AutoCAD Civil 3D Hydraflow Express Extension

# User's Guide

Autodesk®

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# Contents

# Getting Started

# 1

Welcome to the AutoCAD Civil 3D Hydraflow Express Extension. This chapter describes Hydraflow Express Extension features, including the user interface, printing, working with files, and exporting.

Hydraflow Express Extension is an application for solving typical hydraulics and hydrology problems. It addresses a wide variety of tasks, including culverts, open channels, inlets, hydrology and weirs, using a unique user interface. Just select the task you want from a tool bar, fill in the blanks on a simple input grid, and click a button. Hydraflow Express Extension quickly displays informative graphs, rating curves, on-screen reports, as well as printed reports.

This User's Guide starts with a quick overview of the user interface and contains separate chapters for each task. Those chapters include detailed reference on input, output, and the associated computational methods. The appendix on page 75 contains reference tables for runoff coefficients, SCS curve numbers, and Manning's n-values.

## Help and Documentation

Use the Hydraflow Express Extension User's Guide to answer questions about using the Hydraflow Express Extension. The User's Guide is accessible from the Hydraflow Express Extension Help menu. Click Help menu ➤ User's Guide (PDF) to open the Hydraflow Express Extension User's Guide.

## Support and Sample File Locations

**Hydraflow Express Support and Sample Files**

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

- Express.ini
- SampleExpress.hxp
- SampleExpress.pcp

These files are installed to the following locations:

**Microsoft Vista**

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

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

**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\C3D2011\enu\HHApps\IDF

# Features

Hydraflow Express Extension has hundreds of features covering a broad range of hydraulics and hydrology tasks. Some of the most popular features are summarized in the following sections.

### Culverts

- Models and designs culverts with circular, box, elliptical and arch shapes.
- Automatically designs pipe sizes and slopes.
- Computes hydraulic grade line (HGL) with any flow regime, including supercritical flow, hydraulic jumps, pressure flow, and roadway/embankment overtopping.
- Uses energy-based methodology and HDS-5.
- Computes by a user-defined range of Qs, or single known Q, including a rating curve.

### Channels

- Computes normal depth rating curves for rectangular, trapezoidal, triangular, compound gutter, circular, and user-defined (station, elevation) shapes.
- Describe channel sections using up to 50 user-defined points.
- N-values can vary across sections.
- Provides a variety of calculation options, including Known Q, Known Depth, or Q vs. Depth with user-defined increments.

### Inlets

- Calculates hydraulics for six different inlet types, including curb, grate, combination, drop curb, drop grate, and slotted.
- Computations adhere to standard HEC-22 methodology.
- Computes spread widths for both inlet and gutter sections.
- Supports inlets with localized depressions and compound cross-slopes.
- Develops rating curves.
- Creates three-dimensional and two-dimensional plots.

### Hydrology

- Computes runoff hydrographs with minimal input.

- Supports SCS, Rational, and Modified Rational methods.
- Contains built-in SCS 24-hour and 6-hour design storms, as well as IDF-based synthetic storms of durations from 15 minutes to 24 hours.
- Supports user-defined shape, receding limb, and storm duration factors.
- Computes composite CNs and runoff coefficients.
- Computes Tc by FAA, Lag, TR55, Kirpich, or user-defined.
- Supports low one-minute time intervals with up to 48-hour coverage.
- Supports all storm frequencies with built-in Precip Manager.
- Creates IDF curves from map data, known equation coefficients, or user-defined intensities.
- Estimates required detention storage, including a Depth vs. Outlet Diameter rating curve with optional Target Q input.
- Computes estimated drawdown times.
- Computes Modified Rational Method Storm Duration Factor, which maximizes detention storage.

### Weirs

- Computes hydraulic properties for six different weir types, including rectangular, v-notch, trapezoidal, circular, compound, and proportional.
- Automatically computes weir coefficients with user override.
- Computes by Known Q, Known Depth, or Q vs. Depth rating curves.

### Common user interface

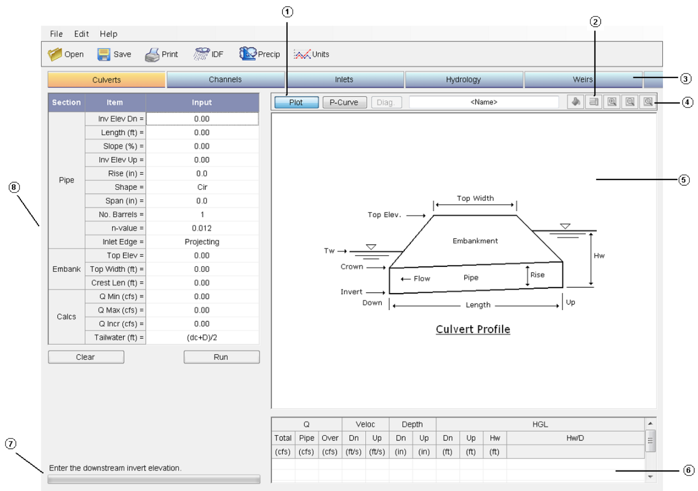
Although many different disciplines are covered in the Hydraflow Express Extension, it uses only one user interface style. The input, output, and reporting procedure is the same throughout.

### Help-assisted data entry

Data entry is simplified with a standard input grid, a graphical display area, and on-screen instructions.

## Common User Interface

Whether modeling a culvert or analyzing a weir, the procedure is the same. The following dialog box is displayed when you start the Hydraflow Express Extension.



- 1 – Graph Type Buttons
- 2 – Graphic Toolbar
- 3 – Task Bar
- 4 – Zoom Buttons
- 5 – Graphic Display
- 6 – Results Grid
- 7 – Input Assist
- 8 – Input Grid

Begin by selecting one of the items on the Task Bar. Note that Culverts is the default each time the application is started. Once you have selected your task, the standard procedure is as follows:

1. Enter data in the Input Grid.

   This grid works like any other spreadsheet style data entry. Simply type the value or select from a list under the Input column, and then press Enter or Tab. The cursor advances to the next item. While doing this, Hydraflow Express Extension displays a Help Diagram in the Graphic Display, as well as tips in the Input Assist box. To edit an item, double-click the cell, or press F2.

   **NOTE** Some data items are not required in the input grid. These cells display a 0 or a blank.

2. Click Run located below the Input Grid.

Hydraflow Express Extension then computes the output, populates the Report Grid, and draws the picture in the Graphic Display.

# Results Grid

This grid contains your numerical output. The column headings change according to the task. You can click a row in the Results Grid to see the corresponding Graphic Display. When you select another grid row, the Graphic Display automatically updates.

# Graphic Display

Hydraflow Express Extension has two types of graphic charts; Plot and Performance Curve. When you click Run, the Graphic Display is automatically updated and defaults to Plot. Plot is typically a section or profile drawing, while the Performance Curve is a chart showing Q vs. Depth. You can toggle back and forth between these types of graphs by clicking the Plot or P-Curve located at the upper left of your Graphic Display.

# Graphic Toolbar

The toolbar, located across the top of the Graphic Display, lets you change the information displayed in the Graphic Display area, as well as other features.

### Graph Type

Click the Plot and P-Curve buttons on the Graphic toolbar to display profile/section plots or performance (rating) curves respectively.

Click the Diag. button to display the task help dialog box.

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**NOTE** When you switch back to the Plot or Performance Curve graphs, you need to re-run the calculations. To do this, click Run.

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### Name

Enter any name for this task in the Name box and then click Run. It displays on your graphic output, as well as in printed reports.

### Zoom In, Zoom Out, Reset Scale

Hydraflow Express Extension has three zoom options that enlarge, reduce, and reset the drawing scale.

**Zoom In**: This feature allows you to enlarge the drawing. When you click Zoom In, the mouse cursor changes to a cross-hair centered inside of a red rectangle. This rectangle represents the scale limits of the enlarged drawing. Move the rectangle to the area you want to enlarge, and then click the left mouse button. Hydraflow Express Extension then redraws the system to an enlarged scale. Repeat this process to enlarge further.

**Zoom Out**: Clicking Zoom Out enlarges the drawing extents. Repeat as desired.

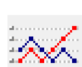
**Reset Scale**: When Hydraflow Express Extension draws your system on the dialog box, it selects a scale so that the entire system is displayed. To redraw the system to this default scale, click Reset.

Other features contained on this toolbar are specific to the task, and are described in detail in the following chapters.

