for a uniform-shaped pond, in the Stage / Storage / Discharge Setup dialog box, click Trapezoid.

8 Enter the data as follows and click Apply.

Item	Input
Storage Type	Trapezoid
Bottom Elev. (ft)	600
Bottom Length (ft)	50.00
Bottom Width (ft)	50.00
Side Slope, z:1	2.00
Depth (ft)	7.00

Item	Input
Voids (%)	100.00

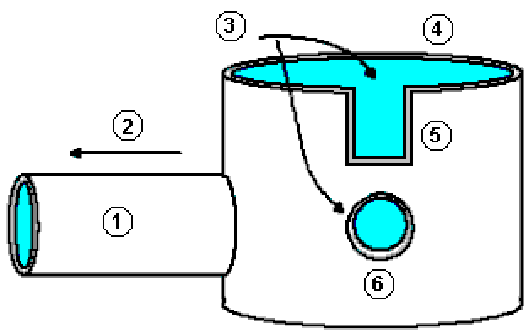
9 Optionally, enter a name for the pond.

Hydraflow Hydrographs Extension computes a stage-storage table.

10 Click the Outlets tab to set up the pond outlet structure for the stage-discharge curve.

11 Enter the data for the outlet structures as shown below.

NOTE The size and placement of these outlet structures have been previously designed to meet the target Qs established above using the Interactive Pond Tools. See Using the Interactive Pond Tools on page 48.



(1) Culvert A	(3) Inflow	(5) Weir B
(2) Outflow	(4) Weir A - Riser	(6) Culvert B

This device contains a 15-in culvert, 15-in orifice, an 8-ft riser weir and a 1.3-ft rectangular secondary weir. Culverts, orifices, and weirs are entered as follows.

Culv/Orifice	A	B	C	Prf Riser
Rise (in)	15	15	-	-
Span (in)	15	15	-	-
No. Barrels	1	1	-	-
Invert Elev. (ft)	600	600.01	-	-
Length (ft)	25	0	-	-
Slope (%)	0.5	0	-	-
N-Value	0.013	0.013	0.013	-
Orifice Coeff.	0.6	0.6	0.6	0.6
Multi-Stage	n/a	Yes	No	No

Culv/Orifice	A	B	C	Prf Riser
Active	Yes	Yes	Yes	Yes

Weirs	A	B	C	D
Weir Type	Riser	Rectang	Choose...	Choose...
Crest Elev. (ft)	603.55	602.80	-	-
Crest Length (ft)	8.00	1.30	-	-
Weir Coeff.	3.33	3.33	3.33	3.33
Multi-Stage	Yes	Yes	No	No
Active	Yes	Yes	Yes	Yes

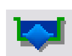
NOTE Click Yes for the multi-stage option. By default, the flow from a multi-stage structure is directed through Culvert A.

12 Click Compute.

Hydraflow Hydrographs Extension calculates the stage-discharge curve using the structure data provided. It will use the stage-storage data as a basis for the calculation increments.

13 Click Exit to return to the workspace.

14 To route the post-developed hydrograph through the pond, click anywhere in the workspace.

15 On the toolbox, click  (Route Hydrograph Through Pond).

16 In the Reservoir Route dialog box, enter the following data.

Description	Pond Route
Inflow Hydrograph	2 - Rational - Post-developed
Pond Name	1. My Pond
Lower Pond	-
Wet Pond Elevation	600.00 - Stage 0, Dry pond

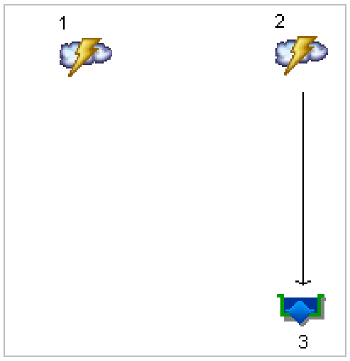
17 Click OK.

18 Click Results to view the routed hydrograph.

19 In the Hydrograph Plot dialog box, select the required return period option to view the respective graph.

20 Click  (Exit) to return to the workspace.

21 Your model appears as follows.



NOTE Detention ponds are not part of the watershed schematic.

See also:

- Refining Pre- and Post-Development Models on page 49

Printing the Output

You can generate and print reports of your projects. The reports may include summary data, point-by-point numerical hydrograph data and the associated graphical plots.

To print a detailed report

1. On the toolbar, click  (Open Reports Menu).
2. In the Reports Print Menu dialog box on page 63, customize the report and enter the required data.

You can also print the onscreen images of the plots along with summary input data.

IMPORTANT The primary working units of Hydraflow Hydrographs Extension are English units. However, you can output your reports either in English or SI units. You can also display and print the plots in both systems of measurement.

See also:

- Printing Reports on page 62

Before You Begin

Before you start working on your project, familiarize yourself with the functionality of the application. Hydraflow Hydrographs Extension is installed with sample project files. For information on the location of the sample files, see Support and Sample File Locations on page 2. For example, *Sample2007.gpw* has a sample watershed that includes the features you use for creating runoff hydrographs, combining hydrographs, routing channels, creating a detention pond, and diverting a hydrograph. You can do the following:

- Double-click each of the hydrographs to view the input data that was used.
- On the toolbar, click  (Open Event Manager). In the Event Manager you activate the return periods to work with and their respective precipitation values. You need to do this only once. Hydraflow

Hydrographs Extension saves this data and uses it each time you create a hydrograph. See Setting Up the Event Manager on page 17.

- If you plan to use the Rational method or the synthetic storm option (recommended), set up your IDF curves. See Setting Up IDF Curves on page 13.

Running Hydraflow Hydrographs Extension

2

Setting Up IDF Curves

Hydraflow Hydrographs Extension automatically computes the rainfall intensity from its own IDF curves for use in the rational method and when using synthetic storm distributions in the SCS method. To make the calculations work, you must provide data so that the new curves match the current ones. Hydraflow Hydrographs Extension comes with sample IDF curve files *SampleFHA.IDF* and *FLZone1.IDF*. For information on sample file location, see Support and Sample File Locations on page 2. You can use these files while learning the program.

After you enter the data, Hydraflow Hydrographs Extension stores the IDF curves in the corresponding file. IDF curves are automatically loaded at startup. During calculations, Hydraflow Hydrographs Extension uses the IDF curve data along with the computed time of concentration (Tc) to compute the intensity.

To view the existing IDF curves

- On the toolbar, click  (View/Edit IDF Curves).

Hydraflow Hydrographs Extension can store an unlimited number of rainfall files for various jobs or locations. These IDF curves can be loaded for use at any time.

To create your own IDF curves

1. Click Design Storm menu ➤ I-D-F Curves.
2. Enter points from the existing IDF curves or create them from map data.

Setting Up IDF Curves Using Existing Data

Use this method if you get your data from the new National Oceanic and Atmospheric Administration (NOAA) Atlas 14. Follow the Atlas updates for the most up-to-date information. This method is suitable for the Western states included in the latest NOAA Atlas 14. Use the provided intensity values.

To setup your curves to match existing IDF data

1 Click Design Storm menu ➤ I-D-F Curves ➤ View Current File or click  (View/Edit IDF Curves).

The current IDF curve displays.

2 Click the IDF Table tab.

The Intermediate Intensity Values table appears.

Hydraflow Hydrographs Extension allows you to set up curves that match your existing IDF data. The required data consists of the intensity values in inches per hour, for the 5-, 15-, 30-, and 60-minute durations corresponding to the 1-, 2-, 3-, 5-, 10-, 25-, 50-, and 100-year storms. Any return period data can be left blank. For example, if you do not have one-year data, leave the first row blank.

3 Click Clear to remove the existing data.

4 Enter the corresponding intensity amounts in inches per hour or centimeters per hour from your intensity-duration-frequency curves. You must enter all of the data for each return period used.

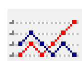
5 Click OK.

Hydraflow Hydrographs Extension calculates the corresponding rainfall intensity equation coefficients. See Viewing and Editing IDF Curves on page 16.

Working in SI Units

AutoCAD Civil 3D Hydraflow Hydrographs Extension is designed to operate in either U.S. Customary or SI units. All input data is entered in the current units setting. At any time, you can switch the current units setting, and the program automatically performs a data conversion.

To change units

1 In the main application window, click  (Units) on the toolbar.

2 Click U.S. Customary or SI.

Selecting SI as the unit type allows you to enter metric values.

TIP If you need to create a straight-line graph to represent rainfall data, see Entering Rainfall Data at a Constant Rate on page 14.

Entering Rainfall Data at a Constant Rate

In situations where you need to create a straight-line graph to represent constant rainfall, you can use the FHA equation and manipulate the values.

To create a constant rate graph

1 Click  on the toolbar.

2 In the Rainfall IDF Curve dialog box, click the Coefficients tab and then click FHA.

There are three coefficients in this equation, B, D, and E.

Enter a value of 0 for coefficients D and E. The B value represents the intensity in inches/hour. The resulting graph is a straight-line graph that you would expect from a constant rate.

Creating IDF Curves from Map Data

You can generate IDF curves from the National Weather Service (NWS) precipitation data. Hydraflow Hydrographs Extension uses the computational procedure described in the US Department of Transportation FHA Circular No. 12, Drainage of Highway Pavements.

When using Hydro-35 data or existing curves, Hydraflow Hydrographs Extension manipulates your input data to generate coefficients B, D, and E for use in the intensity vs. time of concentration (Tc) equation.

$$I = \frac{B}{(Tc + D)^E}$$

Where:

I = rainfall intensity (in/hr)

Tc = time of concentration

B = coefficient

D = coefficient

E = coefficient

The required data can be precipitation values from NWS Hydro-35 (Eastern United States) or NOAA Atlas (Western United States) or the latest NOAA Atlas 14. Hydro-35 and the NOAA Atlases may be available from the National Technical Information Service (NTIS), publication number PB272112 (Hydro-35).

To generate IDF curves from map data

1. Click Design Storm menu ➤ I-D-F Curves ➤ Create New from Map Data ➤ Eastern States / Western States.
2. Do one of the following:
   - If you are located in the Eastern and Central United States, use the precipitation data from NWS Hydro-35 or NOAA Atlas 14. The values are in total inches, not inches per hour (in/hr) and consist of the five-, 15-, and 60-minute durations corresponding to the two-year and 100-year frequencies. In the Build I-D-F Curves From Hydro-35 Data dialog box, enter the precipitation amounts and click OK.

     Hydraflow Hydrographs Extension calculates the corresponding rainfall intensity equation coefficients.

     NOTE Consult the Precipitation Frequency Data Server (PFDS) website or to get your local rainfall data.

   - If you are located in the Western United States, use the precipitation data for your state from the NOAA Atlas. The values are in total inches, not inches per hour (in/hr) and consist of the six-hour and 24-hour durations corresponding to the two-year and 100-year frequencies. You also need the average elevation (in feet).
     In the Build I-D-F Curves From NOAA Atlas dialog box, enter the precipitation amounts and the average ground elevation for the area. For example, the average ground elevation for Colorado Springs, Colorado could be 6000.
3. Click OK.

   Hydraflow Hydrographs Extension calculates the corresponding rainfall intensity equation coefficients.

Creating Polynomial-Based Curves

Some regions have IDF curves that are based on a third-degree polynomial equation. These IDF curves typically do not plot as a straight line on log-log scales. You can create IDF curves using a third-degree polynomial equation as follows:

$$I = A + Bx + Cx^2 + Dx^3$$

Where:

I = rainfall intensity (in/hr)

X = Ln (time duration: from 8 to 180 minutes)

A = coefficient

B = coefficient

C = coefficient

D = coefficient

To create polynomial-based curves

1. Click Design Storms menu ➤ I-D-F Curves ➤ View Current File or on the toolbar, click (View/Edit IDF Curves).

   A graph appears showing the current IDF curve.
2. In the Rainfall IDF Curve dialog box, click the Coefficients tab.
3. Click the Poly tab to make sure the table is in the polynomial mode.

   The Intensity values table appears.
4. Click Clear to remove the existing data and then enter your data in the appropriate fields.
5. Click OK.
6. Click the IDF Graph tab to view the curves.

Viewing and Editing IDF Curves

Hydraflow Hydrographs Extension always generates equation coefficients and a graphical display of the IDF curves. To view this data, on the toolbar, click (View/Edit IDF Curves).

In the Rainfall IDF Curve dialog box, you can:

- Edit the equation coefficients.
- Save the current IDF file.
- Open a previously saved IDF file.
- Print a hard copy of the plot or get a numerical report of the IDF data.

To edit the equation coefficients

1. Click the Coefficients tab.
2. Click in any table cell and enter the value.

3 Click OK.

4 To see the effect of the change on the plot, click the IDF Graph tab.

After the IDF curve has been generated, save the file. The number of IDF curve files that you can save is limited only by the amount of free disk space.

To save an IDF file

1 In the Rainfall IDF Curve dialog box, click .

2 Specify the file name and location.

NOTE Save this file in the location where you installed Hydraflow Hydrographs Extension, because this is the default location from where Hydraflow Hydrographs Extension loads this file when started.

To print the curves graph

1 In the Rainfall IDF Curve dialog box, click .

2 In the Graphs Print Menu dialog box, specify the printing options: select Numerical Report to get a numeric version of the report. See Printing Reports on page 62.

3 Click Print.

To open an existing curve

1 In the Rainfall IDF Curve dialog box, click .

2 Select the IDF file to load.

3 Click OK.

The new plot appears along with its corresponding numeric data.

4 Click (Exit) to return to the main menu.

Hydraflow Hydrographs Extension uses the loaded IDF curve in all subsequent calculations. The name of the current IDF curve is displayed on printed reports. When you exit Hydraflow Hydrographs Extension, this file is saved and then reloaded the next time you start Hydraflow Hydrographs Extension.

Setting Up the Event Manager

Use the Event Manager to enter data and perform automatic processing of multiple return periods. Each hydrograph you create is calculated for each activated frequency using the corresponding precipitation values entered in the Event Manager. You can save the event file for loading at a later time. When you exit Hydraflow Hydrographs Extension, event files are automatically saved, and then reloaded on start-up.

NOTE The *.pcp* event files are embedded in the *.gpw* project files. You do not need to attach the associated event file to the *.gpw* project file when you send it to a third party.

To set up the Event Manager

1 On the toolbar, click (Open Even Manager).

2 Select the corresponding Active check box to activate or deactivate the return periods that you want Hydraflow Hydrographs Extension to automatically calculate.

For example, if you select 2 and 10, for each type hydrograph you create, Hydraflow Hydrographs Extension calculates the return period for the 2-year and 10-year frequencies automatically.

TIP For better performance, activate only the frequencies that you are going to use.

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3 Enter the precipitation values you typically use for the activated return periods for each of the storm distribution types you plan to use.

TIP If you do not plan to use the Huff distributions, leave those boxes blank. Rational Method hydrographs use the IDF curves, so you do not need to enter data.

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4 Click Apply and then click  (Save These Settings).

TIP Save the event file in the folder where you installed the program, because Hydraflow Hydrographs Extension loads this file on start-up. An event file has a *.pcp* extension and the file name appears on the status bar.

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5 To open a previously saved event file, in the Event Manager dialog box, click  (Open .pcp File).

Creating Runoff Hydrographs

After you set up IDF curves and event files, you can start creating hydrographs. In the watershed, you work from the upstream point to the downstream point.

As you work downstream, Hydraflow Hydrographs Extension automatically calculates the activated return periods and displays the model in the Model or Hydrographs view. At any time, you can print hydrograph reports. See Printing Reports on page 62.

NOTE While in the Hydrographs view, you can select any of the unused hydrograph rows for your next hydrograph, but while in the Model view, Hydraflow Hydrographs Extension automatically increments the hydrograph number.

Creating SCS Hydrographs

The Soil Conservation Service (SCS) (now known as National Resources Conservation Service [NRCS]) hydrologic methods are widely used for the analysis of large and small watersheds. In the United States, this method is often required for projects that need state approval. The SCS methods are also being used internationally. The unit hydrograph method and a known design storm allow you to generate an accurate hydrograph.

About Unit Hydrographs

A unit hydrograph is a hydrograph that results from one inch of excess rainfall on a watershed over a given time interval.

IMPORTANT A unit hydrograph is not the final runoff hydrograph. It only reflects the watershed characteristics and geologic factors.

With a known unit hydrograph of a watershed, you can apply any design storm and compute the final runoff hydrograph. Many hydrologists use the SCS 24-hour storms, but any storm of any length can be used with the unit hydrograph method. The Bulletin 71, Huff, and Hydraflow Hydrographs Extension synthetic distributions are other examples.

Hydraflow Hydrographs Extension computes SCS runoff hydrographs by convoluting rainfall hyetograph through a unit hydrograph. This method is also used in SCS TR-20. Convolution is known as linear superpositioning, and means that each ordinate of the rainfall hyetograph is multiplied by each ordinate of the unit hydrograph, thus creating a series of smaller hydrographs. These hydrographs are then summed to form the final runoff hydrograph. For example, if the rainfall hyetograph (design storm) contained 1,440 ordinates and the unit hydrograph contained 30, then a total of 43,200 ordinates (1,440 x 30) would have to be computed before reaching the final hydrograph. This method is highly accurate, but not very practical without the use of a computer.

RELATED Many projects contain small watersheds with short times of concentration (Tc). Since the time interval (unit duration) of the unit hydrograph should be 0.133(Tc), a great number of ordinates will be required to perform the convolution when modeling long design storms such as the SCS 24-hour storms. A drainage basin with Tc of 30 minutes requires a time interval of four minutes, 0.1333(30). The resulting hydrograph, when using a 24-hour storm, needs at least 360 ordinates (1,440 minutes / 4). Hydraflow Hydrographs Extension can use up to 2,880 points for each hydrograph, allowing you to model very small watersheds (with Tc as low as two minutes) while using a 24-hour storm with accuracy that is difficult to obtain by shortcut methods. Hydraflow Hydrographs Extension creates its design storms compatible with the selected time interval of the final hydrograph. This enables you to achieve the highest degree of accuracy and eliminates any interpolation between fixed ordinates or the need to convert the final hydrograph to match the time interval.

To create an SCS Runoff hydrograph

1. Click Edit menu ➤ Runoff Hyd. ➤ SCS Method or on the toolbox, click  (Create SCS Hydrograph).
2. In the SCS Runoff Hydrograph dialog box, enter the required data. See SCS Runoff Hydrograph dialog box on page 19.
3. Click OK.
   Hydraflow Hydrographs Extension plots the unit hydrograph on page 18.
4. Click Results to view the hydrograph.

There are three methods of computing Tc, including a user-defined Tc and a number of built-in design storms. See Computing Tc by TR-55 on page 21.

See also:

- SCS Runoff Hydrograph dialog box on page 19

SCS Runoff Hydrograph Dialog Box

Use this dialog box to create hydrographs using the SCS method.

Descr.

Specifies a name or any description for the hydrograph. This information appears in the printed reports.

Basin Data

Drainage Area (Ac)

Specifies the subbasin area in acres.

Curve Number (CN)

Specifies the SCS Curve Number for this area. See Reference Tables on page 91 for coefficient values.

For a composite CN, click 

(Compute Composite CN). You can enter up to six drainage areas and corresponding CNs for a composite CN.

Time of Concentration

Time of concentration (Tc) is the time it takes for runoff to travel from the most remote upstream point in the drainage area to the downstream point in question. There are four methods for computing Tc. See Computing Time of Concentration on page 75. Hydraflow Hydrographs Extension automatically computes Tc, except if you select User as the method of computing Tc.

Lag

Select to use the Lag method, the TR-20 default method.

Kirpich

Select to use the Kirpich method. This method is normally used for natural basins with well defined routes for overland flow along bare earth or mowed grass roadside channels. It is similar to the Lag method but typically yields shorter times.

User

Select to override the computed Tc and enter the value manually.

TR-55

Select to compute Tc by using three components as implemented by TR-55. Hydraflow Hydrographs Extension has a built-in TR-55 worksheet that computes Tc. See Computing Tc by TR-55 on page 21.

Basin Slope (%)

Specifies the average basin slope in percent. This value is required only if you selected Lag or Kirpich methods.

Hydraulic Length (Ft)

Specifies the distance, in feet, from the most remote point in the drainage area to the catchment point. This value is required only if you selected Lag or Kirpich methods.

Time of Conc. (Min)

Specifies Tc. This control is available only if you selected User as the method for computing Tc.