# Working in SI Units

AutoCAD Civil 3D Hydraflow Express 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 55.

# Printing

Hydraflow Express Extension can produce a printed report for each task, as well as a printed Report Grid. To print a report, click Print on the Top Toolbar, or select Print from the File menu. There are two choices: Report or Results Grid.

### Report

Choose this for the formal report. It consists of a numeric input and output section on the top of the page, and a graph at the bottom. The printed graph matches the graph in the current Graphic Display. In other words, if Plot is selected, the printed graph will display the Profile or Section plot. If P-Curve is selected, the Performance Curve is printed. Reports can only be printed after computing.

### Results Grid

Select this to print the Results grid as it is shown.

A print dialog box is displayed to allow specifying a printer, number of copies, and so on.

# Exporting

While viewing, you can save a plot as a bitmap image, or a report to a comma-delimited or tab-delimited text file. Import this file into other programs, such as spreadsheets, word processors, or perhaps your own program for further processing. To import this file into other programs, such as spreadsheets, word processors, or perhaps your own program for further processing. To export a file, select Export from the File menu. There are two choices: Plot as *.bmp* and Results Table.

### Plot as .bmp

This saves the displayed graph as a bitmap image, which can then be imported into many other applications.

### Results Table

This saves the contents as shown in the current Results Table. You can choose to save as a comma (*.csv*) or tab (*.txt*) delimited file. Either file can be opened in a word processor or spreadsheet application.

Hydraflow Express Extension displays a Save As dialog box. Specify a file name and location to save the report.

# Saving and Retrieving Files

Hydraflow Express Extension allows you to save and retrieve your project files. It is recommended that you save your projects often while you are working on them. When saving, Hydraflow Express Extension saves all input data, including all tasks.

# Hydraflow Express Extension Files

Hydraflow Express Extension uses several different types of files.

| File Type | Description |
|---|---|
| Project Files | These files are used to store all of your project data including the IDF curves and precipitation data that were 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 an *.hxp* extension. |
| IDF curves | These files store the IDF curves. They have an *.idf* extension and are compatible with Hydraflow Hydrographs Extension and Hydraflow Storm Sewers Extension software. |
| Precipitation file | This file stores the rainfall precipitation data for the Hydrology section. They have a *.pcp* extension. |
| Initialization file | This file is named Express.ini and is used to store information about the different settings in Hydraflow Express Extension, such as culvert design constraints, last used inlet input data (to be used as defaults) the IDF curve and precipitation file that was being used when the program was last run. This file is automatically saved and retrieved from the file folder where Hydraflow Express Extension is installed. For more information on modifying this file, see Design Constraints on page 19. If you get runtime errors during the install or uninstall of this software, it's most likely that Hydraflow Express Extension cannot find this *.ini* file. |

# Saving Projects

Hydraflow Express Extension works much like a spreadsheet or word processor. To save a project, select Save from the File menu, or click Save. If you are saving the file for the first time, select Save As. When using Save, Hydraflow Express Extension automatically saves the project under its current name displayed on the top title bar of the application window.

**NOTE** Hydraflow Express Extension only saves data for one culvert, one channel type, one inlet type, one hydrograph, and one weir type per project file.

# Opening Projects

To retrieve a project, select Open from the File menu, or click Open. Hydraflow Express Extension searches for files with the *.hxp* extension.

# Summary

Hopefully this overview has provided a basic understanding of Hydraflow Express Extension features, as well as general operating procedures. Pick your task, fill in the input grid, and click Run. Along the way on-screen tips and diagrams will guide you. The output has a number of graphing options and export features. Remember that you can save your project data at any time, and data for all tasks are saved in one file. It is not necessary to save a file for each task.

The remainder of this guide covers each Hydraflow Express Extension task in more detail. Each section describes input items, output in the Results Grid, and the associated computational methods.

# Culverts

# 2

The Culverts task in Hydraflow Express Extension is a sophisticated culvert modeler that can quickly give answers to some basic input. It is assumed that you have a good understanding of fundamental hydraulic principles, and the variety of flow conditions for culverts. This section provides a review of some standard principles governing culvert hydraulics.

Hydraflow Express Extension is capable of modeling culverts of various slopes, lengths, sizes, materials, and shapes, including circular, box, elliptical, and arch. It also deals with a multitude of inlet configurations. The purpose of this application is to compute capacities, rating tables, and hydraulic profiles, including a host of hydraulic properties for highway-type culverts.

For design purposes, Hydraflow Express Extension uses sophisticated energy-based methods to compute the hydraulic grade line (HGL). It can handle inlet control and outlet control in any flow regime from partial depth, full depth, surcharged, roadway overtopping, as well as supercritical flow profiles with hydraulic jump. Methods used are those generally described in HDS-5 (Hydraulic Design of Highway Culverts).

## Input

To enter data, type in the value, or select from a list, and then press Enter or the Tab on your keyboard. The following sections describe each of the required input items. While entering data, on-screen instructions are provided below the Input Grid, and a basic drawing is shown in the Graphic Display. Once the data is input, compute the results by clicking Run.

### Pipe

**Invert Elevation Down** - Enter the invert elevation for the downstream end of the culvert.

**Length** - Enter the length of the culvert barrel.

**Slope** - Optional. Enter the slope of the culvert as a percent (feet/100). Hydraflow Express Extension automatically computes the upstream invert based on this slope. Enter zero to have Hydraflow Express Extension design the invert slope.

**Invert Elevation Up** - Optional. Enter the upstream invert elevation in feet. If a slope was entered, Hydraflow Express Extension fills in a default value. If zero was entered for slope, this item is skipped and designed by Hydraflow Express Extension. For more information, see Computational Methods on page 13.

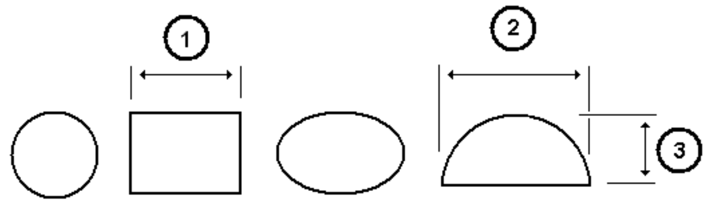
**Rise** - Optional. Enter the pipe barrel height or rise in inches. This is also the diameter of a circular section. Enter zero to design a circular section.

**Shape** - Select the barrel shape from the drop-down list. Design options are available for circular only.

**Span** - Optional. Enter the pipe barrel width or span in inches. Enter zero to design a circular section. For arch shapes, the span must be equal to 2 x rise (half circle).

In the following illustration:

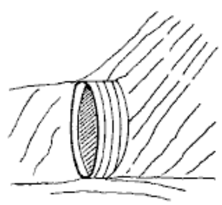
- 1 = Span (typical)
- 2 = Span = 2 x Rise
- 3 = Rise



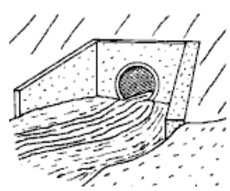

**No. Barrels** - Select the number of pipes or barrels from the drop-down list. Four maximum.

**N-Value** - Enter Manning's roughness coefficient, n. See the Appendix for a table of suggested coefficients. 0.013 is a typical value.

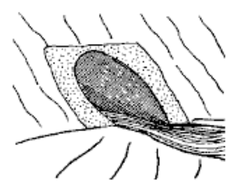
**Inlet Edge** - Select the edge type for the upstream end. The HDS5 coefficients c, Y, M, K as well as minor loss coefficient, K, is derived from the selected inlet edge.



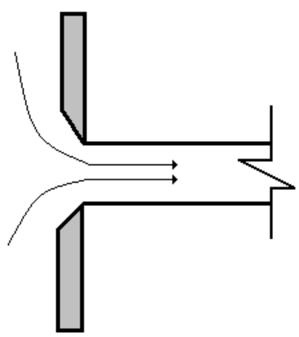
Projecting



Square Edge



Mitered



Beveled Edge

### Embankment

The embankment serves as the cover or roadway above the pipe section. The only items required are the top elevation, top width and crest width, to serve as a weir for overtopping flow. The top width is centered along the pipe length. The side slopes are automatically computed by Hydraflow Express Extension.

**Top Elevation** - Enter the elevation for the top of the embankment, which must be above the pipe crown. If your roadway is superelevated, enter the elevation of the highest side. This is the elevation at which overtopping occurs.