Hydrologic Data

Time Interval (Min.)

Select a time interval for the hydrograph. If you plan to combine this with other hydrographs, use the same time interval as those you plan to combine. Typically, the smaller the time unit the more accurate the resulting hydrograph is. Hydraflow Hydrographs Extension can use up to 2,880 points for each hydrograph. Therefore a time interval of two minutes spans 96 hours.

Storm Distribution

Select the type of storm distribution. Types I, IA, II, and III are built-in 24-hr SCS storm distributions. The SBUH typically uses type IA storm. Select Custom to use the current custom design storm file. See Design Storms on page 65.

Storm Duration (Hrs.)

If you are using the synthetic or Huff storm distribution, enter the total storm duration in hours (typically about twice the anticipated time of concentration (Tc)). This option is available when Synthetic or Huff are selected. It reads 24 or 6 hours when you selected any of the SCS distributions.

Unit Hydrograph

Displays the unit hydrograph on page 18.

Options

Shape Factor

This value is usually 484. It can become smaller in coastal regions. Check local ordinances, but this value should typically stay at 484. See SCS Runoff Hydrographs computational methods on page 80.

Return Period/Precip

You don't have to select a return period or enter the precipitation value, as they are already set in the Event Manager. To verify these settings, click (Open Event Mgr).

Related procedures:

- Creating SCS Hydrographs on page 18.

Computing Tc by TR-55

Hydraflow Hydrographs Extension contains a built-in TR-55 worksheet that computes time of concentration (Tc). This method computes Tc by adding the travel times of sheet flow, shallow concentrated flow and open channel flow from each of the components A, B and C, as described in *Technical Release 55 (TR-55) Urban Hydrology for Small Watersheds*.

To compute time of concentration using the TR-55 method

1. On the toolbox, click (Create SCS Hydrograph).
2. In the SCS Runoff Hydrograph dialog box, select TR55 as a time of concentration option.
3. Click (Open TR55 Worksheet).
4. In the TR-55 Tc Worksheet dialog box, enter the required data. See TR-55 Tc Worksheet Dialog Box on page 21.
5. Click Compute.

   Hydraflow Hydrographs Extension computes Tc and travel times for each segment.
6. Optionally, click Print to print a worksheet report.

   NOTE You can also include this report in the set of formal hydrograph reports, so it is not necessary to print it now. See Printing Reports on page 62.
7. Click Exit.

   Hydraflow Hydrographs Extension returns to the SCS Runoff Hydrograph dialog box and uses the computed Tc value.

See also:

- TR-55 Tc Worksheet Dialog Box on page 21

TR-55 Tc Worksheet Dialog Box

Use this dialog box to compute time of concentration (Tc) using the TR-55 method.

You can specify up to three components for each flow type: areas A, B, and C. These values are saved in the GPW project file.

Sheet Flow

Sheet flow is flow over plane surfaces usually in the upper reaches of the drainage area.

A typical Manning's n-value of 0.001is used for smooth surfaces such as concrete, asphalt or bare soil. Dense grasses yield 0.24, Bermuda grass 0.41, while woods range from 0.40 to 0.80 depending on the underbrush.

NOTE This method for computing sheet flow is limited to a flow length of 300 feet or less. After 300 feet, sheet flow turns to shallow concentrated flow.

Shallow Concentrated Flow

This flow segment is best described as the surface between sheet flow and open channel flow. Hydraflow Hydrographs Extension automatically computes the average velocity based on the watercourse slope and surface type, either paved or unpaved.

Channel Flow

For these data items, it is assumed the channel is bank full. Hydraflow Hydrographs Extension automatically computes the average velocity.

Related procedures:

- Computing Tc by TR-55 on page 21.

Creating Rational Method Hydrographs

The Rational method of creating hydrographs is a simple and easy to understand. The formula is accurate up to 200 acres, but it is recommended for use on 20 acres or less.

The formula, Q = CiA, was developed from a simplified analysis of runoff, and assumes there is no temporary storage of water on the surface of the drainage area. On a perfectly impervious surface, C = 1.00, and 1 inch per hour rainfall over 1 acre produces flow rate of 1 cubic foot per second (cfs).

If the duration of the rainfall equals time of concentration (Tc), the hydrograph reaches a peak of Ci, expressed as cubic feet per second per unit area. If the rainfall duration is longer than Tc, the hydrograph remains constant after reaching this peak and continues on at this peak for a time equal to (rainfall duration - Tc). In either case, the time to rise and time to recess is always equal to Tc. Therefore, you can easily attest to the shape of this well-known hydrograph as an isosceles triangle with a time base equal to twice Tc.

There are several Rational Method hydrographs. Hydraflow Hydrographs Extension uses the following types:

- Standard Rational with optional ascending and receding limb factors.
- Modified Rational.
- Dekalb Rational, developed for Dekalb (Atlanta) County, Georgia.

To create a Rational method hydrograph

1. In the Hydrographs view, click an empty hydrograph row, or in the Model view, click in the workspace.
2. Click Edit menu ➤ Runoff Hyd. ➤ Rational Method or on the toolbox, click  (Create Rational Method Hydrograph).
3. Select a hydrograph creation method (Standard Rational, Modified Rational, or Decalb Rational).
4. Enter the required basin data. See Rational Method Hydrograph dialog box on page 23.

NOTE Hydraflow Hydrographs Extension automatically sets the time interval to one minute when calculating Rational Method hydrographs. However, with 2,880 available points, Hydraflow Hydrographs Extension can provide 48 hours of coverage.

5 Select a method for computing Tc and do one of the following:
   - If you selected User, enter the Tc value in the respective field.
   - If you selected FAA, click FAA (Open Tc Worksheet) and in the Tc by FAA Method dialog box, enter the required data.
   - If you selected TR-55, click (Open Tc Worksheet), and in the TR-55 Tc Worksheet dialog box, enter the required data.
     Hydraflow Hydrographs Extension computes the hydrograph.

6 Under Options, enter the limb factors. See Rational Method Hydrograph dialog box on page 23.

7 Optionally, click Results to view the plotted hydrograph.

8 Click OK to generate the hydrograph and then click Exit to return to the initial view.

See also:

- Rational Method Hydrograph dialog box on page 23

Rational Method Hydrograph Dialog Box

Use this dialog box to create hydrographs using the Rational Method.

Descr.

Specifies the name or the description of the hydrograph. This information appears in the printed reports.

Std. Rational

Specifies Standard Rational as the method for creating a hydrograph, where peak flow (Qp) = CiA.

Mod. Rational

Specifies Modified Rational as the method for creating a hydrograph. This method takes the Standard Rational to a different level in order to yield a hydrograph for use in detention pond design. According to the Rational Method, the highest Qp occurs when the rainfall duration equals time of concentration (Tc). When the rainfall duration is greater than Tc, the Qp is reduced, and the total runoff volume is increased. This greater volume can increase the required size of a detention pond.
The objective is to find the total duration (critical storm event) that maximizes the required storage of a detention pond. You modify the Storm Duration factor between successive routings to arrive at the critical event.

Decalb

Specifies Decalb Rational as the method for creating a hydrograph. This is a modified version of the Standard Rational Method and was developed by Dekalb County, Georgia. See Decalb Rational calculation method on page 82.

Basin Data

Drainage Area (Ac)

Specifies the subbasin area in acres.

Runoff Coeff. (C)

Specifies the runoff coefficient (C) for the area. See Reference Tables on page 91 for coefficient values.

For a composite coefficient (C), click (Compute Composite C). You can enter up to six drainage areas and the corresponding C-values for a composite runoff coefficient.

Tc method

Specifies a method for computing time of concentration (Tc):

- User — Select to specify a value.
- FAA — Select to compute Tc using the data collected from airfield drainage by the Army Corps of Engineers.
- TR55 — Select to compute Tc by using the three-component Tc as used by TR-55. Hydraflow Hydrographs Extension has a built-in TR-55 worksheet that computes Tc. See Computing Tc by TR-55 on page 21.

NOTE If you plan to model an entire watershed using the Rational Method, use a single common Tc for all runoff hydrographs. Similar to storm sewer design, the Tc should be equal to the highest of all connecting areas.

Time of Conc. (Min.)

Specifies time of concentration (Tc). Tc is the time it takes for runoff to travel from the most remote upstream point in the drainage area to the downstream point in question.

Options

Ascending Limb Factor

This factor is normally 1 and is applied to the ascending side of the hydrograph. The ascending limb is equal to Tc x Ascending Limb Factor (ALF). For example, if ALF = 1.5, the ascending side of the hydrograph is 1.5 x Tc. This option is available only if you selected Std. Rational.
See also computational methods for the Rational Method hydrographs on page 81.

Receding Limb Factor

This factor is normally 1 and is applied to the receding side of the hydrograph. The receding limb is equal to Tc x Receding Limb Factor (RLF). For example, if RLF = 2, the receding side of the hydrograph is 2 x Tc. This option is available only if you selected Std. Rational.
See also computational methods for the Rational Method hydrographs on page 81.

Related procedures:

- Creating Rational Method Hydrographs on page 22

Creating SBUH Hydrographs

The SBUH (Santa Barbara Urban Hydrograph) Method is derived from the conventional SCS unit hydrograph method for use in the Northwest United States, and typically uses the SCS Type 1A storm distribution.

To create an SBUH method runoff hydrograph

1. In the Hydrographs view, click an empty hydrograph row, or in the Model view, click in the workspace.
2. Click Edit menu ➤ Runoff Hyd. ➤ Santa Barbara Method.
3. Select a method for computing time of concentration (Tc).
4. If you selected TR-55, click and enter data in the TR-55 Tc Worksheet dialog box. See TR-55 Tc Worksheet dialog box on page 21.
5. Enter the remaining data and click OK. See Santa Barbara Urban Hydrograph dialog box on page 25.

Hydraflow Hydrographs Extension computes the hydrograph.

6 Optionally, click Results to view the plotted hydrograph.

7 Click OK to generate the hydrograph and then click Exit to return to the initial view.

See also:

- Santa Barbara Urban Hydrograph dialog box on page 25

Santa Barbara Urban Hydrograph Dialog Box

Use this dialog box to create hydrographs using the SBUH method.

Descr.

Specifies the name or the description of the hydrograph. This information appears in the printed reports.

Basin Data

Drainage Area (Ac)

Specifies the subbasin area in acres.

Curve Number (CN)

Specifies the SCS Curve Number for this area. See Reference Tables on page 91 for coefficient values.

For a composite CN, click  (Compute Composite CN). You can enter up to six drainage areas and corresponding CNs for a composite CN.

Time of Concentration

Time of concentration (Tc) is the time it takes for runoff to travel from the most remote upstream point in the drainage area to the downstream point in question. There are four methods for computing Tc. See Computing Time of Concentration on page 75. Hydraflow Hydrographs Extension automatically computes Tc, except when you select User as the method of computing Tc.

Lag

Select to use the Lag method, the TR-20 default method.

Kirpich

Select to use the Kirpich method. This method is normally used for natural basins with well defined routes for overland flow along bare earth or mowed grass roadside channels. It is similar to the Lag method but typically yields shorter times.

User

Select to override the Tc and enter the value manually.

TR-55

Select to compute Tc by using three components as implemented by TR-55. Hydraflow Hydrographs Extension has a built-in TR-55 worksheet that computes Tc. See Computing Tc by TR-55 on page 21.

Basin Slope (%)

Specifies the average basin slope in percent. This value is required only if you selected Lag or Kirpich methods.

Hydraulic Length (Ft)

Specifies the distance, in feet, from the most remote point in the drainage area to the catchment point. This value is required only if you selected Lag or Kirpich methods.

Time of Concentration (Min)

Specifies Tc. This control is available only if you selected User as the method for computing Tc.

Hydrologic Data

Time Interval (Min.)

Select a time interval for this hydrograph. If you plan to combine this with other hydrographs, use the same time interval as those you plan to combine. Typically, a hydrograph is more accurate with a smaller time unit. Hydraflow Hydrographs Extension can use up to 2,880 points for each hydrograph. Therefore a time interval of 2 minutes spans 96 hours.

Storm Distribution

Select the type of storm distribution. Types I, IA, II, and III are built-in 24-hr SCS storm distributions. The SBUH typically uses type IA storm. Select Custom to use the current custom design storm file. The Synthetic or Huff options are not available for the SBUH.

Return Period/Precip

You do not have to select a return period or enter the precipitation value. These values are already set in the Event Manager. To verify these settings, click  (Open Event Mgr).

Related procedures:

- Creating SBUH Hydrographs on page 24

Importing and Manually Inputting Hydrograph Data

You can input hydrograph data created by agencies, such as your local drainage authority. The required input parameters are flow rates (Q) for the specific time interval. AutoCAD Civil 3D Hydraflow Hydrographs Extension allows you to specify up to 2,880 Q-values in time intervals from one minute to 60 minutes.

You can also import hydrograph data that is saved in an ASCII (*.txt*) or comma-separated value (*.csv*) file. The file format must be as follows:

```
TimeLabel$,QLabel$
Time1,Q1
Time2,Q2
Time3,Q3
...
Timen,Qn
```

Where:

TimeLabel$ is any alphanumeric label

QLablel$ is any alphanumeric label

Time = time (in minutes) (integer)

Q = flow (in cfs) (real number)

Hydraflow Hydrographs Extension assumes the incoming time interval to be:

Time Interval (in minutes) = Time (x) - Time (x-1)

The following is a sample *.csv* file with a time interval of six minutes.

```
"Time (min)","Q (cfs)"
0,0
6,1.10
12,2.00
18,3.36
24,4.75
30,4.0
36,3.25
42,1.8
48,0
```

To enter hydrograph data manually

1. Click Edit menu ➤ Runoff Hyd ➤ Manual Entry.
2. In the Manual Hydrograph dialog box, select a return period (1-Yr to 100-Yr) that corresponds to the hydrograph that you want to enter or import.
3. Select the time interval and click (Apply New Time Interval) to update the table values.
4. Enter a multiplier value and click (Apply New Multiplier) to update the table values.

   Hydraflow Hydrographs Extension multiplies each of the current flow rates by the multiplier value.

   NOTE To use multipliers more effectively, first copy the hydrograph from a smaller frequency. Then paste the copied hydrograph into the desired frequency and apply the multiplier.

5. In the Outflow (cfs) column, click the first row and start entering the flow rate (Q) values corresponding to each time interval. Press the *Tab* key to move to the next row.
6. Click Apply.
7. Optionally, click Results to view the plotted hydrograph.
8. Click Exit.

   The hydrograph appears in the workspace.

To import hydrograph data from a file

1. Click Edit menu ➤ Runoff Hyd ➤ Manual Entry.
2. In the Manual Hydrograph dialog box, select a return period (1-Yr to 100-Yr) that corresponds to the hydrograph that you want to enter or import.
3. On the toolbar, click (Import Hydrograph Data) and select a *.csv* file with hydrograph data.

   The table in the Manual Hydrograph dialog box is populated with imported data.

4. Click Apply.
5. Optionally, click Results to view the plotted hydrograph.
6. Click Exit.

   The hydrograph appears in the workspace.

For more information, see Manual Hydrograph Dialog Box on page 28.

Manual Hydrograph Dialog Box

Use this dialog box to manually input hydrograph data into Hydraflow Hydrographs Extension or to import hydrograph data from a file.

Import Hydrograph Data

Click to import hydrograph data from an ASCII (.txt) or comma-separated value (*.csv*) file.

Clear Table

Click to remove all hydrograph data from the current table.

Copy This Hydrograph

Click to copy hydrograph data that is displayed in the table. This action does not create an object in the Windows clipboard.

Paste into Table

Click to paste any previously copied hydrograph data into the current table.

Hydrograph Data

Return periods (1-Yr to 100-Yr)

Specify the current active return periods. These settings reflect the settings in the Event Manager. You can enter hydrographs for any or all of the active return periods.

Time Interval (min)

Specifies the time interval between the points.

Multiplier

Specifies a number that allows you to model various return periods using the current hydrograph as a base hydrograph. For example, the amounts entered here represent the 2 year return period. A 25-year event is identical to a 2-year event in terms of time, but it is 3 times that of the 2-year storm in terms of the flow rates. To create the 25 year hydrograph, use 3 as the multiplier.

(Apply New)

Click to update the table with new data values.

Related procedures:

- Importing and Manually Inputting Hydrograph Data on page 26

Combining Hydrographs

In the Watershed Modeling Workflow on page 4 example, runoff hydrographs are combined at strategic locations. An underlying assumption when creating runoff hydrographs is that the drainage areas are homogeneous, with similar CNs and slopes. When the drainage areas are not homogeneous, break up the watershed into separate, homogeneous subareas, creating individual hydrographs, and then combine them.

Hydraflow Hydrographs Extension can combine any previously generated hydrographs, up to six at a time.

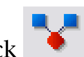
IMPORTANT The inflow hydrographs must have equal time intervals.

The outflow hydrographs are assigned the same time interval as the inflow hydrographs. Starting at time 0 minutes, Hydraflow Hydrographs Extension adds the Q values from each inflow hydrograph in computing the final outflow hydrograph. See the Computing Combined Hydrographs on page 83.

To combine or add hydrographs

1. Ensure that you have at least two hydrographs in the workspace.
2. In the Hydrographs view, click an empty hydrograph row, or in the Model view, click anywhere in the workspace.

   NOTE In the Hydrographs view, you can select any empty hydrograph row for your next hydrograph, but in the Model view, Hydraflow Hydrographs Extension automatically increments the number and assigns it to the current hydrograph. The number for the new hydrograph must be greater than those you plan to combine.

3. Click Edit menu ➤ Combine, or on the toolbox, click  (Combine Multiple Hydrographs).
4. In the Combine Hydrographs dialog box, enter a name or description for the hydrograph.
5. Under Inflow Hydrographs, select the hydrographs that you want to combine and click OK.

   Hydraflow Hydrographs Extension computes the combined hydrograph.
6. Optionally, click Results to view the plotted hydrograph.
7. Click Exit to update the hydrograph.

See also:

■ Combine Hydrographs dialog box on page 29

Combine Hydrographs Dialog Box

Use this dialog box to select hydrographs that you want to combine.

Description

Specifies the name or the description of the hydrograph. This information appears in the printed reports.

Inflow Hydrographs

Hydrograph list

Contains a list of available hydrographs.

Related procedures:

■ Combining Hydrographs on page 28

Routing Channels

Use channel routing when the inflow hydrographs must pass through a long and well-defined channel, where the channel storage is expected to have a significant impact on attenuation of the hydrograph.

NOTE In cases where the channel is small (either less than five feet wide or has a travel time that is less than or equal to the time interval used) it is not necessary to perform channel routing. In these cases, include the channel portion in the runoff hydrograph drainage area and time of concentration (Tc) calculations.

Hydraflow Hydrographs Extension routes any previously generated hydrograph through a channel. The outflow hydrograph is assigned the same time interval. Hydraflow Hydrographs Extension uses the Modified Att-Kin routing method as described in 1992 TR-20.

The Modified Att-Kin Method is dependent on two parameters —coefficients x and m. Using your input data, Hydraflow Hydrographs Extension computes these coefficients. You also have the option of directly entering the known x and m values. For more information on the x and m coefficients, see Computing Channel Routing on page 83.

To route a hydrograph

1. Ensure that you have at least one inflow hydrographs in the workspace.
2. In the Hydrograph view, click an empty hydrograph row or in the Model view, click anywhere in the workspace.

   NOTE In the Hydrographs view, you can click any unused hydrograph row for your next hydrograph, but in the Model view, Hydraflow Hydrographs Extension automatically increments the hydrograph number. The new hydrograph number must be greater than the number of the hydrograph that you plan to route.

3. Click Edit menu ➤ Reach, or on the toolbox, click  (Route Hydrograph Through Channel).
4. In the Reach dialog box, enter the description for your hydrograph.
5. Under Reach Data, select the hydrograph that you want to route.
6. Under Section Data, enter values in the fields. For more information, see Reach Dialog Box on page 30.
7. Under Rating Curve, enter the known x and m coefficients (see Computing Channel Routing on page 83). If you do not have the coefficient values, leave the fields blank.
8. Click OK.

   Hydraflow Hydrographs Extension computes the average velocity, routing coefficient, Cr, and the outflow hydrograph.

9. Optionally, click Results to view the plotted hydrograph.
10. Click Exit to update the hydrograph.

NOTE If your channel enters a small culvert at its downstream end, treat it as a detention pond rather than a channel route.