**Top Width** - Enter the width of the top of embankment. This is strictly cosmetic and is centered along the length of the culvert barrel. Width must be less than culvert length.

**Crest Width** - Enter the width of the embankment crest. This value is used as the weir crest length for overtopping flow. This value can be left blank. However, in situations where overtopping occurs, Hydraflow Express Extension interrupts the calculations and prompts you to enter a value.

### Calcs

Hydraflow Express Extension allows you to specify a single flow rate or a range of flows with a user-defined flow increment. A range allows Hydraflow Express Extension to create a rating or performance curve; a single Q does not. There are several choices for a starting tailwater elevation, including a known elevation.

**Q Min** - Enter the smallest Q to be used for the rating calculations.

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**NOTE** If a hydrograph exists in the Hydrology task and Q Min is equal to zero, Hydraflow Express Extension inserts the Q peak from the hydrograph.

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**Q Max** - Enter the largest Q to be used for the rating calculations. Set to Q Min to analyze a single flow rate.

**Q Incr** - Enter the incremental Q to be used for the rating calculations. The default is 1.0. For example, if Q Min = 20, Q Max = 40 and Q Incr = 2, the results are computed from 20 to 40 in increments of 2; for example, 20, 22, 24, 26.

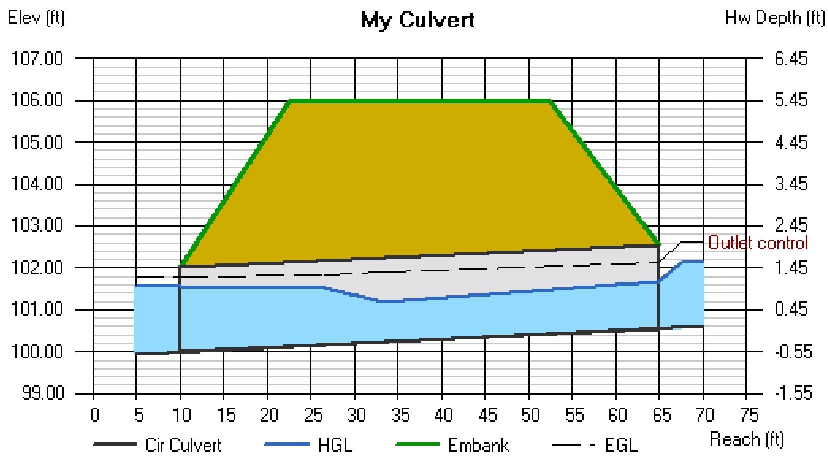
**Tailwater** - Select a starting HG (Tailwater) elevation or enter a known elevation. A known elevation cannot be below critical depth. When this occurs, Hydraflow Express Extension automatically raises it to critical depth. The default is (Critical depth + Rise) / 2.

# Output

Click Run to generate the output. The graphic bar below the Help Assist box displays the progress. If any erroneous data is present, Hydraflow Express Extension prompts you before proceeding. Once completed, the Graphic Display and Results Grid are drawn and populated. If a range of Qs was specified, that range and increment is the basis for the data in the Results Grid. The Graphic Display plots corresponding to the selected row in the Results Grid. For example, to plot a profile corresponding to 26 cfs, click on the row that contains Q total of 26.

### Graphic Display

The following illustration shows a profile of a culvert. The flow runs from right to left. This profile shows outlet control with supercritical flow and hydraulic jump.




The profile graph is mostly self explanatory with each line type indicated in the legend located at the bottom of the graph. The scale on the left indicates the Hw elevation. The one on the right side is absolute depth above the upstream invert elevation. The Hw is labeled Outlet or Inlet control to indicate the flow control.

### Fill

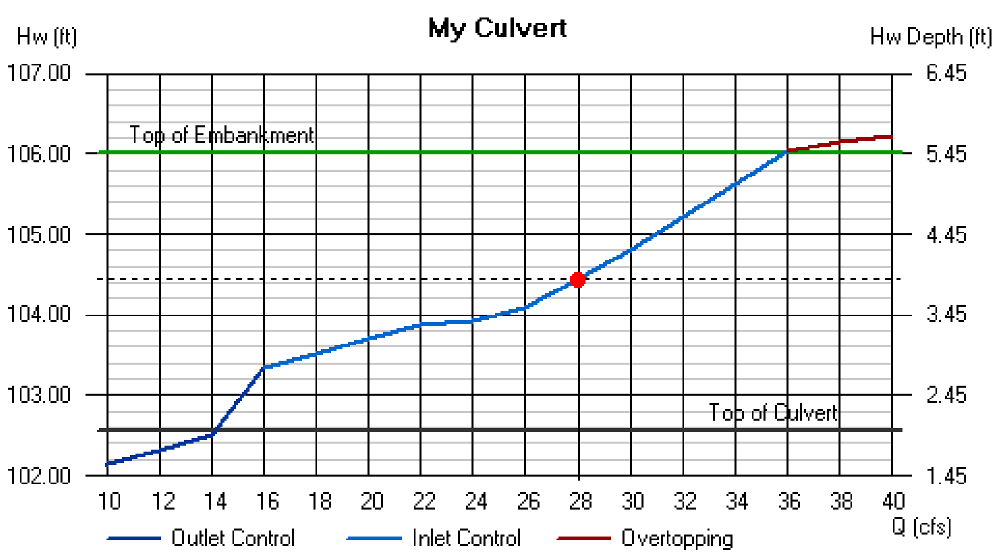
Use this button to turn on/off the color fill. This does not affect printed reports. They do not include filled areas.

### EGL

In the culvert profile graph shown above, note that the Energy Grade Line (EGL) is displayed. This can be toggled on or off by the EGL button located at the top of the graph. EGL = HGL + Velocity Head.

### Performance Curve

If a range of Qs were specified, Hydraflow Express Extension builds a rating curve that can be displayed by clicking the P-Curve button located at the upper left of the graph.



The rating curve plots Hw vs. Q. The dot on the curve corresponds to the currently selected row on the Results Grid. To remove this dot, click the graph.

### Results Grid

| Q | | | Veloc | | Depth | | HGL | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Total (cfs) | Pipe (cfs) | Over (cfs) | Dn (ft/s) | Up (ft/s) | Dn (in) | Up (in) | Dn (ft) | Up (ft) | Hw (ft) | Hw/D |
| 10.00 | 10.00 | 0.00 | 3.78 | 5.41 | 18.83 | 13.67 | 101.57 | 101.69 | 102.19 | 0.82 |
| 12.00 | 12.00 | 0.00 | 4.39 | 5.80 | 19.51 | 15.02 | 101.63 | 101.80 | 102.39 | 0.92 |
| 14.00 | 14.00 | 0.00 | 4.98 | 6.20 | 20.11 | 16.22 | 101.68 | 101.90 | 102.59 | 1.02 |

Click on a row to plot the corresponding values. The following section provides brief descriptions of the output variables.

**Total Q** - The total Q used for this computation.

**Pipe Q** - The Q conveyed by the pipe barrel only.

**Over Q** - Overtopping Q. This is flow over the embankment.

**Velocity Dn** - This is velocity of flow exiting the culvert. It is computed as Pipe Q / area of flow. The area of flow is computed from the HGL.

**Velocity Up** - The velocity of flow just inside of the upstream end of the culvert barrel. It is computed as Pipe Q / area of flow. The area of flow is computed from the HGL.

**Depth Dn** - The depth of flow at the downstream end of the pipe. HGL Dn minus Invert Elev Dn. Not greater than pipe rise.

**Depth Up** - The depth of flow at the upstream end of the pipe. HGL Up minus Invert Elev Up. Not greater than pipe rise.

**HGL Dn** - The hydraulic grade line at the downstream end of the pipe.

**HGL Up** - The hydraulic grade line at the upstream end of the pipe. Does not include minor loss.

**Hw** - The headwater elevation or depth. Includes minor loss in outlet control.

**Hw/D** - Headwater over pipe diameter ratio.

# Computational Methods

As previously mentioned, Hydraflow Express Extension follows those procedures outlined in HDS-5 (Hydraulic Design of Highway Culverts). Culvert analysis is difficult and time consuming, in that flow conditions can vary for no apparent reason. Culvert barrels may flow full or partly full, but full flow throughout the culvert length is rare. Generally, at least part of their length is in partial depth flow. The upstream end may be totally under water, while underneath, the barrel is in supercritical flow, ending downstream in subcritical flow. Raising the tailwater just a little can change the entire flow regime to full.

Hydraflow Express Extension uses a digital processor, and sophisticated algorithms and methods, to make sense of these conditions. This chapter outlines those methods, but first begins with a brief discussion of a concept that confuses many people.

### Inlet Control

Culverts flow under two regimes: inlet control and outlet control. Inlet control implies that it is more difficult for water to get into the pipe than it is to get through it. During outlet control, it is more difficult for flow to get through the barrel than to get into the barrel.

Inlet control is a lot like traffic going from a four-lane highway into a two-lane tunnel. As the traffic nears the tunnel, it must squeeze together causing a slowdown that affects the cars approaching the tunnel. Once in the tunnel, traveling is easier and traffic speeds up. As you use Hydraflow Express Extension, you'll find that culverts usually flow in partial depth throughout its barrel while under inlet control.

Inlet control is largely influenced by the entrance geometry of the pipe, such as edge configuration, pipe area and shape. Outlet control is influenced most by n-value (barrel roughness), pipe area, shape, length and slope. A 500-foot long, 10-inch barrel most likely flows under outlet control.

### Outlet Control

Hydraflow Express Extension uses the energy-based Standard Step method when computing the hydraulic profile for outlet control. This methodology is an iterative procedure that applies Bernoulli's energy equation between the downstream and upstream ends of the culvert. It uses Manning's equation to determine head losses due to pipe friction. The greatest benefit to using this method is that a solution can always be found, regardless of the flow regime. This method makes no assumptions as to the depth of flow, and is only accepted when the energy equation has balanced.

Hydraflow Express Extension uses the following equation:

$$\frac{V_1^2}{2g} + Z_1 + Y_1 = \frac{V^2}{2g} + Z_2 + Y_2 + HL$$

Where:

V = velocity in ft/s

Z = invert elevation in feet

Y = HGL minus the invert elevation in feet

Friction losses are computed by:

$$HL = \frac{(hf_1 + hf_2)}{2}$$

Where:

$$hf = \left( \frac{Qn}{KmAR^{.667}} \right)^2 \times PipeLength$$

Where:

Km = 1.486

n = Manning's n

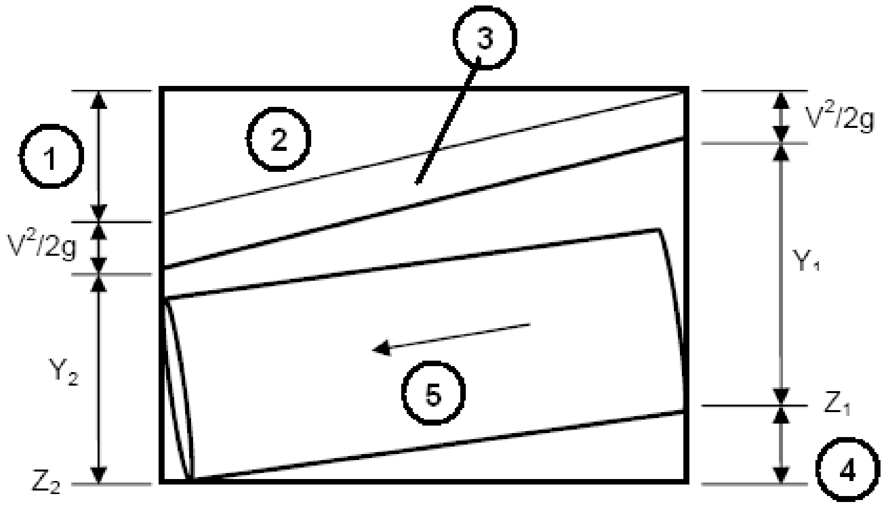
A = Cross-sectional area of flow in sqft

R = Hydraulic radius

In the following illustration:

- 1 – HL
- 2 – EGL

- 3 – HGL
- 4 – Datum
- 5 – Invert




## Pipe and Open Channel Flow

Hydraflow Express Extension computes the hydraulic grade line similar to methods used for open channels, and works in a standard step procedure upstream. This method assumes the starting hydraulic grade line elevation, HGL, is known. Hydraflow Express Extension first assumes an upstream HGL, and then checks the energy equation. If the energy equation does not balance, another HGL is assumed, and the iterative process continues until the assumed HGL equals the computed HGL.

Hydraflow Express Extension reports the HGL at three places: HGL Down, HGL Up, and Hw.

### HGL Down

The downstream end of the culvert. This is a user-defined elevation. Either a known elevation, Crown, Normal Depth, Critical Depth or (dc + D)/2. If this starting HGL is below critical the energy equation cannot balance and Hydraflow Express Extension automatically changes the HGL to Critical Depth.

### HGL Up

The upstream end of the pipe. Computed using the Standard Step Method previously described.

### Hw

Just upstream from the upper end of the pipe. This value is equal to the HGL Up plus any minor or junction loss. If the culvert is flowing under inlet control, Hw is equal to the depth determined by the Inlet Control procedure, described in the following sections.

The energy grade line (EGL) is computed as HGL plus velocity head. If the line is flowing under inlet control, velocity at this point is zero and EGL equals HGL.

## Critical Depth

Critical depth is computed using the following equation. If Dc is greater than 85% of D, then a trial and error method is used to find the minimum specific energy, also known as critical depth. See "Open Channel Hydraulics", McGraw - Hill, 1985, by Richard H. French.

$$Dc = \left(\frac{1.01}{D^{.26}}\right) \times \left(\frac{Q^2}{g}\right)^{.25}$$

Where:

Dc = Critical depth

D = Pipe diameter

Q = Flow rate

## Minor Loss

Minor losses are computed by the following equation.

$$MinorLoss = k\left(\frac{V^2}{2g}\right)$$

Where:

k = Entrance loss coefficient based on HEC-22

Entrance loss coefficients for culverts; outlet control

V = Velocity of flow exiting the junction

## Supercritical Flow

Hydraflow Express Extension has the ability to compute supercritical flow profiles with hydraulic jumps automatically. When the energy equation cannot balance, it reverses the calculation procedure and computes the supercritical profile.

## Hydraulic Jump

Hydraflow Express Extension uses the Momentum Principle for determining depths and locations of hydraulic jumps. At each step (one tenth of the culvert length) during supercritical flow calculations, Hydraflow Express Extension computes the momentum and compares it to the momentum developed during the subcritical profile calculations. If the two momentums equal, it is established that a hydraulic jump must occur. There may be occasions when a hydraulic jump does not exist or when it is submerged.

The condition which must be satisfied if a hydraulic jump is to occur is:

$$M_1 = M_2$$

Momentum of the subcritical profile equals the momentum of the supercritical profile. Where:

$$M = \frac{Q^2}{gA} + \bar{y}A$$

Where:

Q = Flow rate in cfs

A = Cross-sectional area of flow in sqft

y = Distance from the water surface to the centroid of A

The location of the jump is the point along the line when M1 = M2 and is reported as the distance from the downstream end of the culvert. The length of the jump is difficult to determine, especially in circular sections. Many experimental investigations have yielded contradictory results. Many have generalized that the jump length is somewhere between 4 and 6 times the Sequent depth. Hydraflow Express Extension assumes 5.

It should be noted that Hydraflow Express Extension does not compute supercritical flow profiles for elliptical or arch shapes. In these cases, critical depth is assumed.

## Inlet Control

Inlet control occurs when it is harder for the flow to get into the pipe than it is to get through it. Outlet control is the reverse. Compute the HGL assuming both exist, and then select the larger of the two.

Per the HDS-5 method, the following inlet control equations are used. If Hw is above the pipe crown, the submerged equation is used. Otherwise the unsubmerged equation is used.