See also:

- Reach Dialog Box on page 30

Reach Dialog Box

Use this dialog box to enter data for routing a channel.

Descr

Specifies the name or the description of the hydrograph. This information appears in the printed reports.

Reach Data

Inflow Hyd. No.

Specifies a hydrograph to route.

Section Data

Section Type

Specifies the type of section that best describes this channel: Trapezoidal, Rectangular, Triangular, Circular, or Known x / m (if you want to directly enter known x and m values). The remaining section data will not be required.

NOTE Pipe sections that flow full or higher are not recommended for this procedure. It is highly probable that detention storage would occur upstream and therefore would require a storage-indication reservoir routing procedure.

Reach Length (ft)

Specifies the reach length of the channel.

Channel Slope (%)

Specifies the slope of the channel.

Manning's n

Specifies the Manning's n-value for the channel. See Manning's n-Values on page 93.

Bottom width (ft)

Specifies the width of the bottom of the channel. Enter zero for triangular sections.

NOTE The Kinematic Wave Method has a minimum bottom width of 5 feet.

Side Slope (z:1)

Specifies the side slope of the channel in the ratio form, z (horizontal) to 1 (vertical). Enter 0 for rectangular sections.

Maximum depth (ft)

Specifies the maximum depth of the channel.

Rating Curve

Coefficient, x

Specifies the known value of the x-coefficient. Leave blank if the x-coefficient value is unknown. See computational methods for channel routing on page 83.

Coefficient, m

Specifies the known value of the m-coefficient. Leave blank if the m-coefficient value is unknown. See computational methods for channel routing on page 83.

Related procedures:

■ Routing Channels on page 29

Using Detention Ponds

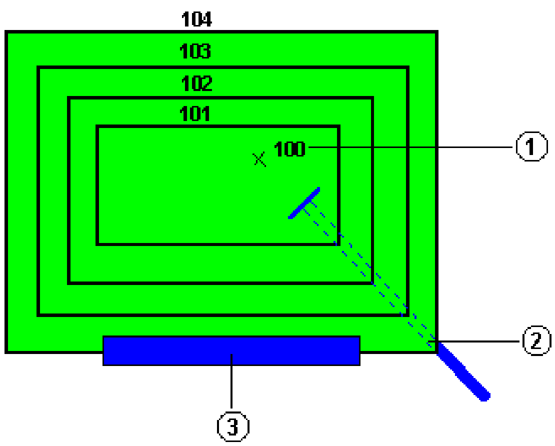
You can use a detention pond in pond routing procedures. After you set up the detention pond, Hydraflow Hydrographs Extension allows you to route any hydrograph through it. Before performing detention pond routing procedures, you must set up the stage-storage-discharge relationship, which governs detention ponds. The stage-storage-discharge relationship is represented by a table of values that determine how the pond performs when the water level reaches certain pre-determined depths or stages, similar to a pump performance curve (Q vs. head). In this situation, Q is paired with stage.

A typical stage-storage-discharge table could look as follows:

Stage (ft)	Storage (cuft)	Discharge (cfs)
0.00	0.00	0.00
1.00	5,400	5.75
2.00	11,780	11.89
3.00	17,000	21.43

For example, at a depth of two feet, this pond would produce an outflow of 11.89 cubic feet per second, while storing 11,780 cubic feet of water.

The following image shows a plan view of a typical detention pond.



(1) Elevation at stage 0 (2) Culvert structure (3) Weir structure

Creating Detention Ponds

Hydraflow Hydrographs Extension allows you to set up a maximum of 25 unique detention ponds for a project. Any detention pond can be used by any hydrograph at any time. Each detention pond can use up to 20 stage values to describe the stage-storage curve and can use up to four culvert-orifice outflow structures (one of which can be a perforated riser), four weir structures, and an exfiltration component. These structures can act as individual outlet structures or you can set them up in series as a multi-stage structure.

To maximize the accuracy of the routing calculations, Hydraflow Hydrographs Extension automatically computes ten intermediate stage values between each of the stage values that you enter.

To create a detention pond

1. Click the Ponds tab.

   The Ponds view displays a list of 25 existing and available ponds.

2. In the pond list, double-click an empty row or on the toolbox, click  (Add/Edit Detention Pond).

3 In the Stage / Storage / Discharge Setup dialog box, set up a pond:

a Click Storage and enter the required data for each storage type. See Storage Tab - Stage/Storage/Discharge Dialog Box on page 34. Click Apply and then click Done.

NOTE To modify the displayed values, you must edit the input parameters.

b Click Outlets and enter the required data. See Outlets Tab - Stage/Storage/Discharge Dialog Box on page 37. Click Compute.

c Click Pond Tools and enter the required data. See Pond Tools Tab - Stage/Storage/Discharge Dialog Box on page 39. Click Estimate Storage.

d Click Graphs to view the plotted curve. See Graphs Tab - Stage/Storage/Discharge Dialog Box on page 40.

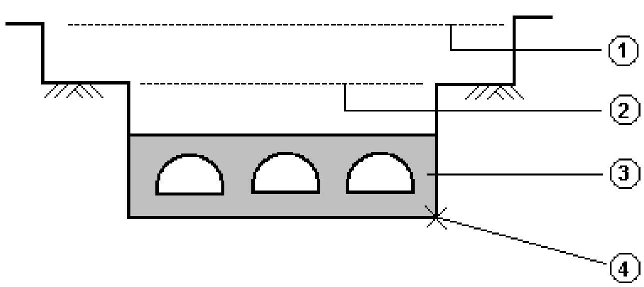
e Click Table to view the data. See Table Tab - Stage/Storage/Discharge Dialog Box on page 40

Combining Detention Ponds

Hydraflow Hydrographs Extension allows you to set up a detention pond using user-defined Contours, Trapezoids, Underground Chambers, and by Manual Entry. Note that each storage type can have its own voids ratio. In addition, you can claim all available storage at a given site by combining different storage types. The following restrictions apply:

- You can combine up to two storage types.
- You cannot combine Trapezoid storage types with Chambers.
- You cannot combine Contours storage types with Manual.
- Trapezoid and Chambers storage types must always be at the bottom of any combination. Contours can be above Trapezoids or Chambers but Trapezoids or Chambers cannot be placed above Contours.

The following illustration shows adding a contour detention pond above an encased underground chamber system.



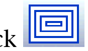
(1) Contour 2 | (3) Underground chambers

(2) Contour 1 | (4) Stage 0

To combine detention ponds

1 Add the lower storage type. For example, click (Chambers).

2 Enter the required data in the table and click Apply.

3 Add the upper storage type. For example, click  (Contours).

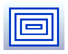
4 Enter the required data in the table and click Done.

Storage Tab - Stage/Storage/Discharge Dialog Box

Use this tab to enter storage-related data when you set up detention ponds.

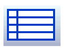
Storage type

Specifies the type of the detention pond.

Click  (Contours) to enter the starting elevation and corresponding contour areas at any elevation or contour interval.

Click  (Trapezoid) to enter data for a rectangular detention pond that has a known bottom area at stage 0, equal side slopes (z:1) on all four sides, and a desired maximum depth.

Click  (Chambers) to enter data for an underground detention pond in the shape of circular, arch, or rectangular pipes that lay flat or on a slope. Headers and a stone encasement are optional.

Click  (Manual) to enter stage, elevation, and storage values manually. Contours and incremental storages are not allowed.

Storage type data table

The contents of this table vary according to the storage type. Bottom Length, Bottom Width, and Side Slope apply only to Trapezoidal storage types. Data fields from Invert Elev. Dn through Width apply only to Chambers storage types.

Storage Type

Specifies a selected storage type. Option items that are available depend on the selected storage type.

Bottom Elev. (ft)

Specifies the elevation at the bottom of the detention pond or encasement. The bottom elevation of the encasement must be equal or less than the chamber invert elevation.

Bottom Length (ft)

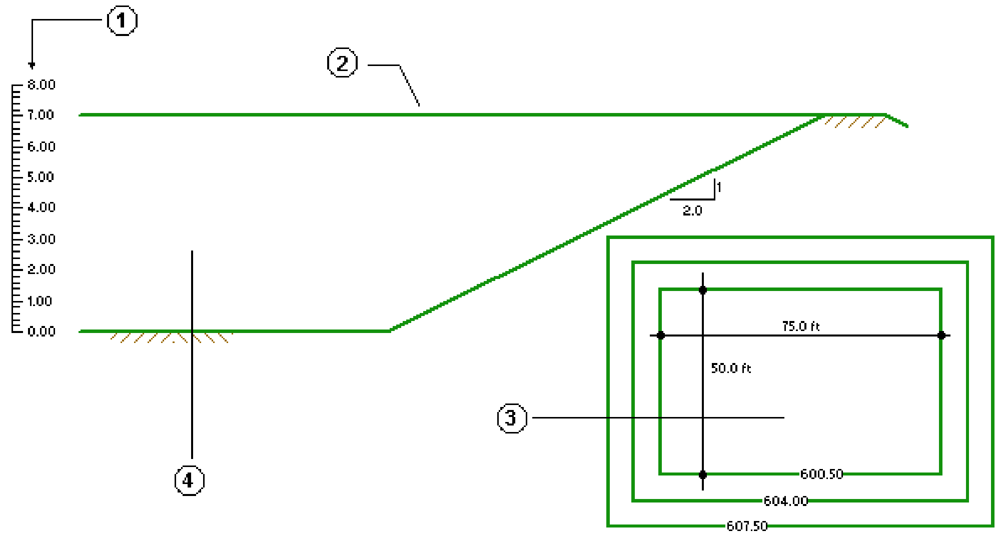
Specifies the length of the bottom of the detention pond in feet.

Bottom Width (ft)

Specifies the width of the bottom of the detention pond in feet.

Side Slope, z:1

Specifies the slope of the side walls of the detention pond as a ratio (horizontal to vertical). For example, for a 2:1 side slope, enter 2.
The following pond has a bottom area of 50 x 70 with 2:1 side slopes.



(1) Stage

(2) Top of pond (Elev. 607.50)

(3) Plan view

(4) Section view

Invert Elev. Dn (ft)

Specifies the elevation at the lowest point in the pipe. If an encasement is not used, the value is set to 0.

Rise (ft)

Specifies the diameter or the height of the chamber vessel.

Shape

Specifies the shape of the underground chamber: Circular, Box, or Arch.

Span (ft)

Specifies the width of the chamber vessel.

Barrel Length (ft)

Specifies the length of the pipe (a single barrel).

No Barrels

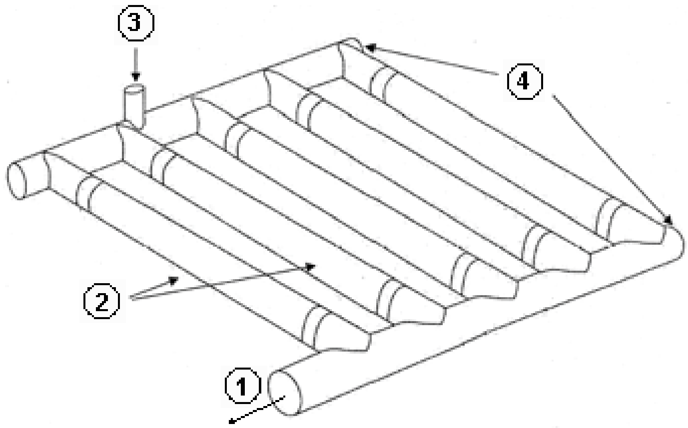
Specifies the number of pipe runs or barrels.

Pipe Slope

Specifies the slope of the barrel in percent.

Headers

Specifies whether or not to add transverse header pipes at the upstream and downstream ends. The following pipe storage system has five barrels with headers.



(1) Outlet (3) Inlet

(2) Barrels (4) Headers

Stone Encasement

Specifies whether or not you use a stone encasement in your setup.

Width (ft)

Specifies the width of the encasement. This value refers to a single barrel and must be equal or greater than the chamber span. The total encasement width is calculated as Width x No Barrels.

Depth (ft)

Specifies the total depth of the detention pond or the encasement.

Voids (%)

Specifies value defaults up to 100. This option is useful for modeling underground gravel-filled trench drains because it allows for a reduction in storage due to gravel fills, but still allows the total surface area available for exfiltration calculations. The Voids value can be used on any storage type except Manual. In the Manual storage type you have already entered values that account for voids.

Volume By

Specifies a preferred method of computing incremental storages: Ave End Area or Conic. See Using Detention Ponds on page 31.

Pond Name

Specifies the name of the pond. This is a required entry.

Stage-storage table

Stage

Specifies the stage value in feet.

NOTE The first stage value is always 0 and is skipped. The first entry is the elevation of the first contour.

Elevation

Specifies the elevation corresponding to the current stage. In most cases Hydraflow Hydrographs Extension computes the value and displays it as a default.

Contour Area

Specifies the contour area, in square feet, corresponding to the current stage.

Incremental Storage

Specifies the value automatically computed by Hydraflow Hydrographs Extension. This value is set to 0 at stage 0.

Total Storage

Specifies the total value, in cubic feet, automatically computed by Hydraflow Hydrographs Extension. This value is set to 0 at stage 0.

Total Discharge

Specifies the current discharge value at each stage. You cannot edit this column in this view.

Auto Update Stage-Discharge

Select to update the discharge value in the stage-storage table, for example, after you increase or decrease the total depth.

Outlets Tab - Stage/Storage/Discharge Dialog Box

Use this tab to enter the stage-storage-discharge data to specify the discharge values that correspond to the stage values.

Culverts / Orifice

Rise (in)

Specifies the diameter of the outlet pipe or the height of the box section.

Span (in)

Specifies the diameter of the outlet pipe or the width of the box section. **This is a required entry**.

NOTE If the Rise and Span values are equal, Hydraflow Hydrographs Extension assumes a circular section. If they are unequal by any amount, then Hydraflow Hydrographs Extension assumes a box or rectangular section.

No. Holes

Specifies the total number of orifices in the perforated riser. For more information, see Perforated Risers on page 43.

No. Barrels

Specifies the number of barrels or pipes for the structure.

Invert Elev. (ft)

Specifies the elevation of the invert at the upstream end.

Height (ft)

Specifies the distance from the invert of the lowest hole to the top of the highest hole or the center of the lowest orifice of perforated riser to the center of the highest orifice plus the S-value. For more information, see Perforated Risers on page 43.

Length (ft)

Specifies the length of structure. If you are modeling an orifice, enter 0.

Slope (%)

Specifies the slope of the culvert in percent. If you are modeling an orifice, enter 0.

N-Value

Specifies Manning's n-value.

Orifice Coeff.

Specifies the orifice coefficient. The default value is 0.60.

Multi-Stage

Specifies the model as a multi-stage structure. Use only for orifice B, C, and Perf. Riser. Multi-stage structure implies that all of the flows from this structure passes through culvert A.

Active

Specifies the structure as an active component in the final stage-discharge calculation. When testing various scenarios and structures, you can use this control to activate some structures and deactivate others.

Tailwater

Tailwater Elevation (ft)

Specifies the elevation of the HGL (hydraulic grade line) at the downstream end.

Weirs

Weir Type

Specifies the type of the weir: Rectangular, Cipoletti, Broad crested, Riser, or V-Notch (from 5 to 120 degrees).

NOTE Only weir A can be a structure of type Riser.

Crest Elev (ft)

Specifies the elevation of the weir crest.

NOTE Crest elevation for V-Notch weirs is the bottom of the weir, not the top.

Crest Length (ft)

Specifies the length of the weir crest. For a standpipe weir, the length is equal to the circumference of the weir. For V-Notch weirs, the length is 0.

Weir Coeff.

Specifies a weir coefficient. Hydraflow Hydrographs Extension automatically selects the default coefficient, which is based on the selected weir type. It is recommended that you use the default values. See weir calculation methods on page 86.

Multi-Stage

Specifies whether or not you are modeling a multi-stage structure. For more information, see About Multi-Stage Structures on page 41.

Active

Specifies the structure as an active component in the final stage-discharge calculation. When testing various scenarios and structures, you can use this control to activate some structures and deactivate others.

Exfiltration

Contains data to be added to the outflow exfiltration component of your structure.

Rate (in/hr)

Specifies the exfiltration rate.

Apply to

Specifies a type of area to which apply exfiltration data: Contour or Wetted Surface Area.

Extract from Outflow Hyd (y/n)

Specifies the removal of the exfiltration flows from any hydrograph routed through the current pond. If you select No, the outflow hydrograph contains these flows, and it may be necessary to divert the exfiltration component before further downstream processing.

Compute button

Click to update the table.

Stage-storage-discharge table

Contains the computed discharges at each stage and elevation for each outlet structure, as well as the total discharge. Specify the known discharges at each stage in the User-defined column. The values are then added to the total.

Pond Tools Tab - Stage/Storage/Discharge Dialog Box

Use this tab to add and modify outlet structures and perform the routing of the detention ponds.

Storage Estimate

Contains data for storage estimates.

Inflow Hyd. No.

Specifies the inflow hydrograph.

Event (yrs)

Specifies the return period. The field is automatically populated if based on the Event Manager.

Vol In (cuft)

Specifies the volume of the inflow hydrograph. The field is automatically populated.

Qp In (cfs)

Specifies the Q peak value of the selected inflow hydrograph. The field is automatically populated.

Target (cfs)

Specifies the target flow rate (Q).

Req. Stor (cuft)

Specifies the volume of the required storage.

Estimate Storage

Click to calculate the estimated storage.

Interactive

These options enable you to make adjustments to the size and positions of the components of the structure.

Increment slider

Specifies the increment for the Diameter (in) and Invert El. (ft) spin buttons.

Culv/Orif

Enables the selection and activation of the current culvert/orifice structures.

Diameter (in)

Specifies the diameter of the culvert/orifice structure.

Invert El. (ft)

Specifies the invert elevation of the culvert/orifice structure.

Weir

Enables the selection and activation of the current weirs.

Crest Len (ft)

Specifies the weir crest length of the riser structure.

Crest Elev (ft)

Specifies the weir crest elevation of the riser structure.

Update

Click to update the stage-discharge curve manually after each change.

Auto Update

Select to update the stage-discharge curve automatically as you make changes.

Trial Route

Click to preview the effect of the entered values on the detention pond design.

Auto Route

Select to perform automatic trial routing each time you change a value.

IMPORTANT If you are making significant changes, clear this option to avoid errors during routing procedures.

Graphs Tab - Stage/Storage/Discharge Dialog Box

Use this tab to view the plotted graphs.

Storage button

Click to display the controls for viewing the stage-discharge graphs.

Discharge button

Click to display the controls for viewing the stage-storage graphs.

Table Tab - Stage/Storage/Discharge Dialog Box

Use this tab to view the stage-storage-discharge data in numerical format.

Stage

Specifies the depth above the pond bottom (in feet or meters).

Elev

Specifies the elevation corresponding to the stage (in feet or meters).

Storage

Specifies the total storage (in cubic feet or meters) up to corresponding stage.

Culvert / Orifice (A, B, C, Prf Riser)

Specifies the outflow which occurs at the corresponding stage (in cubic feet or meters per second). When multi-stage structures exist, this value under Culvert A is equal to the total outflow when it is in control. If this value is greater than the total outflow, the multi-stage structures are in control. These values have an “-ic” suffix when the flow is under inlet control and an “-oc” suffix when the flow is under outlet control.

Weir (A, B, C, D)

Specifies the outflow which occurs at the corresponding stage (in cubic feet or meters per second). If weir A is used as a riser, it is automatically checked for orifice conditions and has an “-ic” suffix if it is flowing under an orifice regime. These values have an “-s” suffix when an adjustment has been made for submergence.

Exfiltration

Specifies the outflow (in cubic feet or meters per second) due to exfiltration.

User Defined

Specifies the outflow values (in cubic feet or meters per second) that you entered in the Outlets page.

Total Outflow

Specifies the sum total of outflows (in cubic feet or meters) from each structure. For multi-stage setups, the total is equal to the flows of culvert A or the sum of the multi-stage devices and independent structures, exfiltration, and user-defined Qs.

Zoom In

Click to expand the table to show all intermediate points.

Zoom Out

Click to return to the default table view.

Export

Click to export the current table as a comma-separated value (*.csv*) file, which you can later import into a spreadsheet.

Print Pond Report w/o Graph

Click to print a numerical report. See Printing Reports on page 62.