**Submerged**

$$Hw = D \times \left[ c \left( \frac{Q}{A\sqrt{D}} \right)^2 + Y - .5S \right]$$

**Unsubmerged**

$$Hw = D \times \left[ K \left( \frac{Q}{A\sqrt{D}} \right)^M \right]$$

Where:

Hw = Headwater depth above invert

D = Line Rise, ft

Q = Flow rate, cfs

A = Full cross-sectional area of pipe, sqft

K, M, c, Y = Coefficients based on edge configurations

S = Line slope, ft/ft

## Overtopping Flow

If the computed Hw is above the top of the embankment, Hydraflow Express Extension, through an iterative procedure, computes flow over the top of the embankment. It uses the following broad crested weir equation:

$$Q = CwLH^{1.5}$$

Where:

Q = Overtopping flow in cfs

Cw = Broad crested weir coefficient = 3.09

L = Crest Width in ft

H = Hw - Top Elevation

## Design Options

Hydraflow Express Extension offers the following design options:

- designing pipe sizes
- setting invert elevations
- designing both simultaneously

Hydraflow Express Extension uses Manning's equation.

$$S = \left( \frac{Vn}{1.49 R^{2/3}} \right)^2$$

Where:

S = Slope of the invert in ft/ft but not less than a minimum slope of 0.002

V = Design velocity (set to 3 ft/s)

n = Manning's n-value

R = Hydraulic radius

This procedure assumes that the pipe is flowing full, and that the slope of the invert is equal to the slope of the energy grade line.

Hydraflow Express Extension automatically computes a pipe size using the following formula:

$$Area = \frac{Q}{V_d}$$

It then selects an available pipe size whose area matches Area. It only chooses certain sizes that have been predetermined. That is, 12 to 36 inches in 3-inch increments, and 42 to 102 inches in 6-inch increments. When a specific pipe size is not available, Hydraflow Express Extension selects the next smaller size. For example, if the theoretical size is 31.5 inches, Hydraflow Express Extension rounds down, and selects the 30-inch.

## Design Constraints

Hydraflow Express Extension uses fixed values for the design velocity, min. and max. pipe sizes, min. slope, and so on. These constraints have been preset to minimize user input. However, you can modify these values by editing Hydraflow Express Extension's initialization file (*Express.ini*), shown below.

The Express.ini file is loaded and read each time Hydraflow Express Extension starts, and is saved upon exit. It is an ordinary text file that can be opened in any text editor, such as Microsoft WordPad. There you can change the defaults and save the file.

**WARNING** Be sure to preserve this file's structure and name including the *.ini* file extension. This file is located in the folder where Hydraflow Express Extension was installed.

```
   "Hydraflow Express initialization file. V1.0.0.0"
"Design velocity(ft/s) = ",3
"Min Pipe Size(in) = ",12
"Max Pipe Size(in) = ",120
"Omit 21-Inch Pipes ",#TRUE#
"Omit 27-Inch Pipes ",#TRUE#
"Omit 33-Inch Pipes ",#TRUE#
"Min Design Slope(%) = ",.2
"Standard Curb Height(ft) = ",.5
"Default Inlet n-value = ",.016
"Depth Used to Design Grate Inlets(ft) = ",.3
"Default Inlet Length = ",4
"Default Throat Height = ",6
"Default Grate Area = ",2
"Default Grate Width = ",1.5
"Default Grate Length = ",2.453954
"Default Cross Slope Sx = ",.02
"Default Cross Slope Sw = ",.08
"Default Gutter Width = ",2
"Default Local Depression = ",1.44
"Default Gutter n-value = ",.013
```

# Channels

# 3

The definition of an open channel is a conduit for flow that has a free surface exposed to the atmosphere. These conduits generally include channels, streams, natural or man-made, highway gutters and even circular pipes. When water flows in a uniform channel it ultimately reaches and maintains a constant velocity and depth, called normal depth. The energy grade line parallels the water surface (hydraulic grade line) because the energy loss is exactly compensated for by gravity. There have been many empirical formulas developed to compute normal depth but Hydraflow Express Extension uses the most popular, Manning's Equation.

Six channel shapes are available:

- Rectangular
- Triangular
- Trapezoidal
- Gutter
- Circular (Pipe)
- User-defined (up to 50 user-defined stations, elevation points)

It is assumed that these channels are uniform, have a constant shape, slope and flow rate. Q and N values can be varied across the sections by converting any uniform shape to a user-defined shape. See User-defined Channels on page 23 for more information. Working within these parameters, Hydraflow Express Extension can quickly compute these values:

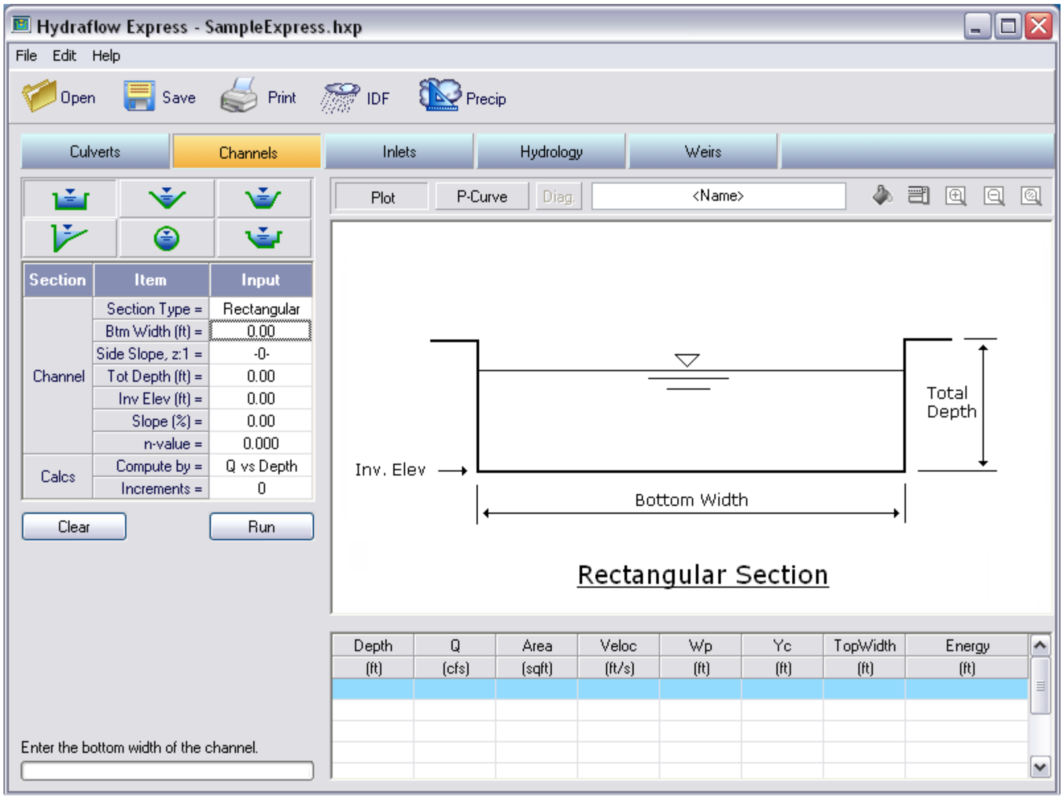
- A rating table of Q vs. normal depth based on a range of flow rates
- Normal depth from a single known Q
- Q from a user-defined normal depth

In all cases, the Hydraflow Express Extension displays plots of cross-sections, performance curves, numerical tables, and report-style printouts.

## Input

The input requirements are minimal and are easily entered into Hydraflow Express Extensions Input Grid. For more information, see Getting Started on page 1. This grid works like any other spreadsheet style data entry. Simply type the value or select from a list under the Input column and press the Enter or Tab keys on your keyboard. The cursor advances to the next item. While doing this, Hydraflow Express Extension displays a Help Diagram in the Graphic Display, as well as tips in the Input Assist box. To edit an item, double-click the cell or press F2. Once the data is input, compute the results by clicking the Run button.

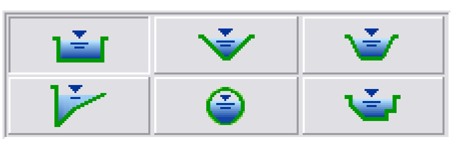
**NOTE** Some data items are not required or do not apply to that particular channel section. These cells display a 0 or a blank.




Hydraflow Express Extension offers normal depth rating curve calculations for up to six unique channel shapes including user-defined.

### Channel

**Section Type** - Choose a channel shape first by clicking the corresponding section type button.



**Bottom Width** - Enter the bottom width of the channel.

**Side Slope (z:1)** - Enter the left and right side slopes, z horizontal to 1 vertical, for the channel. Separate values with a comma; for example, 2,3.

**Total Depth** - Enter the total depth to be analyzed for this channel.

**Sx** - Enter the roadway cross-slope in ft/ft.

**Sw** - Enter the gutter cross-slope in ft/ft.

**Gutter Width** - Enter the width of the gutter. Note that this is the width corresponding to Sw, as represented in the Help diagram.