RELATED The pond report lists the data from the stage-storage-discharge data table for the pond. The actual pond routing appears on the corresponding routed hydrograph report. The values shown on the hydrograph report describe the stage, storage, and outflows at a particular time during the routing.

About Multi-Stage Structures

In most cases, each outlet structure is treated independently, but you can put the structures in series, that is, create a multi-stage structure. This enables you to direct the outflows from culvert B, C and perforated riser, and weirs A, B, C and D through culvert A. The structure with the least capacity at any given stage controls the final outflow.

A typical multi-stage structure consists of a standpipe weir (box or circular) with an orifice attached to the lower side of the standpipe, near the invert. The standpipe is connected to the upstream end of culvert A. All flows from the orifice and weir are combined and directed to and through culvert A.

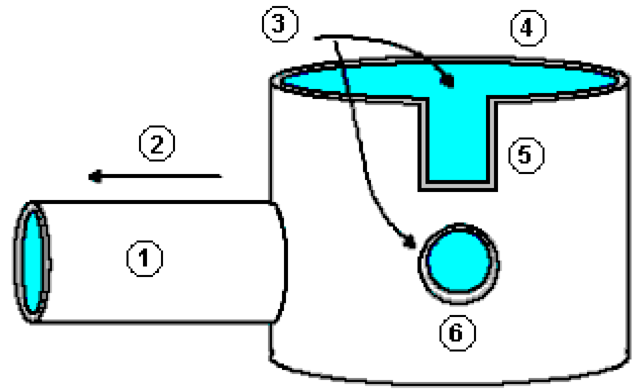
NOTE Culvert A does not have the Multi-Stage option. It is always the final outflow structure.

You can have more than one orifice or weir. You can specify orifices, weirs B, C, and D, each at different elevations. Select the multi-stage option when entering data.

IMPORTANT You must set multi-stage orifice elevations at least 0.01 feet above ground to prevent culvert A from taking control too early in the process.

RELATED When using the Multi-stage option, Hydraflow Hydrographs Extension checks the head elevation produced by culvert A. This value is then used as a tailwater elevation against other multi-stage structures. As the head increases, the outflows from the orifices and weirs decrease. When the head equals the current stage, culvert A is the controlling structure and the contributing flows from the orifices and weirs diminish.

The following is a typical multi-stage structure.



(1) Culvert A

(3) Inflow

(5) Weir B

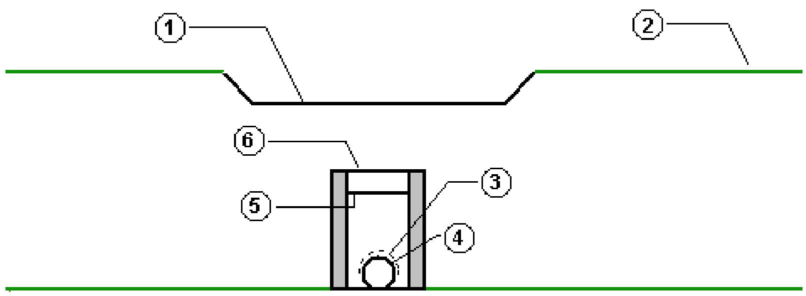
(2) Outflow

(4) Weir A - Riser

(6) Culvert B

Independent Structures

In many instances you will want to use an emergency spillway or just a single culvert outlet pipe. These structures are independent, that is their flows exit the pond without interacting with culvert A first. The following illustration shows a Cipoletti weir used independently. The graphic shows a front view of a multi-stage structure and an independent structure. Weir C (1) is used as an independent emergency overflow structure and is not a multi-stage device.



(1) 8.00 ft Cipoletti weir (weir C)

(3) 25.0 LF of 15.0 in @ 0.50 %
culv A - Inv. 600.00

(5) 2.00 ft Rectangular weir
weir B - Elev. 603.08

(2) Top of pond.
Elev. 607.00

(4) 11.3 in orifice
culv B - Inv. 600.01

(6) 6.00 ft Riser
weir A - Elev. 603.82

Using Stage-Discharge Data

Hydraflow Hydrographs Extension allows you to specify:

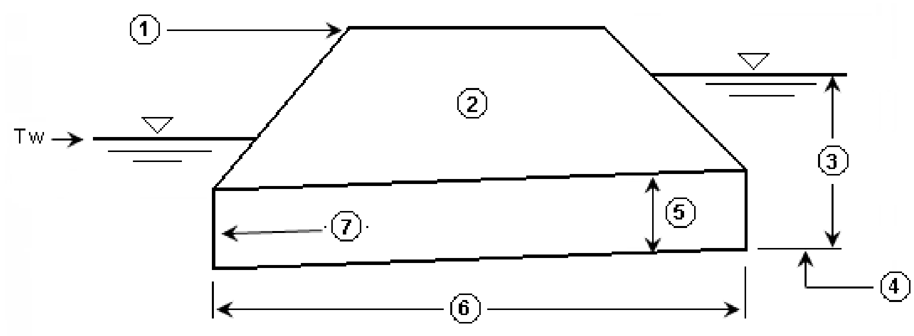
- Up to four unique culvert/orifice structures (including a perforated riser).
  The culvert/orifice structures are labeled as A, B, C, and Prf Riser and can act like culverts or orifices depending on the inputs. See Perforated Risers on page 43.
- Four unique weir structures.
  The four weir structures are referred to as weir A, B, C, and D. See Weir Structures on page 44.

- An exfiltration component. See Exfiltration on page 46.
- Known flow rates (Qs).
- A single tailwater elevation. See Tailwater Elevation on page 45.

Each structure can be used as an independent outflow structure or can be used in series or a multi-stage structure.

In computing the outflows, Hydraflow Hydrographs Extension treats the operation of these outlet structures as a function of stage or water surface elevation. Partial and full flow conditions are computed as well as inlet and outlet control.

The following illustration shows a profile of typical culvert.



Tw - Tailwater elevation	(3) Stage	(6) Pipe length
(1) Top of pond	(4) Invert elevation	(7) Flow
(2) Embankment	(5) Rise	

RELATED During the calculation process, both inlet control and outlet control are evaluated. Under inlet control, the discharge depends on the barrel shape, cross-sectional area, and inlet edge. The inlet of the culvert controls the amount of flow that the culvert can handle. Under outlet control, the discharge depends on the slope, length and roughness of the barrel. Outlet control means that flow can enter the structure at a faster rate than it can exit.

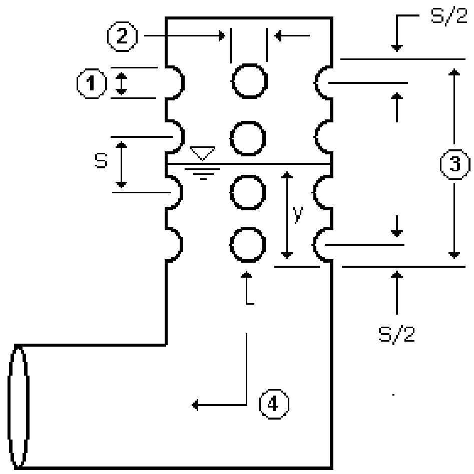
Hydraflow Hydrographs Extension computes the discharge at each stage as established by the stage-storage table, including intermediate stage points that it generates, using both inlet and outlet control equation parameters. The smallest value is used as the discharge at that elevation. This is reflected on the table report as **ic** (inlet control) and **oc** (outlet control).

NOTE Hydraflow Hydrographs Extension does not assume full flow when the depth is partial.

Perforated Risers

Culvert D is reserved for a perforated riser and is treated differently from other culvert/orifice devices. Perforated risers consist of a riser pipe with several holes of the same size and at a uniform distance (S) apart. These structures are typically used in a multi-stage configuration with culvert A as the outlet pipe and in conjunction with a riser weir. The inputs for perforated risers are the same as for culvert/orifice structures, except Length, Slope and n-value are substituted for Height.

The following illustration shows a typical perforated riser.



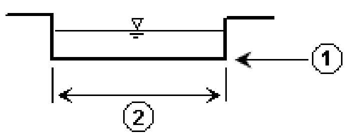
(1) Rise	(3) Height	S - Distance between the centers of the two adjacent holes
(2) Span	(4) Outlet pipe flow	y - Stage minus the invert elevation

Weir Structures

Hydraflow Hydrographs Extension offers a variety of weir types. Riser structures can be circular or rectangular. However, when checking for orifice conditions, Hydraflow Hydrographs Extension assumes the riser to be circular.

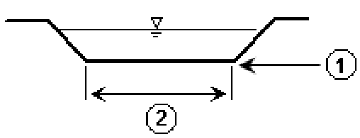
Hydraflow Hydrographs Extension supports the following weir structures:

- Rectangular weirs



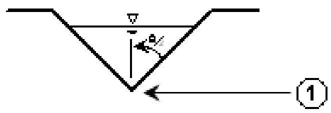
(1) Crest elevation (2) Crest length

- Cipoletti weirs



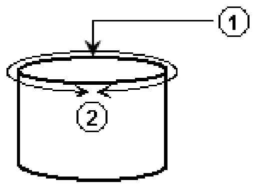
(1) Crest elevation (2) Crest length

- V-Notch weirs



(1) Crest elevation

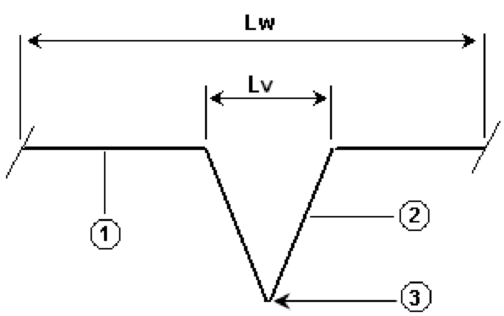
- Riser structures



(1) Crest elevation (2) Crest length

Hydraflow Hydrographs Extension automatically checks riser structures for orifice flow conditions. This feature assumes the riser to be a box structure and it computes the flow rate (Q) using both weir and orifice equations. Inlet control typically occurs at a depth approximately equal to the diameter of the structure or about H = 0.13 x (crest length), where H = depth of water above the crest. If you do not want to check for orifice conditions, use a rectangular structure instead.

NOTE If you are modeling multiple weirs in a multi-stage structure (for example, modeling a standpipe or box section that has a secondary weir cut from the top), deduct the crest length of the secondary weir from the crest length of the primary weir. If a V-notch weir is the secondary weir, deduct the length of the V-notch at the primary weir crest elevation (Crest length of primary weir = Lw - Lv).



(1) Primary weir (3) Secondary weir crest elevation Lv - Secondary weir crest length

(2) V-notch weir Lw - Primary weir crest length

Tailwater Elevation

If your outlet structure is submerged, enter the elevation of the HGL at the downstream end. Hydraflow Hydrographs Extension compares the pond stage with this elevation and computes a corresponding head. This head is then used to calculate outflows.

NOTE Only a single tailwater elevation can be specified per pond.

In most cases, a single tailwater elevation is sufficient, but you may need to model unique tailwater elevations for unique return periods. When performing the pond routing procedures, Hydraflow Hydrographs Extension automatically computes the routing for each active return period as set in the Event Manager, using only the single pond specified.

To model for different tailwater elevations at each return period

1 In the Event Manager, activate a single return period.

2 Run the model using the corresponding pond and tailwater elevation.

3 Print the reports.

4 Update the tailwater elevation and repeat the procedure for each return period.

For information on variable tailwater conditions with ponds in series, see Routing Through Interconnected Ponds on page 56.

Exfiltration

You can add an exfiltration component to your outflows by entering a percolation rate in inches per hour. Exfiltration is an outflow similar to any other pond structure. You can apply exfiltration to the contour areas of a pond or to the wetted surface area. During calculations, Hydraflow Hydrographs Extension computes exfiltration by multiplying this rate by either the contour area at each stage or by the wetted surface area.

NOTE The Exfiltration option is unavailable when you use the Manual Storage type. The Wetted Surface option is unavailable when you use the Contour Storage type.

See also:

- Outlets tab - Stage/Storage/Discharge dialog box on page 37

Adding User-Defined Outflows

You can add user-defined outflows (Q) to any stage-discharge table. Structures are not required.

To add a user-defined outflow

1 On the toolbox, click  (Add/Edit Detention Pond).

2 In the Outlets tab of the Stage/Storage/Discharge Setup dialog box, in the User Defined column of the stage-discharge table, enter custom flow rates for each stage.

NOTE There can be no outflow at stage zero.

3 Click Compute.

Hydraflow Hydrographs Extension computes the stage-discharge table and populates the Results grid.

See also:

- Outlets tab Stage/Storage/Discharge dialog box on page 37

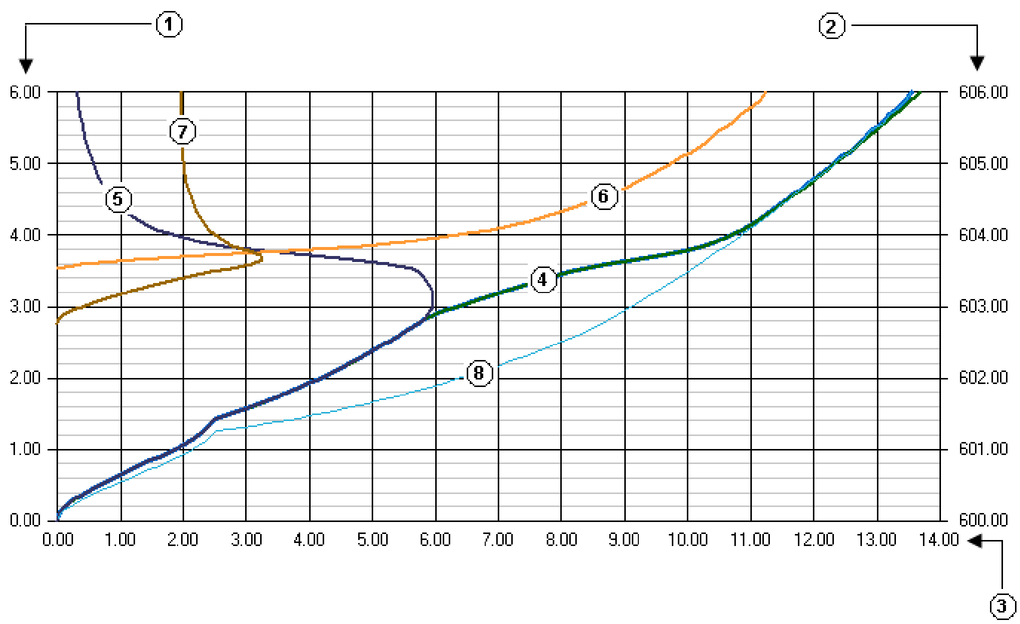
Viewing the Stage-Storage-Discharge Graphs

After setting up the stage-storage-discharge relationships, review the data in graphic form to make sure your pond is behaving as expected. If the curves of the pond look irregular, you may experience irregularities with any hydrograph routed through this pond.

To view a stage-storage-discharge graph

1. On the toolbox, click  (Add/Edit Detention Pond).
2. In the Stage/Storage/Discharge Setup dialog box, click the Graphs tab.
3. Click Storage or Discharge, depending on the type of graph that you want to generate (stage-storage or stage-discharge).
4. From the set of controls along the top, select the required options for outflows from the individual structures of a multi-stage structure.

   The following illustration is a stage-discharge graph that shows a multi-stage structure with all structures turned on. The graphs represent culvert A (4) and B (5) and weir A (6) and B (7) outflows. It also shows the structure HG (8). Notice how the flows from culvert B diminish as the structure HG approaches the stage in the pond. The same is true for weir B.



(1) Stage (ft or m) (3) Discharge (cfs or cms) (5) Culvert B (7) Weir B

(2) Elevation (ft or m) (4) Culvert A (6) Weir A (8) Structure HG

Understanding the Structure HG (Hydraulic Grade)

When you select the multi-stage option, Hydraflow Hydrographs Extension checks the head elevation produced by culvert A. This value is then used as a tailwater elevation against other multi-stage structures. As the head elevation increases, the outflows from the orifices and weirs decrease.

Graph (8) on the stage-discharge graph in Viewing the Stage-Storage-Discharge Graphs on page 47 indicates the structure HG. At any given discharge this line shows the elevation of the water at the upstream face of culvert A. When this line merges with the total Q line, culvert A is the controlling structure and the contributing flows from the multi-stage orifices and weirs diminish.

You can:

- Click  (Export) to save the current plot as a bitmap (*.bmp*) file.
- Click  (Print Pond Report) to print a graphical pond report. See Printing Reports on page 62.

See also:

- Table Tab - Stage/Storage/Discharge Dialog Box on page 40

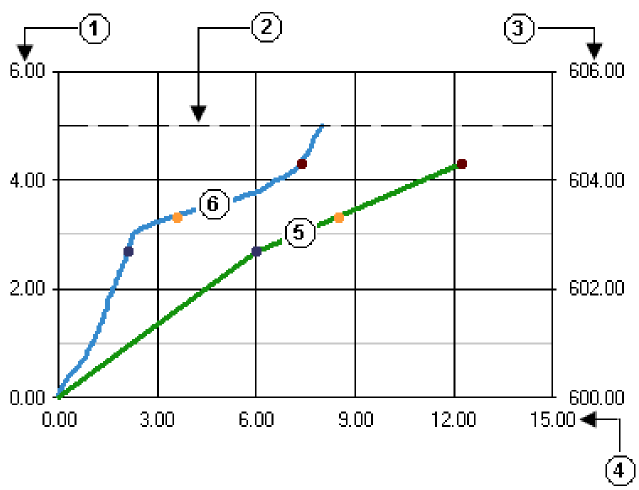
Using the Interactive Pond Tools

The Hydraflow Hydrographs Extension pond tools simplify the difficult task of setting up detention ponds. The tools allow you to see the outcomes of the routing while the routing is performed, which allows you to create a wide variety of outlet combinations and configurations.

Similar to the Hydraflow Storm Sewers Extension for AutoCAD® Civil 3D® interactive feature, the interactive pond tools let you create, edit, and activate or deactivate structures to your pond graphically. You can see the results of your changes during the routing process in real time. This is an excellent way to fast-track the design process.

The pond creation procedure begins with the estimation of the storage requirements by comparing the pond size with target outflows and the inflow hydrograph. See Storage Estimate in the Pond Tools Tab - Stage/Storage/Discharge Dialog Box on page 39.

Hydraflow Hydrographs Extension then creates a target stage-discharge curve as shown in the following illustration.



(1) Stage (ft)	(3) Elevation (ft)	(5) Target Q
(2) Top of pond	(4) Discharge (cfs)	(6) Actual Q

The goal is to create an actual stage-discharge curve that matches the target. Using the functions from the interactive frame of the workspace, you can set the sizes and positions of your outlet structures in real time.

Refining Pre- and Post-Development Models

The pre- and post-development models tutorial on page 6 describes how to use pond tools to design pond structures. This section adds more details to the high-level procedure. It is assumed that you have set up the two runoff hydrographs and the stage-storage table for the pond from step 3 of the tutorial procedure. You can also use the *PondToolsExample.gpw* sample file that is installed with Hydraflow Hydrographs Extension. For information on sample file locations, see Support and Sample File Locations on page 2.

To adjust outlet structures

1. In the toolbox, click  (Add/Edit Detention Pond).
2. In the Stage/Storage/Discharge Setup dialog box, enter the required data to set up the pond.

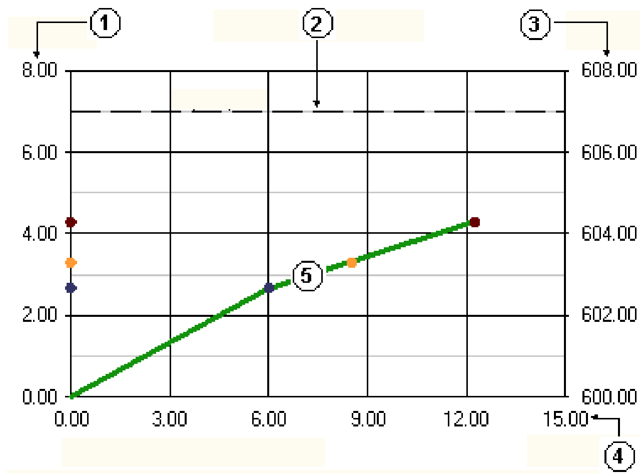
   After you set up the pond stage-storage, you must set up the outlet structures. The objective is to create the outlet structures to match the target outflows of 6.0, 8.5, and 12.25 cfs.
3. Click the Ponds Tools tab.
4. Under Storage Estimate, select an inflow hydrograph.
5. Click in the Target column 2-year return period and enter the target outflows as follows:

Return Period	2	10	100
Pre Qp	6.05	8.49	12.24
Post Qp	12.91	17.57	24.86

6. Click Estimate Storage.

   Hydraflow Hydrographs Extension estimates the storage needed to accommodate the target Qs. The maximum storage estimated in this case in 14,904 cubic feet and is below the capacity of the pond. It is necessary to enlarge the pond.

   Hydraflow Hydrographs Extension builds the following target stage-discharge curve. The three dots on the graph correspond to the target Qs - 6.0, 8.5, and 12.25 cfs. The corresponding elevations are based on the estimated storages and the actual pond stage-storage curve.



(1) Stage (ft)

(2) Top of pond

(3) Elevation (ft)

(4) Discharge (cfs)

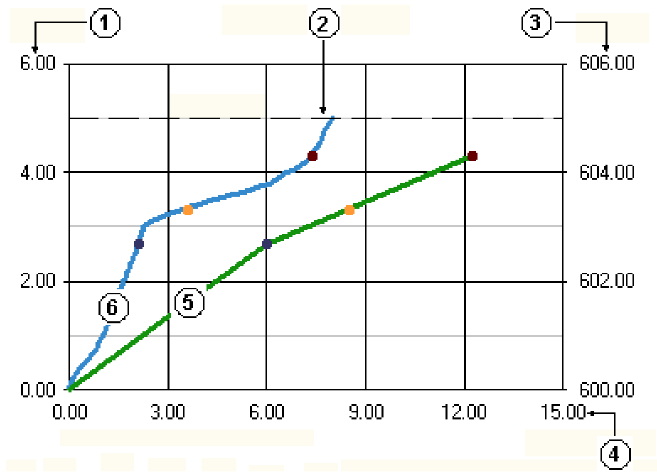
(5) Target Q graph

7 To adjust the stage-storage setup, click the Outlets tab and add data for outlet structures. For example, enter the following data (based on the structure shown in Setting Up Pre- and Post-Development Models on page 6.

Culvert/Orifice Structures			**Weir Structures**		
Item	**A**	**B**		**A**	**B**
Rise (in)	12	8	Weir Type	Riser	Rect
Span (in)	12	8	Crest Elev (ft)	604	603
No. Barrels	1	1	Crest Length (ft)	12	2
Invert El. (ft)	600.00	600.01	Weir Coeff.	3.33	3.33
Length (ft)	25	0	Multi-stage (y/n)	Y	Y
Slope (%)	0.50	0			
n-value	0.013	0.013			
Orifice Coeff.	0.60	0.60			
Multi-stage (y/n)	n/a	Y			

8 Click Compute.

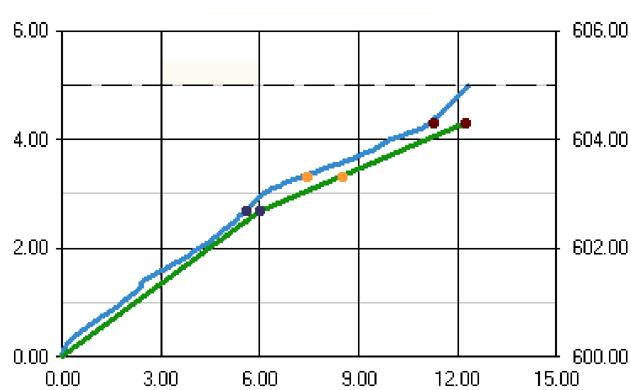
9 Click the Pond Tools tab and view the actual and target stage-discharge graphs.



(1) Stage (ft)
(2) Top of pond
(3) Elev (ft)
(4) Discharge (cfs)
(5) Target Q graph
(6) Actual Q graph

10 Use the interactive tools to make adjustments to the culverts of the structure:

- Move the slider to 1.0 to set the spin button increment.
- Select culvert A.
- Click the spin button to increment the Diameter value until the two 100-year dots on the graphs are approximately in the same position. You increased the size of Culvert A from 12 to 15 inches.
- Working upstream from culvert B (culvert B controls the low, 2-year target flow of 6.0 cfs), repeat the procedure for the remaining structures.
- See how the actual graph changes, as you increment the values.



11 Use the interactive tools to make adjustments to the weir structures:

NOTE The easiest way to set weir crest elevations is to perform a routing and observe where the maximum elevation reached for the 2-year event.

- Under Interactive Tools, click Trial Route.
  The results show that the maximum elevation (Max El) for the 2-year event reached 602.80. This is where you must set the crest elevation for the next upstream structure.

- Select Weir B and set the crest elevation to 602.80 using the spin button.

TIP Elevations are best set using smaller increments. Move the slider control to 0.10.

- Click Trial Route to see the effect of the change.
- Adjust the crest length for weir B until the Qp is at the target or below the target of 8.5.
- Repeat the procedure for the remaining structure, weir A. The maximum elevation reached for the next 10-year event is 603.55. Set the crest elevation for weir A to 603.55
- Click Trial Route.

12 Adjust the structures if necessary.

TIP Set the riser structure as the last step in the process. Set the size large enough where the riser structure does not control the final outflow.

Pre- and Post-Development Models Design Consideration

When designing ponds with Hydraflow Hydrographs Extension interactive pond tools, consider the following:

- Set the weir crest length for the riser structure large enough, so that it does not interfere with culvert A. The riser structure acts as a container for other multi-stage devices. Use the spin controls to increase the crest length so that it no longer affects the actual stage-discharge curve. The crest length is too large when you begin to see oscillations in the upper parts of the curve
- You can add or delete structures anytime during the design process. In the previous example, you added all components first and made revisions on the fly. You could have first added culvert A, then orifice B, weir B, and finally the riser weir A. Work your way upstream (lower return period to higher return period).
- You can edit the pond size during the design process. Simply click the Storage tab and make any changes.
- The interactive pond tools allow you to activate or deactivate structures. This may be useful for exploring different options. In some cases, for example, you may be able to use a single culvert instead of a complex multi-stage structure.
- After designing a pond, you must complete the routing process from the main menu. See Pond Routing on page 52.

Pond Routing

Routing is an important step in detention pond modeling and should not be confused with pond setup. In pond setup, you define a stage-storage-discharge relationship that results in an output that is similar to a pump performance curve. The stage-storage-discharge relationship describes how the pond performs at given depths. To develop an outflow hydrograph you must perform the routing.

Hydraflow Hydrographs Extension routes any previously generated hydrograph through a detention pond or reservoir, wet or dry. You can also use any second pond as a downstream influence - interconnected pond. For more inforamation, see Routing Through Interconnected Ponds on page 56.

The outflow hydrograph is assigned the same time interval as the inflow hydrograph.

Hydraflow Hydrographs Extension uses the widely accepted Storage Indication method which is based on the equation: Inflow - Outflow = Change in Storage. See Computing Detention Pond Routing on page 89.

To route a hydrograph

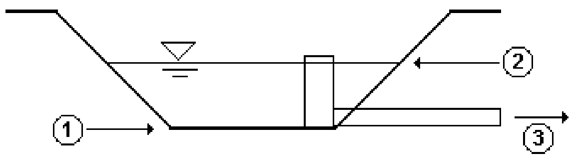
1 In the Hydrograph view, click an empty hydrograph row or in the Model view, click anywhere in the plan view area.

> **NOTE** In the Hydrograph view, you can select an unused hydrograph row for your next hydrograph. In the Model view, Hydraflow Hydrographs Extension automatically increments the number. The new hydrograph number must be greater than that you plan to route.

2 Click Edit menu ➤ Reservoir or in the toolbox, click  (Route Hydrograph Through Pond).

3 In the Reservoir Routing dialog box, enter the pond routing data:

- To route one pond through another, select Lower Pond. Select the lower pond from the list (you can select any pond but the one designated as the upper pond). See Routing Through Interconnected Ponds on page 56.
- Normally, the ponds are initially dry and the routing calculations begin at stage 0. Routing through wet ponds, that is, ponds that are full or partially full is handled using the Wet Pond Elevation option.



(1) Stage 0 (2) Wet pond elevation (3) Outlet

- Optionally, if another runoff hydrograph enters the lower pond downstream of the upper pond, select an additional hydrograph from the Additional Inflow list.

See Reservoir Route Dialog Box on page 55.

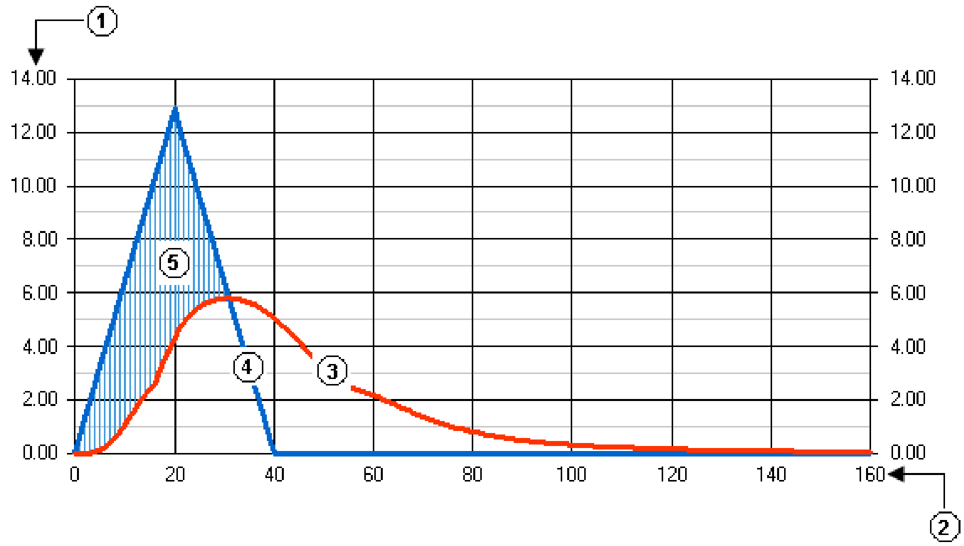
4 Click OK.

Hydraflow Hydrographs Extension computes the hydrograph.

5 Click Results to view the hydrographs or Exit to return to the work area.

Your hydrograph may display as one of the following types:

- Typical routing hydrograph.



(1) Q (cfs)

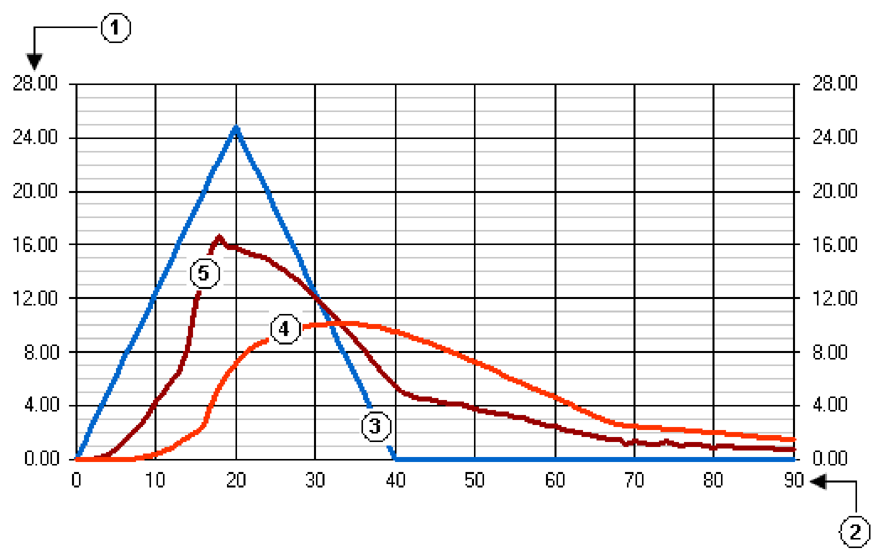
(2) Time (min)

(3) Outflow (routed) hydrograph

(4) Inflow hydrograph

(5) Total storage used

- Interconnected ponds routing hydrograph.



(1) Q (cfs)

(2) Time (min)

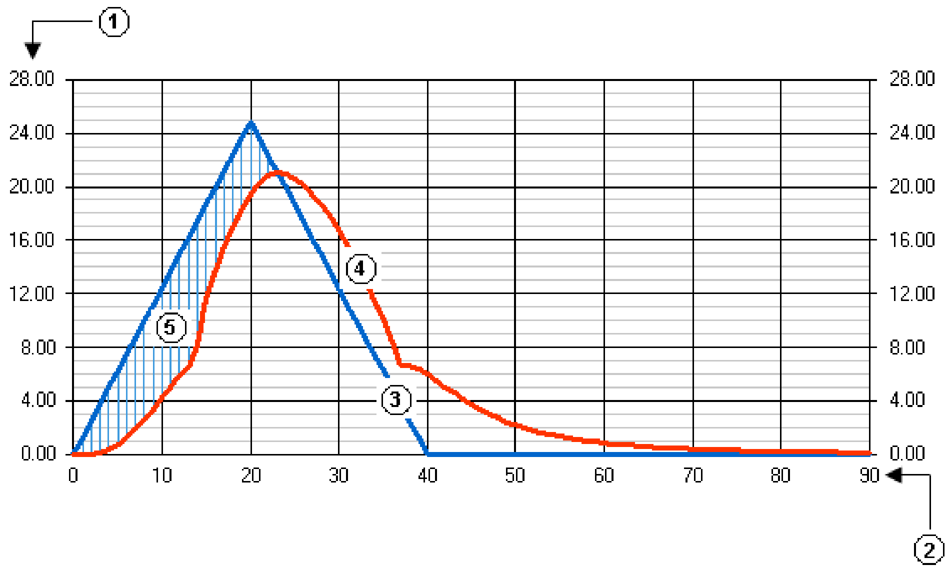
(3) Inflow hydrograph

(4) Lower pond outflow hydrograph

(5) Outflow from upper pond, inflow for lower pond

NOTE Notice the location of the peak at 18 minutes and 16.7cfs, and shape of the Outflow from the upper pond as it compares to the following hydrograph which was routed without the lower pond.

- Single pond routing hydrograph (this one peaked at 23 minutes and 21 cfs without the lower pond).



(1) Q (cfs)

(2) Time (min)

(3) Inflow hydrograph

(4) Outflow hydrograph

(5) Total storage used

See also:

- Reservoir Route Dialog Box on page 55
- Routing Through Interconnected Ponds on page 56

Reservoir Route Dialog Box

Use this dialog box to enter data for routing a detention pond.

Description

Specifies the name or the description of the hydrograph. This information appears in the printed reports.

Reach Data

Inflow Hydrograph

Specifies a hydrograph to route.

Pond Name

Specifies the name of the pond through which the hydrograph is routed.

NOTE You must set up your detention pond before giving it a name. See Using Detention Ponds on page 31.

Lower Pond

Unlocks and activates the interconnected pond feature.

Wet Pond Elevation

Specifies the elevation of existing water level in the pond.

NOTE This entry must correspond to a point on the stage-discharge curve. These values are shown in the list. You cannot begin a wet pond routing at a stage where the outflow is greater than zero.

Additional Inflow

Specifies an additional hydrograph to be combined with the outflow hydrograph from the upper pond.

Progress

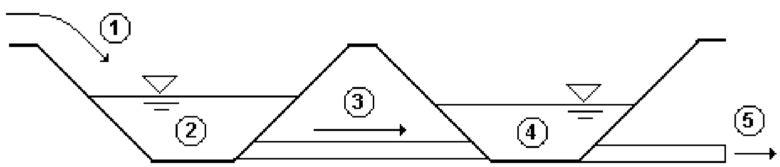
Displays the progress of the routing operation.

Related procedures:

- Pond Routing on page 52
- Routing Through Interconnected Ponds on page 56

Routing Through Interconnected Ponds

You can route any hydrograph through two interconnected ponds. In most cases, the routed outflow hydrograph from an upstream pond can be used as the inflow hydrograph into the second pond by doing two separate routings. However, in some cases the downstream pond is at or near the same bottom elevation as the upper pond and can affect the stage-discharge relationship of the upper pond, which can affect the outflow hydrograph from the upper pond. This scenario rarely affects the final outflow hydrograph from the lower pond.



(1) Inflow

(2) Upper pond

(3) Out/In

(4) Lower pond

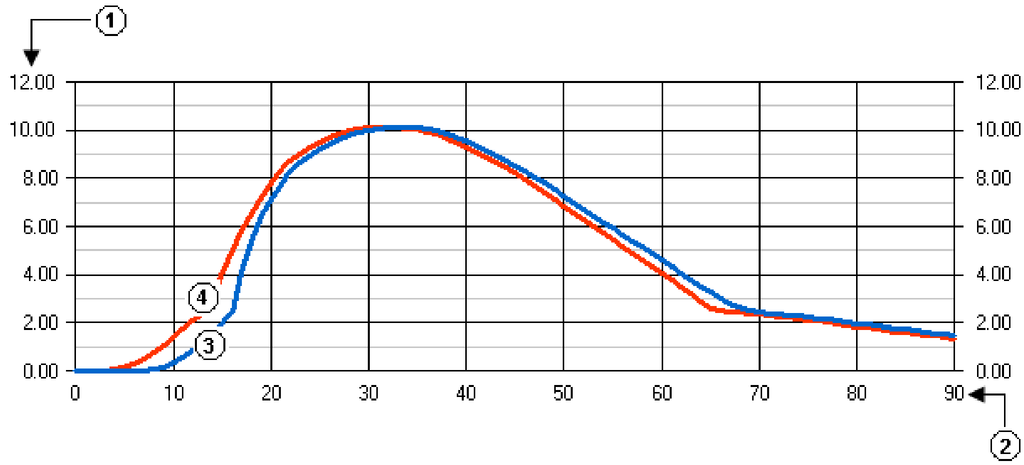
(5) Out

The routing process is accomplished by dynamically linking the two ponds. The routing calculation procedure is performed in single time increments (equal to the time interval of the inflow hydrograph). During this procedure, the outflow from the upper pond, over one time increment, is in turn routed through the lower pond. The computed stage in the lower pond is then used as a tailwater condition for the upper pond for the next calculation increment. Its stage-discharge curve is recomputed. A new outflow is computed from the upper pond and the process is repeated for the remaining time increments. Thousands of detailed computations take place during this procedure.

NOTE Although Hydraflow Hydrographs Extension computes two hydrographs during this procedure, only the final outflow hydrograph is available for further downstream processing. The upper hydrograph is attached to the lower (primary) hydrograph and will appear on all reports and graphs. The Total Storage Used as shown on plots is the combined maximum storage. Only two ponds can be interconnected at a time.

Interconnected vs. Combined Ponds

The interconnected ponds scenario rarely affects the final outflow hydrograph from the lower pond. The following graph shows the comparison of the lower interconnected pond routing (previously described) and combining the two ponds into one larger pond. The resulting hydrographs are very close.



(1) Q (cfs)

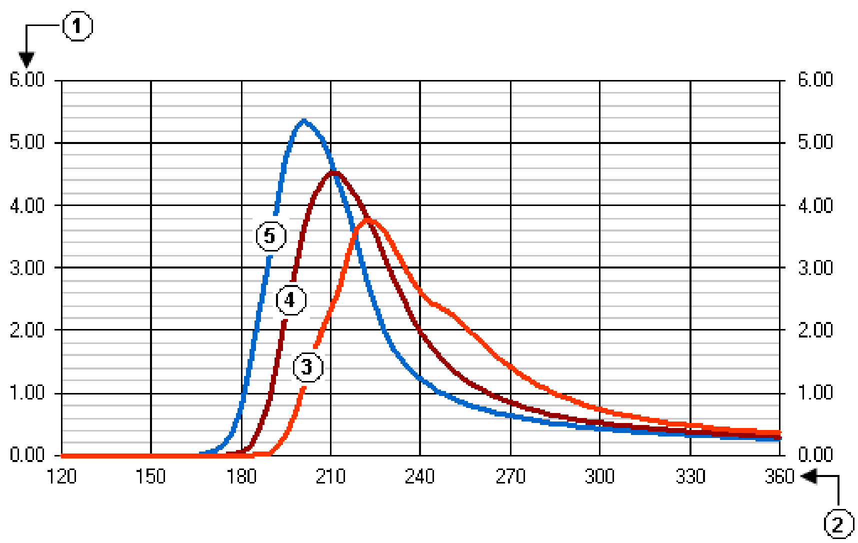
(3) Interconnected pond hydrograph

(2) Time (min)

(4) Combined pond hydrograph

Is Interconnection Needed?