**Diameter** - Enter the diameter of the pipe section in feet.

**Sta Elevation** - For user-defined sections, click the ellipsis [...] to open the Sta Elevation input screen. See User-defined Channels on page 23 for more information.

**Invert Elevation** - Enter the invert elevation of this channel. This is automatically extracted from User-defined section data.

**Slope** - Enter the channel slope as a percentage (ft/100).

**Mannings n-value** - Enter the channel roughness coefficient. See the Reference Tables on page 75 for a table of suggested values. For user-defined sections, click [...] to open the Sta Elevation input screen where you can enter varying n-values. See User-defined Channels on page 23 for more information.

### Calcs

Hydraflow Express Extension allows you to specify a single depth, flow rate or a range of depths with a user-defined number of increments. A range of depths allows Hydraflow Express Extension to create a rating or performance curve. A single depth or Q does not.

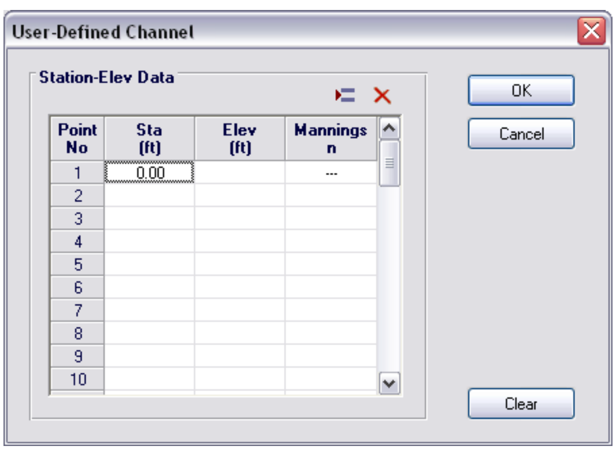
**Increments** - For "Q vs. Depth" only. Enter the number of increments or points to be created for the rating table. The default is 10. This value cannot exceed 50. For example, if the Total Depth is 5, and the Increments are 10, Hydraflow Express Extension computes Qs for each 5/10 or 0.5 feet of depth. The Results Grid populates with 10 rows, from 0.5 feet to 5.0.

**Known Q** - Enter a known flow rate in cfs. Hydraflow Express Extension computes a corresponding normal depth. If this computed depth is above Total Depth, Hydraflow Express Extension aborts and prompts you to reduce Q or raise Total Depth. If a hydrograph exists in the Hydrology task, and Known Q is equal to zero, Hydraflow Express Extension inserts the Q peak from the hydrograph.

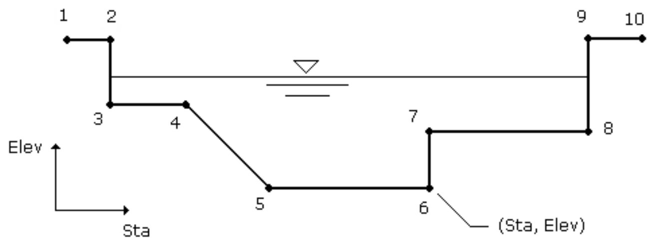
**Known Depth** - Enter a known depth in feet. This must be less than or equal to Total Depth.

# User-defined Channels

Hydraflow Express Extension allows you to enter up to 50 station and elevation points that describe a channel section. In addition, each of these points can contain an n-value. To use this channel feature, select the User-defined selection button at the top of the Input Grid. Next click [...] to open the User Defined Channel dialog box.




Hydraflow Express Extension can input up to 50 station, elevation, and n-value points to describe a channel.




User-defined Section

A user-defined section is described by entering points containing offset stations, elevations, and related n-values. N-values apply between the point in question and the previous point. Thus point number 1 does not require an n-value. The n-value entered at point number 2 describes the roughness between points 1 and 2. The n-value at point 3 is the roughness from 2 to 3, and so on.

To enter data in the grid, type in the value and press the [Tab] key. You can also use your cursor keys or mouse. To speed input, the previous n-value is used as a default for subsequent cells.

**Sta** - Enter the station for this point in feet from the left-most side. This is the distance from a baseline. Zero is suggested for point number 1.

**Elev** - Enter the corresponding elevation for this point in feet.

**n-value** - Enter the corresponding roughness coefficient from the last point to this one. Enter zero for point number 1.

For example, points for the user-defined channel section shown in the figure could look like this:

| Point No | Sta (ft) | Elev (ft) | Mannings n |
|---|---|---|---|
| 1 | 0.00 | 100.00 | --- |
| 2 | 10.00 | 100.00 | 0.050 |
| 3 | 10.00 | 95.00 | 0.050 |
| 4 | 25.00 | 95.00 | 0.050 |
| 5 | 40.00 | 90.00 | 0.050 |
| 6 | 60.00 | 90.00 | 0.030 |
| 7 | 60.00 | 92.50 | 0.030 |
| 8 | 90.00 | 92.50 | 0.035 |
| 9 | 90.00 | 100.00 | 0.050 |
| 10 | 100.00 | 100.00 | 0.050 |

### Inserting and Deleting Points

You can insert and delete coordinates by using the Insert and Delete buttons located at the upper right of the Station Elev input grid.

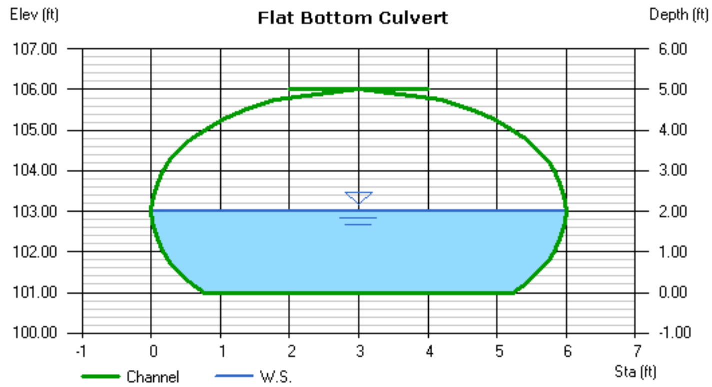
**Inserting** - To insert, highlight or click on the row where you want to insert. Hydraflow Express Extension moves all rows from that row down by one row, and leaves the highlighted row blank.

**Deleting** - Delete a point by first highlighting the row you want to delete, and then click the Delete button.

### Varying n-values on Standard Channel Shapes

You may need to understand how to vary the n-values across the standard channel shapes. To do so, first complete the input and compute the results for any channel shape. Next select, "User-defined" channel shape. Hydraflow Express Extension automatically converts the channel into a User-defined channel. Click [...] in the Sta Elev input item to open the User Defined Channel dialog box, where the Sta and Elev coordinates for the standard shape are displayed. You can modify the n-values, and the channel coordinates.

The following illustration shows an example of a Pipe section that was converted to a flat bottom arch culvert with varying n-values.



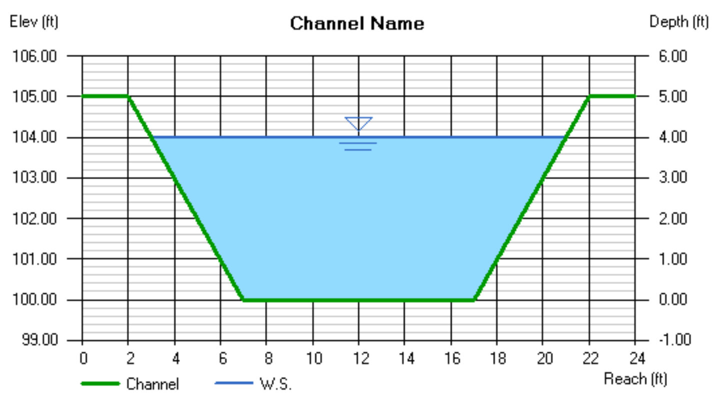

# Output

Click Run to generate the output. The graphic bar below the Help Assist box displays the progress. If any erroneous data is present, Hydraflow Express Extension prompts you before proceeding. Once completed, the Graphic Display and Results Grid are drawn and populated. If Q vs. Depth was specified, that range and increment is the basis for the data in the Results Grid. The Graphic Display plots corresponding to the selected row in the Results Grid. For example, to plot a profile corresponding to a depth of 1.5, click on the row containing a depth of 1.5.

### Graphic Display

In the profile plot, each line type is indicated in the legend located at the bottom of the graph. The scale on the left indicates elevation. The scale on the right is absolute depth above the invert elevation.