In many situations, you do not need to use interconnected ponds. Interconnected ponds are useful in situations when one pond is below another, or when the computed pond elevations stay below those in the upper pond. The following illustration is an example of a situation where an interconnected pond procedure is not required.



(1) Q (cfs)

(3) Hydrograph 1

(5) Hydrograph 2

(2) Time (min)

(4) Outflow pond hydrograph

In this illustration, the ponds route cleanly with peaks occurring at the intersection of the respective inflow hydrographs. There is no need to perform dynamic routings.

See also:

- Reservoir Route Dialog Box on page 55
- Pond Routing on page 52

Diverting Hydrographs

You can divert any hydrograph into two separate hydrographs. This situation can occur when channels divide or when pond outlet structures are designed to direct the outflow in two different directions. For example, you might want the outflows from an emergency spillway to be separated into one hydrograph and the remaining flows into another hydrograph. You may also want to separate the exfiltration component as a hydrograph.

Hydraflow Hydrographs Extension offers four diversion methods:

- **Divide by constant Q**
  Use this method to divide the hydrographs by a constant flow (Q). For example, if you entered 35.5, Hydraflow Hydrographs Extension would generate one hydrograph consisting of all Qs above 35.5 cfs, and another hydrograph that consisted of all Qs equal to or below 35.5.
- **Divide by flow ratio**
  Use this method to divide the inflow hydrograph by a ratio. For example, if you entered 0.25, Hydraflow Hydrographs Extension would generate one hydrograph with flows equal to 25% of the inflow ordinates and another hydrograph that consisted of the remaining 75% flow ordinates.
- **Divide by first flush volume**
  Use this method if you need to strip off an initial volume from the inflow hydrograph. For example, if your detention pond contains a fore bay, you could extract that volume from the inflow hydrograph first. Set it aside and route the remaining hydrograph through the pond.
- **Divide by pond structure**
  Use this method in situations where the inflow hydrograph is a Reservoir Route hydrograph. Then you have the option of dividing the hydrograph by one of the outlet structures for the pond. For example, if the pond has a culvert and a weir structure and you want to redirect the weir flows offsite, you can select the weir structure as the divide. Hydraflow Hydrographs Extension will then create two hydrographs: one consisting of the weir flows, and the other made from the remaining flows.

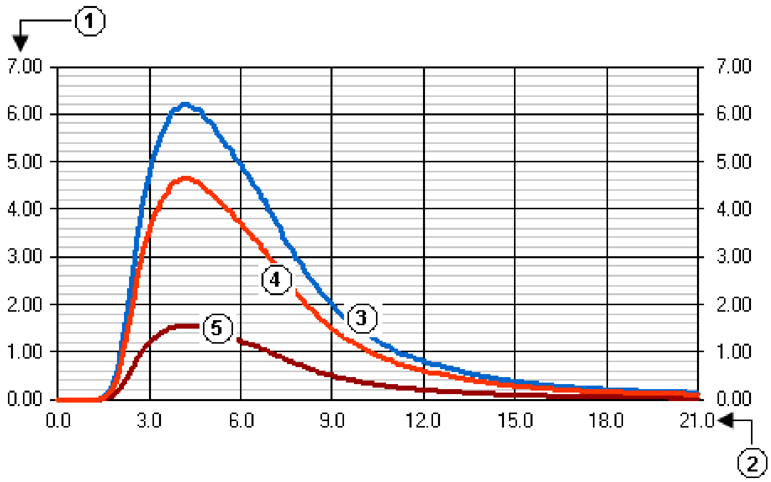
  Use this option after you performed the routing. Using the hydrograph for the pond outflow and the stage-discharge curve, Hydraflow Hydrographs Extension calculates the component flows of the specified outlet structure.

When diverting, Hydraflow Hydrographs Extension creates two hydrographs and labels them as Diversion1 and Diversion2.

To divert a hydrograph

1. In the Model or Hydrograph view, select a hydrograph that you want to to divert.
2. On the toolbox, click (Divide Hydrograph in Two).
3. In the Divert Hydrographs dialog box, enter the required data.
4. Click OK to return to the initial view, or click Results to view the resulting hydrograph.

The following illustration shows an inflow hydrograph (3) split by a ratio of 75%.



(1) Q (cfs) (3) Inflow hydrograph (5) Split hydrograph (25%)

(2) Time (min) (4) Split hydrograph (75%)

See also:

- Divert Hydrographs dialog box on page 59.

Divert Hydrographs Dialog Box

Use this dialog box to enter data for diverting a hydrograph.

Outflow Hydrographs

1st Outflow Hydrograph

Specifies the first outflow hydrograph. This hydrograph must have a number greater than the hydrograph that you divert.

Description

Specifies the name or description of the first diverted hydrograph.

2nd Outflow Hydrograph

Specifies the second outflow hydrograph. This hydrograph must have a number greater than the hydrograph that you divert.

Description

Specifies the name or description of the second diverted hydrograph.

Diversion Method

Constant Q (cfs)

Select to divide the hydrograph by a constant Q.

Flow Ratio

Select to divide the inflow hydrograph by a flow ratio.

First-flush volume (cuft)

Select to strip off an initial volume from the inflow hydrograph.

Pond Structure

Select to divide the hydrograph by one of the outlet structures of the pond. Use this option if the inflow hydrograph is a reservoir routing hydrograph.

Related procedures:

- Diverting Hydrographs on page 58.

Performing Automatic Updates

When you completed developing the runoff hydrographs and performed the necessary routings, you can recompute the entire watershed model.

Recomputing the watershed model is useful in these situations:

- You made changes to one or more upstream runoff hydrographs (for example, you changed the time interval or drainage area) and you want these changes to be reflected throughout the model.
- You made changes to the Event Manager settings. For example, you activated or deactivated additional return periods.

To recalculate a watershed model

- On the toolbar, click (Recompute All Hydrographs).

Hydraflow Hydrographs Extension begins auto-update from hydrograph 1 and works downstream. It recomputes each hydrograph step by step, in the same manner as you would do manually. As a result, the model reflects all the changes made to upstream runoff hydrographs in the downstream pond and reach routings, as well as the combine and diversion operations.

Editing Hydrographs

You can manipulate your model by performing the editing operations, such as cut, copy, paste, insert, and delete.

To edit a developed hydrograph

1. Do one of the following:
   - In the Model or Hydrograph view, double-click the hydrograph icon or the table row respectively.
   - On the toolbar, click (Edit Hydrograph No. n).
2. In the corresponding dialog box, modify the required data and click OK.
3. Click (Recompute All Hydrographs) to update the model.

NOTE You can move, resize, and freeze columns in the table. You can also print the table by clicking (Print Table as Shown). See Printing Reports on page 62.

Deleting Hydrographs

You can delete a single hydrograph or a range of hydrographs.

To delete a hydrograph

1. In the Model view, select the hydrograph icon or in the Hydrograph view, select the table row.
2. Click Edit menu ➤ Delete, or on the toolbar, click  (Delete Hydrograph No. n).
3. In the message box, click Yes.

   If the hydrograph to be deleted is currently an inflow hydrograph for other downstream hydrographs, you receive a warning message. If you proceed, Hydraflow Hydrographs Extension attempts to reconnect and renumber the remaining hydrographs.

TIP Select a range of hydrographs in the Hydrographs view. When deleting diverted hydrographs, Hydraflow Hydrographs Extension deletes both Diversion1 and Diversion2 hydrographs.

Inserting Hydrographs

You can insert a hydrograph into your model.

To insert a hydrograph

1. In the Model or Hydrographs view, select a hydrograph as the insertion point. For example, to insert a hydrograph between hydrographs 4 and 5, select 5.
2. Click Edit menu ➤ Insert or on the toolbar, click  (Insert New Hydrograph No. n).

   Hydraflow Hydrographs Extension moves all downstream hydrographs down by one, leaving a blank hydrograph at the insertion point.

NOTE Hydraflow Hydrographs Extension does not allow you to insert a hydrograph between diverted hydrographs.

Using Cut, Copy, and Paste with Hydrographs

These commands allow you to duplicate hydrographs or manipulate assigned numbers. For example, if you are modeling a pre- and post-development scenario, first create the pre-developed runoff hydrographs. Then you can copy and paste the pre-developed hydrograph to use for the post-developed hydrograph. In the copied hydrograph, you must modify the curve numbers and runoff coefficients, but you do not have to enter duplicate information.

To copy/cut and paste a hydrograph

1. In the Model view, select the hydrograph icon or in the Hydrograph view, select the table row.
2. Click Edit menu ➤ Copy or Cut.

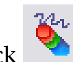
   If you selected Cut, the hydrograph is deleted from the model after it is copied.
3. Click Edit menu ➤ Paste.

NOTE You can copy hydrographs from other project files and paste them in your current project. When you do this using hydrographs other than runoff, however, Hydraflow Hydrographs Extension must change their origins to manual hydrograph.

Editing Detention Ponds

You can edit detention ponds the same way that you edit hydrographs.

To edit a detention pond

1. In the Ponds view, select a pond.
2. Click Edit menu ➤ Edit or on the toolbar, click  (Edit Pond No. n).
3. In the Stage / Storage / Discharge dialog box, modify the required data and click Apply.

To delete pond data

1. In the Ponds view, select a pond.
2. Click Edit menu ➤ Delete or on the toolbar, click  (Delete Pond No. n).

You can duplicate your pond data to quickly perform scenarios of different pond configurations. Instead of editing the same pond data, select different ponds for routing.

To copy and paste pond data

1. In the Ponds view, select a pond that you want to duplicate.
2. Click Edit menu ➤ Copy.
3. Select the destination pond row.
4. Click Edit menu ➤ Paste.

Printing Reports

You can print hydrograph or detention pond data and data for any or all return periods as a report. There are two types of summary style reports and a general hydrograph report. The general report prints all the input data and a tabulated, numeric listing of time vs. outflows. You can also specify additional optional reports and formatting options.

You can print a hydrograph table as it is displayed in the Hydrographs view. Use this feature for printing fast reports or if you have modified the table.

To print a hydrograph display

- In the Hydrographs view,  (Print Table as Shown).

You can print out a formal report at any time. You can also print out hydrograph and stage-storage-discharge diagrams from their screen displays.

To print a report

1 On the toolbar, click  (Open Reports Menu).

2 In the Reports Print Menu dialog box, enter the required data.

3 Alternatively, click Preview to view the report.

4 Click Print.

See also:

- Reports Print Menu dialog box on page 63.

Reports Print Menu Dialog Box

Use this dialog box to set up printed reports.

Report Options

Watershed Schematic

Select to print the watershed model schematic.

Legend

Specifies to include a legend with the watershed model schematic.

Return Period Recap

Select to print a summary tabulation that shows the peak flow for each return period in the hydrograph. This report is useful for comparing peak Qs.

Summary Page

Select to print a summary report that is similar to the Hydrographs view.

Hydrograph Reports

Select to print numerical or graphical reports on the selected hydrographs.

Graphic/Numeric

Specifies whether to print the graphical version of the selected hydrographs reports or their numerical version. Both options report all the input data. The graphical version replaces the Q vs. T tables with a graph.

From/To

Specifies a range of hydrographs and graphs to be printed. Enter the beginning and ending hydrograph numbers. Click All to select all hydrographs.

All

Click to select all hydrographs.

Q's >

Specifies to include only those Q's that are equal to or above this minimum setting. An example entry could be 50. Hydraflow Hydrographs Extension then limits the Q vs. Time table to flow rates greater than or equal to 0.50 x Qp. This option is only available if you selected Numeric as type of report.

Print Interval

Specifies to print the hydrograph reports at an interval greater than one. For example, to minimize the size of the report, enter 4, then only every fourth ordinate on the hydrograph is printed. This option is only available if you selected Numeric as type of report.

NOTE If you specify printing intervals greater than four, the report may not show the peak flow ordinate.

Minutes/Hours

Specifies the time measurement unit to use in the report.

Tc Worksheet

Specifies that the corresponding TR-55 Tc Worksheets are included with the hydrograph report. This option is only available if you selected SCS, SBUH, or Rational hydrographs and used TR-55 to compute the time of concentration (Tc).

NOTE The information prints on one page and only once, regardless of the number of return periods selected.

Storm Hyetographs

Specifies whether to print the rainfall hyetograph or precipitation report. This option is only available if you selected SCS hydrographs and used the Synthetic, SCS 6-Hr, Custom, or Huff rainfall distributions.

NOTE Depending on the time interval, this option can increase the size of the report.

Pond Report

Specifies whether to print pond reports if hydrographs are reservoir routes.

Numeric

Specifies whether the pond report is in a numeric format.

Expanded

Specifies whether to print the expanded stage-storage-discharge table (up to 210 rows). This option increases the size of the report by two to three pages.

Rainfall Report

Select to print a numeric report of the IDF curves and the precipitation values set in the Event Manager.

Page No's

Select for the page number to appear on each page of the report.

Begin With

Specifies the starting page for the report. For example, if you want to include the report as an insert into another report starting on page 12, enter 12.

Table of Contents

Select to add a table of contents to the report. This option is available if you selected Page No's.

NOTE The table of contents prints on the last page of the report.

Frequencies

1-Yr to 100-Yr

Specifies the return periods activated in the Event Manager. Select the options to print. Hydraflow Hydrographs Extension prints the entire range of selected reports one return period at a time.

Output Units

English/SI

Specifies the measuring system used in the report.

Preview

Opens the Print Preview window, where you can view the report and make any changes.

NOTE All secondary reports, such as Tc worksheets and pond reports are printed only once and after the return period for the specified hydrograph.

Related procedures:

- Printing Reports on page 62.

Design Storms

Different types of storm data can be used with SCS methods. You can select the following storm distributions. Enter the associated precipitations for these storms in the Event Manger.

Storm Name	Duration (hrs)	Description
Type I, IA, II, and III	24	Dimensionless distributions developed by SCS using Weather Bureau's Rainfall Frequency Atlases for different geographic regions.
Type II FL	24	Type II modified for parts of Florida.
SCS Standard	6	Dimensionless distribution developed by SCS for a shorter, 6-hr duration.
Synthetic	User defined	Dimensionless distribution is automatically developed using IDF curves and symmetrically arranged rainfall depths. Similar to SCS distributions but with user-defined duration.
Custom	User defined	A user-specified dimensionless hyetograph. User must specify time interval.
Huff	User defined	Developed from Time Distributions of Heavy Rainstorms in Illinois by Floyd A. Huff. Used primarily in the Midwest.
Huff 1st		Durations <= 6 hrs
Huff 2nd		Durations > 6 and <= 12 hrs
Huff 3rd		Durations > 12 and <= 24 hrs
Huff 4th		Durations > 24 hrs
Huff Indy		Used primarily in Indianapolis, Indiana.

SCS 24- and 6-Hour Storms

The Soil Conservation Service (now called NRCS) has developed four dimensionless 24-hour rainfall distributions, including a six hour, using the Rainfall Frequency Atlases from the Weather Bureau. The different distribution types apply to certain regions. These distributions can be applied to a total precipitation hyetograph to define an excess precipitation hyetograph. When running Hydraflow Hydrographs Extension, you only specify the distribution type. The corresponding total precipitation is retrieved from the Event Manager. The total 24-hr rainfall precipitation is available from Technical Paper No. 40 or from your local drainage authority.

Synthetic Storms

The synthetic storm is an accurate way to model a watershed when you want to use a design storm of less than 24 hours. Often, a 24-hour storm is overkill because of its large volume. The synthetic storm is derived from the National Weather Service data. This is the same data that is used to derived the SCS 24-hour storm, but it is in a different format.

The SCS method is derived from the unit hydrograph method. This method creates a hydrograph using one inch of precipitation over a single time interval. This Unit Hydrograph describes the temporal patterns of the watershed and you apply a design storm hyetograph—any storm of any duration—to this Unit Hydrograph to get a final runoff hydrograph. The SCS 24-hour storms are not required.

When you install Hydraflow Hydrographs Extension, set up the rainfall intensity-duration data file, see Setting Up IDF Curves on page 13. After you set up the IDF curve file, you can use it to create any design storm with any time interval, length, and return period between 1 and 100 years. Hydraflow Hydrographs Extension uses the current IDF file to calculate alternating depth increments over a selected time interval, just like the SCS 24-hr storms. The design storm hyetograph is constructed by placing the maximum depth increment near the center of the storm and arranging the other increments in a symmetrical form. See design storms computational methods on page 77.

The only required input is the total Storm Duration in hours. The storm duration should be at least twice the time of concentration (Tc) but not greater than six hours.

Custom Design Storms

You can input precipitation distribution data, such as the SCS storms, that was created by a third party such as your local drainage authority. Input requirements are the cumulative precipitation ratios for the desired duration. You can specify up to 2,880 precipitation ratios in any time interval. Typically, these ratios begin at 0 and increase to 1.0.

The custom design storm is used when you selected Custom as the Storm Distribution for the SCS Runoff hydrograph. You can save and load design storms for different projects. The current custom design storm is remembered by the application when you exit the program, and it will automatically reload the next time you run Hydraflow Hydrographs Extension.

Custom storms can be saved as *.cds* files, however, the current loaded storm automatically attaches to the project file when it is saved.

CDS files are simple ASCII files saved in the following format:

```
Time Interval in minutes
Precip Ratio at Time Interval 1
Precip Ratio at Time Interval 2
Precip Ratio at Time Interval 3
Precip Ratio at Time Interval 4
Precip Ratio at Time Interval 5
..
Precip Ratio at Time Interval n (n<= 2,880)
```

You can create .cds files in a spreadsheet or word processing application and then open them in Hydraflow Hydrographs Extension.

To set up a custom design storm

1 Click Design Storm menu ➤ Create/Edit Custom Distribution.

2 In the Custom Design Storm dialog box, click (Clear Table) to remove sample data from the table.

3 Select a required time interval.

4 Click Apply to update the table.

5 Click in the first cell of the Precip. Ratio column and enter the ratio for the first time interval.

NOTE The zero time interval is not shown because it is assumed that the precipitation ratio is also zero.

6 Enter the values for the remaining time intervals (press the *Tab* key to move between the cells).

7 Click Apply.

8 Alternatively, change time interval and click Apply to refresh the table data.

NOTE The runoff hydrograph time intervals you want to use with this storm must match the time interval of the custom design storm.

9 To save the custom design storm, click  (Save This Storm .cds File).

Huff Distributions

Huff distributions are dimensionless design storms based on the Illinois State Water Survey Bulletin 70/71 and Circular 173, Table 3. These design storms can be used with the SCS runoff hydrograph at any time interval and total duration. Hydraflow Hydrographs Extension interpolates between values as needed. The Huff 1st, 2nd, 3rd, and 4th quartiles, and the Huff Indy are available in Hydraflow Hydrographs Extension.

The following table (Huff 1st quartile) shows the percent precipitation as it varies with the storm time.

% Storm Time	% Precipitation
0	0.0
5	16
10	33
15	43
20	52
25	60
30	66
35	71
40	75
45	79
50	82
55	84
60	86
65	88

% Storm Time	% Precipitation
70	90
75	92
80	94
85	96
90	97
95	98
100	100

Plotting Hydrographs

As soon as Hydraflow Hydrographs Extension computes a hydrograph, the hydrograph is available to plot on the screen. You can generate the following types of plots:

- Hydrograph plots:
  - SCS, SBUH, Rational, and Manual runoff hydrographs
  - Combined
  - Diverted
  - Channel routed
  - Pond routed
  - Elevation vs. Time
  - Volume vs. Time
  - Exfiltration vs. Time

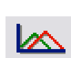
- Detention Pond plots:
  - Stage-storage
  - Stage-discharge

  - Design Storm plots:
    - All Design Storm hyetographs including SCS 24-hour storms in two styles.
    - Rainfall IDF curves

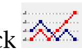
Use the following three types of plots:

- Q vs. Time
- Elevation vs. Time
- Precipitation vs. Time

To generate a hydrograph plot

1. In the Model or Hydrographs view, select a hydrograph.
2. On the toolbar, click  (Plot Multiple Hydrographs).

Hydraflow Hydrographs Extension displays the corresponding hydrograph plot.