The following illustration shows the Graphic Display of a trapezoidal channel.




**Fill**

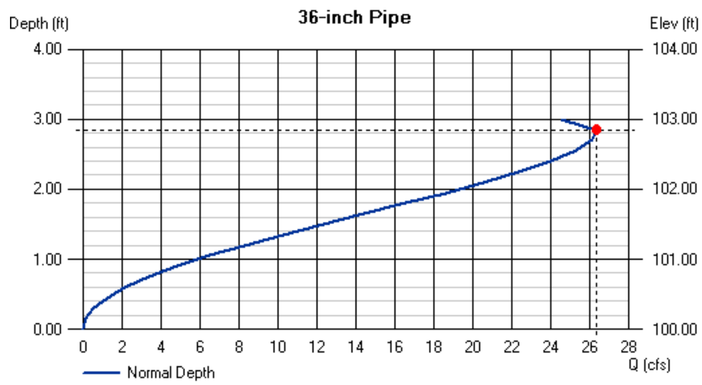
Use this button to turn on/off the color fill. This does not affect printed reports. They do not include filled areas.

**EGL**

In the plot shown above, note the Energy Grade Line (EGL) is not shown. This can be toggled on or off by the EGL button located at the top of the graph. EGL = HGL + Velocity Head.

**Performance Curve**

If a range of depths is specified, Hydraflow Express Extension builds a rating curve, which can be displayed by clicking the [P-Curve] button, located at the upper left of the graph. Below is an example of a performance curve for a Pipe section. Note that it performs best at about 94% full.




The dot on the curve corresponds to the currently selected row on the Results Grid. To remove this dot, click the graph.

**Results Grid**

| Depth (ft) | Q (cfs) | Area (sqft) | Veloc (ft/s) | Wp (ft) | Yc (ft) | TopWidth (ft) | Energy (ft) |
|---|---|---|---|---|---|---|---|
| 2.55 | 25.30 | 6.41 | 3.95 | 7.05 | 1.58 | 2.13 | 2.79 |
| 2.70 | 26.14 | 6.70 | 3.90 | 7.50 | 1.62 | 1.80 | 2.94 |
| 2.85 | 26.35 | 6.94 | 3.80 | 8.09 | 1.65 | 1.30 | 3.07 |
| 3.00 | 24.52 | 7.07 | 3.47 | 9.42 | 1.66 | 0.00 | 3.19 |

Click on a row to plot the corresponding values. A brief description of the output variables follows.

**Depth** - This is normal depth and is determined by the total depth of the channel and the number of increments specified. For example, if the total depth is 5, and increments equal 20, the Results Grid is setup in 5/20 or in 0.25 ft depths.

**Q** - The corresponding computed flow rate.

**Area** - The cross-sectional area of flow.

**Velocity** - The velocity in the channel. It is computed as Q / Area.

**Wp** - The wetted perimeter.

**Yc** - Critical depth.

**Top Width** - Distance across the top water surface.

**Energy** - The energy grade line (EGL). Depth plus velocity head.

# Computational Methods

As previously mentioned, Hydraflow Express Extension uses Manning's equation to compute Qs at varying depths of flow. When a known Q is specified, it solves for the depth using an iterative procedure.

$$Q = \frac{1.49}{n} A R^{2/3} \sqrt{S}$$

Where:

Q = Flow rate in cfs

n = Roughness coefficient

A = Cross-sectional area in sqft

R = Hydraulic radius

S = Channel slope in ft/ft

### Composite Mannings n

With user-defined sections that have varying n values, Hydraflow Express Extension uses an equation defined in HEC-RAS, Eq 2-6, to first compute a composite roughness coefficient. Then it employs Manning's equation, as described in the previous section.

$$n_c = \left[ \frac{\sum_{i=1}^{N} P_i n_i^{1.5}}{p} \right]^{2/3}$$

Where:

nc = Composite n-value

P = Wetted perimeter of entire channel

Pi = Wetted perimeter of subdivision i

ni = n-value for subdivision i

### Critical Depth

Yc, or critical depth is computed using the following equation along with an iterative procedure:

$$\frac{Q}{\sqrt{g}} = \sqrt{\frac{A^3}{T}}$$

Where:

Q = Flow rate in cfs

g = Gravity

A = Cross-sectional area in sqft

T = Top width in ft

Reference: Open Channel Hydraulics, Richard H. French

# Inlets

# 4

Storm drain inlets involve as many shapes and configurations as flow regimes. From weir flow to orifice flow and transitions in between, they are complicated even further by the analytical procedures used, Hydraulic Engineering Circular No. 22 (HEC-22).

Similar to culverts, inlets have some flow characteristics that seem to contradict logical reasoning. For example, you might expect the interception capacity of a grate inlet on continuous grade to significantly increase with increasing length. However, this is not the case. Wider grates are much more effective. Also, the interception capacity of combination inlets does not differ from a single grate inlet. The curb opening portion is useless, except for clearing debris. The most significant factor affecting interception capacity of curb-style inlets on grade is the depth and width of flow just upstream in the gutter.

Most can be modeled on grade, or in a sump condition (sag). Hydraflow Express Extension has the following inlet types:

- Curb
- Grate
- Combination curb and grate
- Drop curb (sag only)
- Drop Grate
- Slotted

Hydraflow Express Extension can compute the following values:

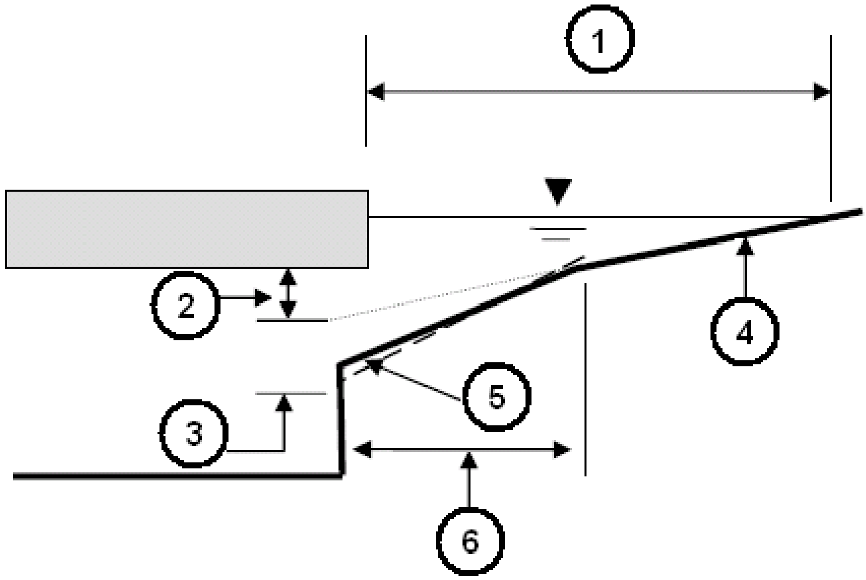
- A rating table of Q vs. Depth based on a maximum depth
- Depth from a single known Q

Hydraflow Express Extension finishes its work with 3-dimensional and 2-dimensional plots of cross sections, performance curves, numerical tables, and report-style printouts.

## Inlet Basics

Gutters can have compound cross-slopes including gutter depressions at the inlet face. The following illustration shows a typical cross section of a curb-style inlet with a compound cross-slope and local depression.

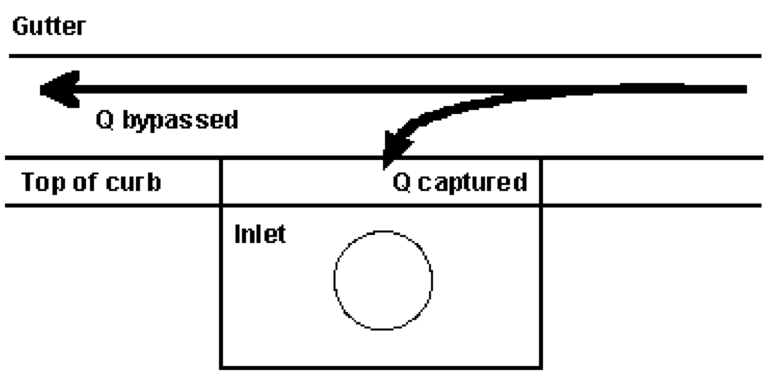
The heavy dashed line near (5) is the cross-slope reflecting the local depression. The fine dotted line is a projection of the pavement slope, Sx (4). Note that the throat height (2) is measured upwards from the projection line, and the local depression (3) is measured downward from the projection line.




| | |
|---|---|
| (1) Spread | (4) Pavement slope (Sx) |
| (2) Throat height | (5) cross-slope just upstream of the inlet in the gutter (sw) |
| (3) Local depression | (6) Gutter width |

### Inlet Captured and Bypassed Flows

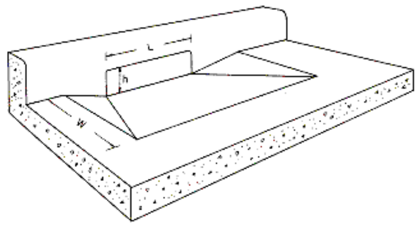
Hydraflow Express Extension automatically computes the captured and bypass flows. Captured flows are intercepted by the inlet and bypass flows are not captured.