3 To change the time units from minutes to hours, in the Hydrograph Plot dialog box, click  (Toggle min/hr).

4 Optionally, export the plot as a bitmap image on page 69 or print it.

5 When finished, click  (Exit).

Hydrograph Plot Dialog Box

Use this dialog box to modify the display of the hydrograph plots.

Return periods (1-Yr to 100-Yr)

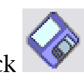
Specifies the different return periods.

Exporting Hydrographs

You can export any hydrograph as a bitmap image (*.bmp*) or as a comma-separated value (*.csv*) file, which you can import into a spreadsheet or word processor.

To export a hydrograph as a bitmap image

1 Generate a hydrograph plot. See Plotting Hydrographs on page 68.

2 In the Hydrograph Plot dialog box, click File menu ➤ Export or on the toolbar, click  (Export as Bitmap .bmp Image).

3 Specify the file name and location and click Save.

To export a hydrograph as a comma-separated value file

1 In the Model or Hydrograph view, select a hydrograph to export.

2 Click File menu ➤ Export Hyd.

3 Specify the file name and location and click Save.

Hydraflow Hydrographs Extension writes the Q vs. Time data to a comma-separated ASCII file.

See also:

- Importing and Manually Inputting Hydrograph Data on page 26

Customizing the Application Appearance

You can customize the appearance of Hydraflow Hydrographs Extension. The customization settings are saved in the *Hydro2007.ini* file in *C:\Program Files\AutoCAD Civil 3D Hydraflow Hydrographs Extension*.

To change the appearance options

1 Click Options menu ➤ Model.

2 Select any of the following options:

- Show Hydrograph Numbers — shows the numbers next to each model entity.
- Show Hydrograph Descriptions — shows the model entity description that you entered in the respective Description fields.
- Show Arrow Heads— adds arrowheads to the connector lines between the model entities.

Customizing the Layout

While creating hydrographs, Hydraflow Hydrographs Extension automatically builds the model and displays the model in the Model view. You can move each model entity anywhere in the workspace. This option is useful to achieve similarity between the model and the actual connectivity of the watershed subareas.

To move model entities in the workspace

- Right-click and drag the entity to the required position.

To reset the diagram to the default layout

- Click Options menu ➤ Reconfigure Diagram.

TIP You can also double-click anywhere in the workspace (not on the symbols) to reconfigure your layout to the default.

Saving and Retrieving Files

Hydraflow Hydrographs Extension uses five types of files.

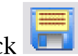
- **Project files** — These files are used to store all the project data including the IDF curves, event files, and the custom design storm file that was being used at the time the project was last saved. These files are saved in an ASCII format and can be viewed in any word processor. Project files have a *.gpw* extension.
- **IDF curve files** — These files store the IDF curves. They have an *.idf* extension.

  NOTE Hydraflow Storm Sewers Extension and Hydraflow Express Extension also use IDF files that are compatible with Hydraflow Hydrographs Extension.

- **Custom design storm file** — This file contains a custom design storm. It has a *.cds* extension.
- **Event files** — These files store all of the data contained in the Event Manager, such as the 24-hour precipitation, and active return periods. These files have a *.pcp* extension.
- **Initialization file** — The *Hydro2007.ini* file is used to store information about the appearance settings in Hydraflow Hydrographs Extension, the name and file path of the IDF curve, event information, and the custom design storm that was used in the last session. This file is automatically saved and retrieved from the folder where Hydraflow Hydrographs Extension is installed.

Hydraflow Hydrographs Extension operates completely in RAM to enhance performance. A power outage could cause the loss of the current project data. Save the project frequently to avoid data loss.

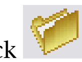
To save a project

1 Click File menu ➤ Save or on the toolbar, click  (Save This Project).

2 If you are saving the project for the first time, in the Save As dialog box, enter the project name and specify the location.

  Hydraflow Hydrographs Extension saves the project as a GPW file.

To open a project

1 Click File menu ➤ Open Project or on the toolbar, click  (Open Project).

2 Enter the name of the project file or select the file from the list and click Open.

Computational Methods

3

This section describes the methodology used in AutoCAD Civil 3D Hydraflow Hydrographs Extension for the calculations of hydrographs, rainfall IDF curves, channel, and pond routing. Review the following computational methods and equations to better understand the results.

Hydrologic Methods

Hydraflow Hydrographs Extension uses the HEC-22, Soil Conservation Service, SCS (now called Natural Resources Conservation Service, NRCS), and the Rational methods for most hydrologic calculations. These methods have become the industry standard among practicing engineers and state agencies. This section provides a summary of the concepts used by Hydraflow Hydrographs Extension.

The following publications have been consulted when implementing the various hydrologic calculation methods:

- *NEH-4: Hydrology; Section 4, National Engineering Handbook*
- *TR-20: Computer Program Manual, 1992*
- *TR-55: Urban Hydrology For Small Watersheds*
- *A Guide To Hydrologic Analysis Using SCS Methods, Richard McCuen*
- *HEC No. 12: FHA, Drainage of Highway Pavements*
- *HEC No. 22: FHA, Urban Drainage Design Manual*
- *Hydrology for Engineers; Linsley, Kohler & Paulhus*
- *Urban Storm Drainage Management; Sheaffer, Wright, Taggart & Wright*
- *Handbook of Hydraulics; Brater, King, Lindell, Wei*

Computing SCS Unit Hydrograph

Hydraflow Hydrographs Extension uses the unit hydrograph method for calculating runoff hydrographs. It uses the triangular D-hour unit hydrograph approach as used in TR-20. The unit hydrograph represents a 1-inch rainfall over one time interval.

The peak flow for the unit hydrograph is computed using the following equation:

$$Qp = \frac{484AQ}{Tp}$$

Where:

Qp = peak flow (cfs)

484 = shape factor

A = area (sq. miles)

Q = total excess precipitation (1 inch)

Tp = time to peak (hrs)

The shape factor is a user defined variable. The default value is 484 and reflects a unit hydrograph that has 3/8 of its area under the rising limb. This factor is higher (for example, 600) in mountainous watersheds, and lower (approximately 300) in flat and swampy watersheds.

TIP If you don't know the exact value of the shape factor, leave the default.

The time to peak (Tp) and the time base (Tb) values determine the characteristics of the unit hydrograph. Hydraflow Hydrographs Extension computes these values using the following equations:

$$Tp = \frac{Tc + D}{1.7}$$

Where:

Tp = time to peak (hrs)

Tc = time of concentration (hrs)

D = unit duration or time interval (hrs)

Tc = 1.67 x L (lag time)

$$L = \frac{l^{0.8}(S+1)^{0.7}}{1900Y^{0.5}}$$

Where:

L = lag time (hrs)

l = hydraulic length (ft)

S = (1000 / CN) - 10

Y = basin slope (%)

CN = SCS curve number

$$Tb = 2.67Tp$$

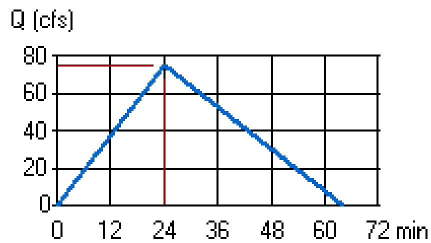
Where:

Tb = time base (hrs)

Tp = time to peak (hrs)

After the unit hydrograph ordinates have been computed, Hydraflow Hydrographs Extension lets you change the unit duration or time interval (D). This feature is useful when the input time interval (D) is too large related to the time to peak (Tp). Normally, the time interval (D) value should not exceed the time to peak (Tp) value by more than 0.5 times. When you change time interval (D), Hydraflow Hydrographs Extension recomputes time to peak (Tp) so that it falls on an even increment of the new time interval.

In the following example of a unit hydrograph (which represents one inch of rainfall over one time interval), peak flow (Qp) = 75, time to peak (Tp) = 24 min, time base (Tb) = 2.64 (24) = 64 min.



Computing Time of Concentration

You can compute the time of concentration (Tc) by hand and input it directly. You can also override the precomputed Tc by selecting Lag, User, Kirpich or TR-55 under Time of Concentration in the SCS Runoff Hydrograph and Rational Method Hydrograph dialog boxes.

Lag Method

This is the TR-20 default method.

$$Tc = 1.67L$$

Where:

L = lag time

Kirpich Method

This method is normally used for natural basins with well defined routes for overland flow along bare earth or mowed grass roadside channels. This method is similar to the Lag method, but typically gives shorter times.

$$Tc = 0.0078L^{0.77}S^{-0.385}$$

Where:

Tc = time of concentration (min)

L = hydraulic length (ft)

S = average basin slope (ft/ft)

User Method

This method allows you to override the computed time of concentration (Tc) value and enter a value manually.

TR-55 Method

This method allows you to compute Tc by using the 3-component Tc as used by TR-55. Hydraflow Hydrographs Extension has a built-in TR-55 worksheet that computes Tc. See Computing Tc by TR-55 on page 21.

$$Tc = SheetFlowTime + ShallowConcFlowTime + ChannelFlowTime$$

Sheet flow time (Tsheet) (hrs)

$$Tsheet = \frac{0.007(nL)^{0.8}}{P_2^{0.5} S^{0.4}}$$

Where:

n = Manning's roughness coefficient

L = flow length (must be <= 300 ft per TR-55)

P2 = two-year 24-hr rainfall (in)

S = land slope (%)

Shallow concentrated flow time (Tshallow) (hrs)

$$Tshallow = \frac{L}{3600V}$$

Where:

L = flow length (ft)

V = average velocity (ft/s) and

$$V = Cp\sqrt{S}$$

Where:

V = average velocity (ft/s)

Cp = 20.3282 paved surfaces

Cp = 16.1345 unpaved surfaces

S = watercourse slope (ft/ft)

Channel flow time (Tchannel) (hrs)

$$Tchannel = \frac{L}{3600V}$$

Where:

L = flow length (ft)

V = average velocity (ft/s) and

$$V = \frac{1.49 R^{2/3} S^{0.5}}{n}$$

Where:

V = average velocity (ft/s)

R = hydraulic radius (ft) = a/wp

S = channel slope (ft/ft) (entered as %)

N = Manning's roughness coefficient

Computing Design Storms

To calculate the direct runoff hydrograph, you need an excess precipitation hyetograph. There are several ways to specify the design storm, most of which are the SCS 24-hour and 6-hour distributions. Other options include the synthetic storm, Huff, and the custom storm.

SCS 24-Hour Distributions

Hydraflow Hydrographs Extension provides the SCS 24-hr distributions in any time interval you specify. The incremental rainfall amounts are computed from a polynomial equation. This equation is used with coefficients that vary depending on the elapsed time of the storm:

$$P_t = C_0 + C_1 T + C_2 T^2 + C_3 T^3$$

Where:

Pt = fraction of 24-hour precipitation

T = elapsed time (hrs)

C0 = coefficient

C1 = coefficient

C2 = coefficient

C3 = coefficient

You can obtain the coefficient values from the Soil Conservation Service or NRCS.

Synthetic Storms

The Synthetic Storm option can produce an infinite number of design storm hyetographs. For each combination of the time interval and total storm duration, Hydraflow Hydrographs Extension can derive a design storm. Hydraflow Hydrographs Extension uses the rainfall IDF curves to compute depth increments over the time intervals. From these data, the design storm is constructed by placing the maximum depth increment near the center of the storm and arranging the other increments in a symmetrical alternating form.

The Perfect Storm

The Synthetic Storm can be perfectly matched to the site, because the total duration can be specified to better fit the computed time of concentration (Tc). For example, if Tc is 30 minutes, you could specify a one-hour storm rather than a 24-hour storm. This way, the storm lasts long enough so that the entire drainage area contributes to flow to the most downstream point. Going beyond Tc only adds unnecessary volume and calculation resources.

To plot this storm at the SCS runoff plot

- On the toolbar, click  (Open Event Manager).

Excess Precipitation Hyetograph

The precipitation increments of the specified storm, including the SCS, synthetic, Huff, and the custom storms directly input, are converted to excess precipitation using the following equation:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

Where:

Q = excess volume of precipitation (in)

P = accumulated precipitation (in)

S = potential maximum retention = (1000 / CN) - 10

CN = SCS curve number

The computed volumes are converted to excess increments which are used in the final excess precipitation hyetograph.

Computing Rainfall IDF Curves

Hydraflow Hydrographs Extension builds its rainfall IDF curves from user-supplied data. If you are using map data (FHA method), Hydraflow Hydrographs Extension computes rainfall intensity values based on the methods presented in HEC-12 (*FHWA Hydraulic Engineering Circular No. 12, Drainage of Highway Pavements*).

The FHA Method

The calculation methods for the Eastern and Central United States are different from the Western region.

IMPORTANT This method does not produce 1- or 3-year return periods.

Eastern and Central States

Precipitation values for the 2-year and 100-year frequencies of 5-, 15-, and 60-minute durations are required for input. Hydraflow Hydrographs Extension uses these values and the following equations to estimate values for 10- and 30-minute durations.

10-min value = 0.59 x (15 min) + 0.41 x (5 min)

30-min value = 0.49 x (60 min) + 0.51 x (15 min)

The following equations are used to compute values for return periods between the 2- and 100-year frequencies:

5-yr = 0.278 x (100-yr) + 0.674 x (2-yr)

10-yr = 0.449 x (100-yr) + 0.496 x (2-yr)

25-yr = 0.669 x (100-yr) + 0.293 x (2-yr)

50-yr = 0.835 x (100-yr) + 0.146 x (2-yr)

Once the rainfall volumes for the 2-year through 100-year frequencies of 5-, 10-, 15-, 30-, and 60-minute durations are computed, Hydraflow Hydrographs Extension converts them to intensity values in inches per hour.

Western States

Precipitation values required for input are the 24-hour and 6-hour durations for the 2-year and 100-year frequencies. Hydraflow Hydrographs Extension uses these values and the following equations to compute 60-min duration values:

Y2 = 0.218 + 0.709 x [X1 (X1/X2)]

Y100 = 1.897 + 0.439 x [X3 (X3/X4)] - 0.008 x Z

Where:

Y2 = 2-yr, 60-min value

Y100 = 100-yr, 60-min value

X1 = 2-yr, 6-hr value

X2 = 2-yr, 24-hr value

X3 = 100-yr, 6-hr value

X4 = 100-yr, 24-hr value

Z = point elevation in hundreds of feet

Hydraflow Hydrographs Extension uses a built-in nomograph to compute precipitation amounts for return periods between the 2-year and 100-year frequencies. Hydraflow Hydrographs Extension then applies built-in ratios to convert the 60-min volumes to 5-, 10-, 15-, and 30-min volumes. See HEC-12.

The rainfall volumes are then converted to intensities in inches per hour.

Equation Coefficients

Hydraflow Hydrographs Extension computes rainfall intensity for any time duration or time of concentration (Tc), using the FHA equation:

$$I = \frac{B}{(Tc + D)^E}$$

Hydraflow Hydrographs Extension computes the coefficients B, D, and E using a log-log interpolation of the rainfall intensity values, which plots to an almost straight line. Next, Hydraflow Hydrographs Extension uses a trial-and-error process to determine a constant D, which is added to corresponding time of concentration (Tc) values, allowing the line to plot straight. The coefficient B is the ordinate at t = 1. The coefficient E is the slope of the plotted line. This procedure is repeated for each frequency.

Using Existing IDF Curves to Develop Coefficients

You can derive your own equation coefficients in case the computed ones do not exactly match those that you are accustomed to. Simply reverse the procedure described in Equation Coefficients.

To develop custom coefficients

1. Plot your existing rainfall intensity - duration curve(s) on log-log paper.
2. Find the values B, D, and E and enter them into Hydraflow Hydrographs Extension.

3 Normally, the initial plotted line is not straight. If it plots straight, then D = 0. Otherwise, select a constant D, such as 5, for example.

4 Add this value to each of the time of concentration (Tc) ordinates and replot the line.

5 If the line is straight, D = 5. If it is not straight, try different constants until the line is straight. B is then the intensity at Tc = 1, while E is the slope of the plotted IDF line.

6 Edit the IDF curve coefficients to match the ones derived and save.

Third Degree Polynomial Equation

Hydraflow Hydrographs Extension has the option of creating IDF curves using a third-degree polynomial equation as follows:

$$I = A + Bx + Cx^2 + Dx^3$$

Where:

I = rainfall intensity (in/hr) (cm/hr)

X = Ln (time duration in minutes)

A = coefficient

B = coefficient

C = coefficient

D = coefficient

Appropriate values for X are 8 to 180 minutes.

Computing SCS Runoff Hydrographs

After computing the excess precipitation hyetograph, Hydraflow Hydrographs Extension computes the direct runoff hydrograph using the concept of convolution or linear superpositioning. Each increment of the design storm hyetograph is multiplied by each ordinate of the unit hydrograph. The resulting hydrographs are then added or superimposed to obtain a final runoff hydrograph.

Computing SBUH Runoff Hydrographs

The SBUH method is similar to the SCS method. It is based on the curve number (CN) and uses SCS equations for computing soil absorption and precipitation excess. The SCS method works by converting the incremental runoff depths (precipitation excess) for a given basin and design storm hydrographs of equal time base according to the basin time of concentration (Tc) and adds them to form the final runoff hydrograph. The SBUH method converts the incremental runoff depths into instantaneous hydrographs which are then routed through an imaginary reservoir with a time delay equal to the basin Tc.

When computing a runoff hydrograph, the SBUH method doesn't involve an intermediate step (a unit hydrograph).

There are two steps of creating the final runoff hydrograph:

1 Computing the instantaneous hydrograph.

The instantaneous hydrograph (I(t)) at each time interval (dt) is computed as follows:

$$I(t) = 60.5 \times R(t) \times A/dt$$

Where:

R(t) = runoff depth at time interval dt

A = basin area (acres)

dt = time interval (min)

2 Computing the runoff hydrograph.

$$Q(t+1) = Q(t) + w[I(t) + I(t+1) - 2Q(t)]$$

Where:

Q(t) = runoff hydrograph ordinate at time t

I(t) = instantaneous hydrograph from Step 1

$$w = dt/(2Tc + dt)$$

Where:

Tc = basin time of concentration

dt = time interval in minutes

Computing Rational Method Hydrographs

In the Standard Rational Method, the peak is equivalent to the peak discharge using the following formula:

$$Qp = CiA$$

Where:

Qp = hydrograph peak discharge (cfs)

C = runoff coefficient

A = basin area (acres)

i = intensity (inches per hour)

The time to peak (Tp) of the hydrograph is equal to the time of concentration (Tc). The ascending limb is equal to the time-to-peak x (ascending limb factor (ALF)). The receding limb of the hydrograph is equal to the time-to-peak x (receding limb factor (RLF)). The hydrograph is an isosceles triangle when ALF = 1 and RLF = 1. Hydraflow Hydrographs Extension assigns a time interval of 1 minute to all Rational method hydrographs. Intermediate hydrograph values are computed through straight-line interpolation.

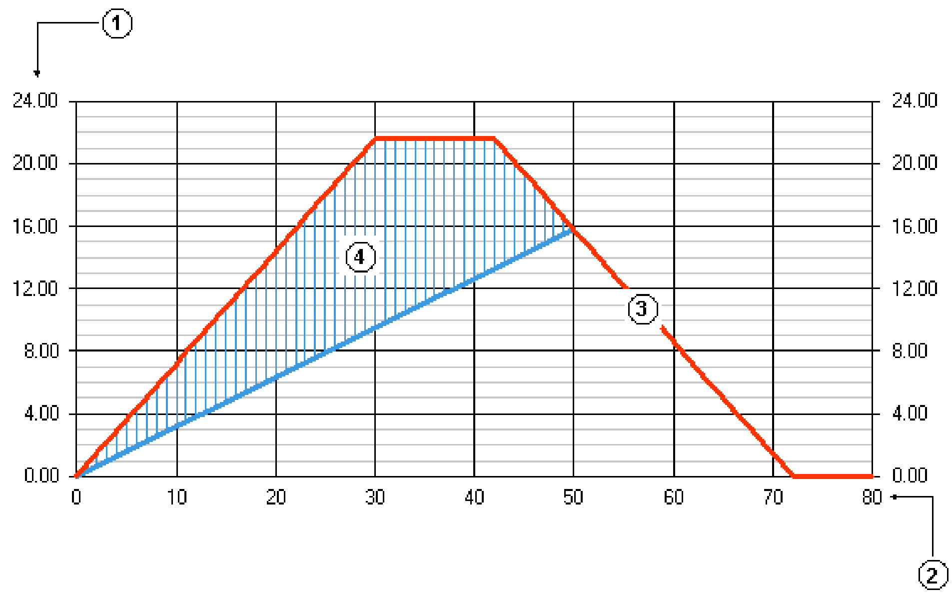
Modified Rational Method

This method takes the standard Rational to a different level in order to yield a hydrograph for use in the design of detention ponds. According to the Rational method, the highest Qp occurs when the rainfall duration equals time of concentration (Tc). When the rainfall duration is greater than Tc, the Qp is reduced, but the total runoff volume is increased. It is believed that this greater volume can increase the required size of a detention pond.

The objective is to find the total duration (critical storm event) that maximizes the required storage of a detention pond. Hydraflow Hydrographs Extension simply modifies the Storm Duration factor between successive storage estimates to arrive at the critical event or the Storm Duration factor.

NOTE This is an estimate only and you will still need to set up a detention pond and perform the routing.

The following illustration shows a Modified Rational Method hydrograph.



(1) Q (cfs)

(3) Hydrograph 1

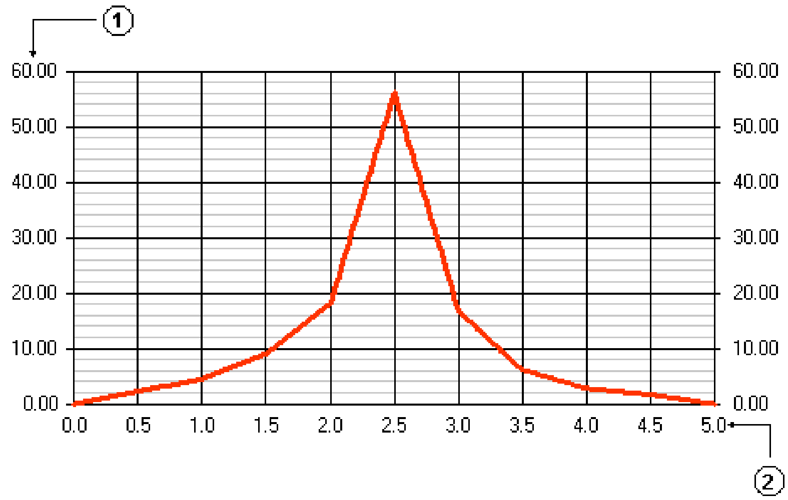
(2) Time (min)

(4) Modified Rational Est. Storage =19,606 cuft

Dekalb Rational Method

The Dekalb Rational method is based on the methods presented in the *Drainage Procedures Manual* of Dekalb County, Georgia. The Dekalb Rational method, typically used on small, urban watersheds (less than 10 acres), where the peak is equivalent to the peak discharge as determined by the Standard Rational formula. The distribution, however, is based on the series of empirically derived constants. These constants along with the hydrograph ordinates are shown in the help screens.

The following illustration shows a Dekalb Rational method hydrograph.



(1) Q (cfs) (2) Time (hrs)

Computing Combined Hydrographs

When adding or combining hydrographs, Hydraflow Hydrographs Extension computes the algebraic sum of each hydrograph ordinate, starting at each hydrograph t = 0, to derive the final hydrograph. This procedure takes into account the individual lag times from each hydrograph.

NOTE Each hydrograph must have equal time intervals.

Hydraflow Hydrographs Extension can add up to six hydrographs at once. See Combining Hydrographs on page 28.

Computing Channel Routing

The objective of channel routing is to estimate the flood hydrograph at a known point downstream of a river or channel reach. The solution requires an inflow hydrograph and a routing coefficient. In general the theory is based on a discharge-flow area relationship where:

$$Q = xA^m$$

The final routing method used is known as the modified Att-Kin:

$$Ot + dt = (1 - C) \times Ot + C \times It$$

Where:

Ot + dt = outflow at time t+dt

Ot = outflow at time t

It = inflow at time t

C = routing coefficient

The routing coefficient is computed as:

$$C = \frac{(2dt)}{2K + dt}$$

Where:

dt = time interval in seconds or hours

K = L/(mV)

Where:

L = channel reach length (ft)

m = factor relating average velocity and wave velocity (celerity)

V = average velocity (ft/s)

The equations and formulas used by Hydraflow Hydrographs Extension to estimate x and m are further described in Technical Release 20, Computer Program for Project Formulation Hydrology.

The following table shows a sample channel routing calculation:

Time	**Inflow**	**Computation**	**Outflow**
0	—	(1-C)Ot + CIt	0
0.5	400	0.7(0) + 0.3(0) =	0
1.0	800	0.7(0) + 0.3(400) =	120
1.5	1200	0.7(120) + 0.3(800) =	324
2.0	1600	.7(324) + 0.3(1200) =	587
2.5	2000 <Pk	0.7(587) + 0.3(1600) =	891
3.0	1700	0.7(891) + 0.3(2000) =	1224
3.5	1500	0.7(1224) + 0.3(1700) =	1367
4.0	1250	0.7(1367) + 0.3(1500) =	1407 <Pk
4.5	1000	0.7(1407) + 0.3(1250) =	1360
5.0	750	0.7(1360) + 0.3(1000) =	1252
5.5	500	0.7(1252) + 0.3(750) =	1101
6.0	250	0.7(1101) + 0.3(500) =	921
6.5	0	0.7(921) + 0.3(250) =	720
7.0	0	0.7(720) + 0.3(0) =	504
7.5	0	0.7(504) + 0.3(0) =	353

NOTE In situations where the channel is less than five feet wide and has a travel time equal to or less than the time interval, it is not necessary to perform channel routing. Instead, you can include the channel portion values in the calculations of runoff hydrograph drainage area and time of concentration (Tc).

Computing Detention Ponds Stage-Discharge

For reservoir routing, Hydraflow Hydrographs Extension can model up to eight outlet structures and an exfiltration component at one time. The operation of these structures is treated as a function of the water surface elevation in the reservoir or pond.

Culverts/Orifices

The equation used for culvert/orifice structures is:

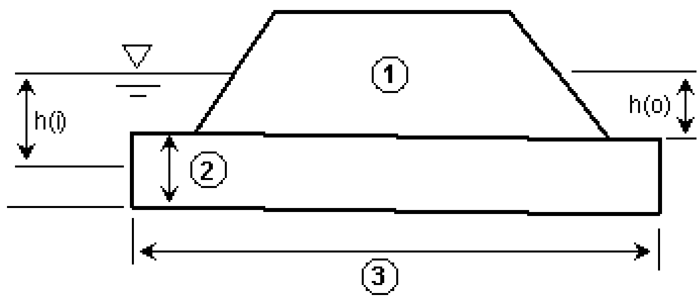
$$Q = C_o A \sqrt{\frac{2gh}{k}} \times Nb$$

Where:

Under inlet control	Under outlet control
Q = Discharge (cfs)	Q = Discharge (cfs)
A = Culvert area (sqft)	A = Culvert area (sqft)
h = Distance between the water surface and the centroid of the culvert barrel (1/2 flow depth during partial flow) (ft)	h = Distance between the upstream and downstream water surface
Nb = Number of barrels	Nb = Number of barrels
Co = Orifice coefficient	Co = 1
k = 1	k = 1.5 + [(29n2L)/R1.33] Where: n = Manning's n-value L = Culvert length (ft) R = Area/wetted perimeter (ft)

NOTE When a non-zero tailwater (TW) elevation is entered, Hydraflow Hydrographs Extension compares the pond stage with TW and computes a tailwater head, hTW. If this head is less than the head computed as h, then h = hTW.

The following illustration shows a profile of a typical culvert, where h(i) is the head under inlet control and h(o) is the head under outlet control.



(1) Embankment (3) Pipe length h(o) - Head under outlet control

(2) Rise h(i) - Head under inlet control

During the calculation process, both inlet and outlet control are evaluated. Inlet control means that the inlet of the culvert controls the amount of flow the culvert can handle. Under inlet control, the discharge depends on the barrel shape, cross-sectional area and inlet edge. Outlet control means that flow can enter the structure at a faster rate than it can exit. Under outlet control, the discharge depends on the slope, length and roughness of the barrel.

Hydraflow Hydrographs Extension computes the discharge at each stage, including intermediate stage points that it generates, using both inlet and outlet control equation parameters. The smallest value is used as the discharge at that elevation. This is reflected on the screen tabulation as "ic", inlet control and "oc", outlet control.

NOTE Hydraflow Hydrographs Extension does not assume full flow when the depth is actually partial.

Perforated Riser

A perforated riser is a special kind of orifice structure which contains a series of same-size holes within a vertical height, see Perforated Risers on page 43. Hydraflow Hydrographs Extension uses the following formula (McEnroe, 1988) to estimate the outflow.

$$Q = Cp \frac{2A}{3Hs} \sqrt{2g}\, H^{3/2}$$

Where:

Q = discharge (cfs)

Cp = 0.61

A = cross-sectional area of all the holes (sqft)

Hs = distance from S/2 below the lowest row of holes to S/2 above the top row (ft)

Weirs

The basic equations used to calculate weir flow are:

- Rectangular, Cipoletti, broad crested, and riser

$$Q = C_W L H^{1.5}$$

Where:

Q = Discharge over weir (cfs)

L = Length of the weir crest (ft)

H = Distance between water surface and the crest (ft)

Cw = Weir coefficient, typically 3.33

NOTE Hydraflow Hydrographs Extension uses the same weir equation for rectangular (sharp-crested weir with end contractions) and the Cipoletti weir (with no end contractions). Currently, there is not enough valid data available to support a unique equation for the weir with end contractions.

The following equation, supplied in HEC-22, attempts to adjust the weir length by subtracting 20% of H. However, by closer inspection, one can see that Q will eventually decrease to zero with increasing H.

$$Q = C_W \left(L - 0.2H\right) H^{1.5}$$

- V-notch

$$Q = 2.54 Tan\left(\frac{\theta}{2}\right) H^{2.5}$$

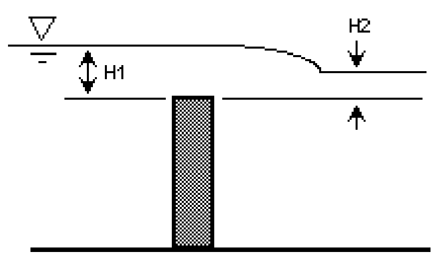
Where:

Q = discharge over weir (cfs)

θ = angle of v-notch (deg)

H = head on apex of v-notch (ft)

Rectangular, V-notch, and Cipoletti weirs are affected by submergence when the tailwater rises above the crest as follows.



This often occurs in multi-stage structures when the water surface in the riser (Riser HG) rises above the riser crest, due to the head produced by culvert A. As a result, the discharge over the weir is reduced. The equation for the reduction in flow is:

$$Qs = Qr\left(1 - \left(\frac{H_2}{H_1}\right)^{1.5}\right)^{0.385}$$

Where:

Qs = submerged flow (cfs)

Qr = unsubmerged flow from standard weir equations

H1 = upstream head above crest (ft)

H2 = downstream head above crest (ft)

NOTE Numbers that are adjusted for submergence have the suffix 's' in the stage-discharge table.

See also:

- Weir Structures on page 44.

Exfiltration

Hydraflow Hydrographs Extension computes exfiltration outflows using the following equation:

$$Qex = \left(\frac{ER \times SA}{12 \times 3600} \right)$$

Where:

Qex = outflow (cfs)

ER = exfiltration rate (in/hr)

SA = surface area, wetted or contour (sqft)

Computing Stage-Storage

Hydraflow Hydrographs Extension has three methods to compute the stage-storage table.

Trapezoids

The volume is computed by treating the structure as a trapezoidal basin.

$$V = LWD + (L + W)Z D^2 + \frac{4}{3} Z^2 D^3$$

Where:

V = storage at stage D (cuft)

D = stage or depth (ft)

L = bottom length (ft)

W = bottom width (ft)

Z = side slope, (Z:1) (H:V)

Underground Chambers

Hydraflow Hydrographs Extension computes the volume of a pipe using the following equation:

$$V = \frac{L}{6} (A_1 + 4M + A_2)$$

Where:

V = storage (cuft)

L = pipe length (ft)

A1 = cross-sectional area of depth at downstream end

A2= cross-sectional area of depth at upstream end

M = cross-sectional area of depth at midsection

When the pipe slope is zero, Volume = LA1

Contours

Hydraflow Hydrographs Extension uses either the average-end-area method applied vertically or the Conic method. The conic method uses the following equation:

$$V = d\left(\frac{A_1 + \sqrt{A_1 A_2} + A_2}{3}\right)$$

Where:

V = storage (cuft)

d = change in elevation between points 1 and 2

A1 = surface area at elevation 1 (sqft)

A2 = surface area at elevation 2 (sqft)

Computing Detention Pond Routing

Detention pond routing is the process of passing a flood hydrograph through a storage reservoir or detention pond. This process changes the pattern of flow with respect to time but conserves volume. The purpose of detention pond routing is usually to reduce the peak flow to a predetermined level, or to delay the peak. The routing procedure used by Hydraflow Hydrographs Extension is known as the Storage Indication method and begins with a stage-storage-discharge relationship, an inflow hydrograph, and the following equation:

$$I - O = \frac{ds}{dt}$$

Where:

I = inflow

O = outflow

ds/dt = change in storage

Hydraflow Hydrographs Extension first uses the specified stage-storage-discharge table to internally plot a curve of 2s/dt + O. It then computes the outflow hydrograph using a procedure similar to the following example.

The following table contains values for sample detention pond calculations.

Time (min) (1)	**Ii (cfs) (2)**	**Ij (cfs) (3)**	**2s/dt-Oi (4)**	**2S/dt+Oj (cfs) (5)**	**Outflow (cfs) (6)**
0	0	24	0	-	0
4	24	95	4	24	10
8	95	206	33	123	45
12	206 +	345 +	174 = 725	334	80
16	345	500	439	725	143
20	500	655	884	1284	200
24	655	794	1509	2039	265
28	794	905	2292	2958	333
32	905	976	3239	3991	376
36	976	1000	4310	5120	404
40	1000	976	5426	6286	430
44	976	905	6502	7402	450
48	905	848	7453	8383	465
52	848	736	8252	9206	477
56	736	638	8866	9836	485
60	638	554	9260	10240	490
64	554	480	9468	10452	492
68	480	417	9514	10502	494<
72	417	0	10411	491	

Routing procedure.

- Column 1 and column 2 are read from the inflow hydrograph.
- Column 3 is the inflow at time j.
- Column 4 is column 5 - 2 x column 6.
- Column 5 for j is [column 2 + column 3 + column 4]j.
- Column 6 is computed by straight-line interpolation from the plot of 2S/dt + O vs. O.

Reference Tables

A

SCS Curve Numbers (CN)

Land Use Description	Hydrologic Soil Group			
Residential	**A**	**B**	**C**	**D**
Average lot size:				
1/8 acre or smaller	77	85	90	92
1/4 acre	61	75	83	87
1/3 acre	57	72	81	86
1/2 acre	54	70	80	85
1 acre	51	68	79	84
2 acre	46	65	77	82
1/8 acre or smaller	77	85	90	92
Paved parking lots and roofs	98	98	98	98
Streets and roads:				
Paved with curbs	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89
Commercial and business areas	89	92	94	95
Industrial districts	81	88	91	93

Land Use Description	Hydrologic Soil Group			
Residential	**A**	**B**	**C**	**D**
Open spaces, lawns, and parks:				
Good condition	39	61	74	80
Fair condition	49	69	79	84
Fallow	77	86	91	94
Row crops	72	81	88	91

*Average Runoff Condition. Ia = 0.2S

Source: Soil Conservation Service TR-55

Runoff Coefficients (C)

Area Description	Coefficient Value	Typical Design
Business:		
Central business	0.70 - 0.95	
District and local	0.50 - 0.70	
Residential:		
Single family	0.35 - 0.45	
Multi-units detached	0.40 - 0.75	
Suburban	0.25 - 0.40	
Apartments	0.50 - 0.70	
Industrial:		
Light	0.50 - 0.80	
Heavy	0.60 - 0.90	
Parks, cemeteries	0.10 - 0.25	
Playgrounds	0.20 - 0.35	
Railroad yards	0.20 - 0.40	
Lawns		
Sandy soil	0.05 - 0.20	
Heavy soil	0.18 - 0.35	0.30

Area Description	Coefficient Value	Typical Design
Unimproved	0.10 - 0.30	0.20
Asphaltic	0.70 - 0.95	0.90
Concrete	0.80 - 0.95	0.90
Roofs	0.75 - 0.95	0.90

Source: ASCE

Manning's n-Values

Pipes	Manning's n
Reinforced concrete	0.013
Vitrified clay pipe	0.013
Smooth welded pipe	0.011
Corrugated metal pipe	0.023
Polyvinyl chloride (PVC)	0.010
Natural Channels	
Gravel beds, Straight	0.025
Gravel beds, large boulders	0.040
Earth, straight, some grass	0.026
Earth, winding, no vegetation	0.030
Earth, winding	0.050
Overland Flow	
Smooth surfaces (concrete, asphalt, bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils, residue <=20%	0.06
Cultivated soils, residue >20%	0.17
Short grass	0.15
Dense grass	0.24
Bermuda grass	0.41

Pipes	Manning's n
Light underbrush woods	0.40
Dense underbrush woods	0.80

Source: Soil Conservation Service TR-55

Weir Coefficients (Cw)

Broad Crested Weirs						
Head (ft)	**Breadth of Crest (ft)**					
H	**1′**	**2′**	**3′**	**5′**	**10′**	**15′**
0.2	2.69	2.54	2.44	2.34	2.49	2.68
0.4	2.72	2.61	2.58	2.50	2.56	2.70
0.6	2.75	2.61	2.68	2.70	2.70	2.70
0.8	2.85	2.60	2.67	2.68	2.69	2.64
1.0	2.98	2.66	2.65	2.68	2.68	2.63
1.2	3.08	2.70	2.64	2.66	2.69	2.64
1.4	3.20	2.77	2.64	2.65	2.67	2.64
1.6	3.28	2.89	2.68	2.65	2.64	2.63
1.8	3.31	2.88	2.68	2.65	2.64	2.63
2.0	3.30	2.85	2.72	2.65	2.64	2.63
2.5	3.31	3.07	2.81	2.67	2.64	2.63
3.0	3.32	3.20	2.92	2.66	2.64	2.63
3.5	3.32	3.32	2.97	2.68	2.64	2.63
4.0	3.32	3.32	3.07	2.70	2.64	2.63
4.5	3.32	3.32	3.32	2.74	2.64	2.63
5.0	3.32	3.32	3.32	2.79	2.64	2.63
5.5	3.32	3.32	3.32	2.88	2.64	2.63

Hydraflow Hydrographs Extension applies the following weir coefficients as defaults:

Weir Type	Weir Coefficient (Cw)
Rectangular	3.30

Weir Type	Weir Coefficient (Cw)
Cipoletti	3.30
Riser	3.30
Broad Crested	2.60
V-Notch	2.54Tan (Angle/2)

Source: *Brater & King, Handbook of Hydraulics*

Orifice Coefficients (Co)

Concrete Pipe, Beveled-Lip Entrance

Length	Diameter				
	12″	24″	36″	48″	60″
10′	.86	.91	.92	.93	.94
20′	.79	.87	.90	.91	.92
30′	.73	.83	.87	.89	.90
40′	.68	.80	.85	.88	.89
50′	.65	.77	.83	.86	.88
60′	.61	.75	.81	.85	.87
80′	.56	.71	.78	.82	.84
100′	.52	.67	.74	.79	.82
120′	.49	.64	71	.77	.80
150′	.45	.60	.68	.74	.77

Concrete Pipe, Square Cornered Entrance

Length	Diameter				
	12″	24″	36″	48″	60″
10′	.80	.80	.79	.77	.76
20′	.74	.78	.77	.76	.75
30′	.69	.75	.76	.75	.74
40′	.65	.73	.74	.74	.74
50′	.62	.71	.73	.73	.73

Concrete Pipe, Square Cornered Entrance					
Length	**Diameter**				
60′	.59	.69	.72	.72	.72
80′	.54	.65	.69	.70	.71
100′	.51	.62	.67	.69	.70
120′	.48	.60	.65	.67	.68
150′	.44	.56	.62	.65	.60

Source: *Brater & King, Handbook of Hydraulics*

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W