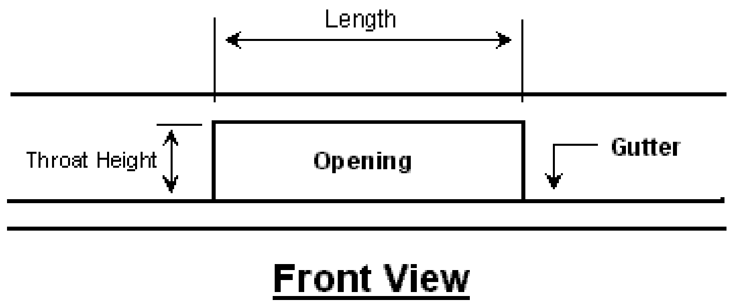

# Inlet Types

This section describes the various inlet types.

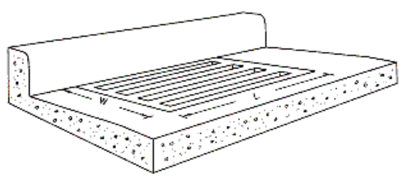
**Curb Inlet**

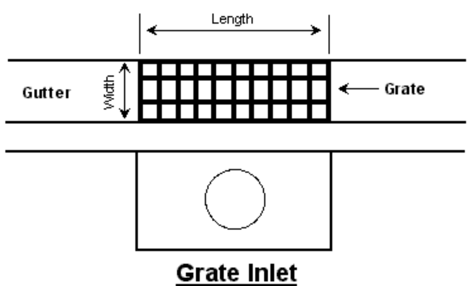



A typical curb opening inlet has a rectangular opening along the face of the curb to which it is attached.

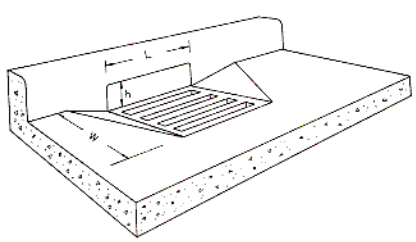



**Grate Inlet**



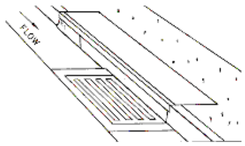



**Combination**




Combination inlets require the same input data as both Curb and Grate Inlets. You can enter unique lengths for the grate and curb opening. When the curb opening is larger than the grate length, Hydraflow Express

Extension assumes that the open curb portion is located upstream of the grate, and is often called a sweeper inlet.



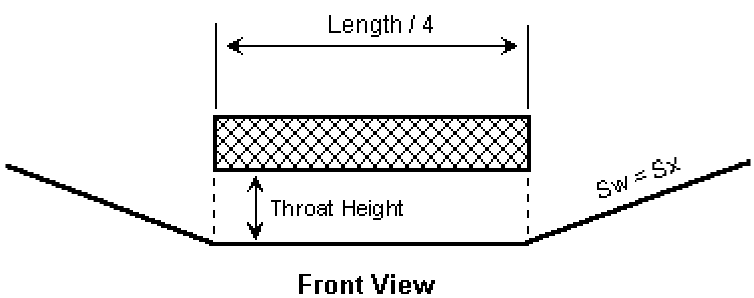

**Sweeper Inlets**

Per HEC-22, the capacity of combination inlets on grade is equal to the grate alone. Capacity is computed by neglecting the curb opening. The sweeper inlet has an interception capacity equal to the sum of the curb opening upstream of the grate plus the grate capacity. The grate capacity of sweeper inlets is reduced by the interception by the upstream curb opening.

**Drop Curb Inlets**

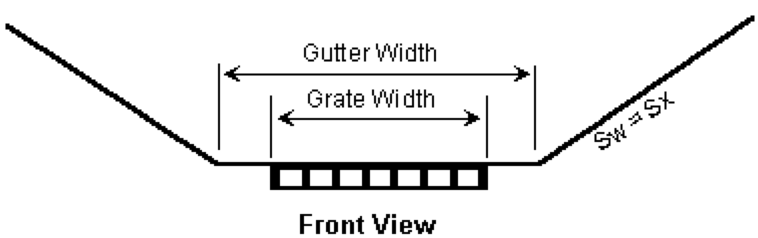
These inlets are a type of curb inlet used in sags only, in open yard areas. They typically have four sides with rectangular openings.

Note that the length entered should be equal to the sum of the four sides, and that compound cross-slopes are not allowed.



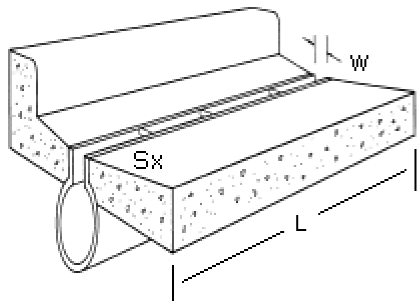

**Drop Grate Inlets**

Drop grate inlets are similar to the drop curb inlets except that they can be in either sag or grade locations. Their Sx and Sw values must be equal.




**Slotted**

Slotted inlets behave much like curb opening inlets but have different input requirements.




**Gutters**

Among other data, each inlet has a gutter cross section that consists of a gutter width and slope, compound gutter cross slopes, and an optional local depression. Any time Sx and Sw have unique values, HEC-22 calculations treat gutters as depressed. The specified Sx and Sw values refer to the gutter upstream of the inlet. At the inlet face, Sx and the depression value are used to describe the section.

**Typical Gutter Section**

Hydraflow Express Extension automatically computes spread widths and flow depths in the gutter section. For drop curb and drop grate inlets, Sw should equal Sx. The program does not allow compound sections for these types.

# Input

The following sections describe individual data items for inlets and gutters. Note that certain cells on the input grid are marked with 0. This indicates that data is not required for that particular junction.

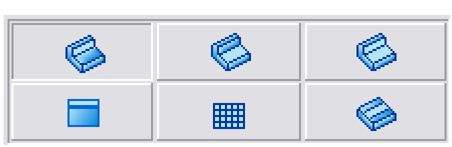
### Dynamic Defaults

Certain input items already have values set for them. These are dynamic defaults that are part of the Express.ini file and are set to the values last used upon exiting the program. This feature is intended to save you some input time on standard inlet types.

There are design options. In general, Hydraflow Express Extension sizes inlet curb opening lengths and grate sizes for 100 percent capture when their respective data items have been set to 0. It is recommended that you use Known Q as the calculation method for design. Otherwise, the first Q in the Q vs. Depth range is used.

### Inlet

**Inlet Type** - Select the appropriate inlet type.



**On Grade or Sag** - If this inlet is on a continuous grade, select On Grade from the list. If it is in a sag or sump location, select Sag. Note that Drop Curb inlets are assumed to be in a sag condition.

**Length, L** - (Curb, Combination, and Drop Curb inlets)

Enter the total length of the opening in feet.

---

**TIP** By setting this value to zero, Hydraflow Express Extension automatically designs it for you based on 100% capture. It is recommended that you use a Known Q for design.

---

**Throat Ht** - Curb, Combination, and Drop Curb inlets)

This is the height of the opening in inches and is measured from the projection of cross slope, Sx. Do not include any local depression amount.

**Opening Area** - (Grate, Combination, and Drop Grate inlets)

Enter the clear opening area of the grate. Required only in sags. Enter zero to have Hydraflow Express Extension design for 100% capture.

**Grate Width** - (Grate, Combination, Drop Grate and Slotted inlets)

Enter the width and length of the grate.

**Grate Length** - (Grate, Combination, Drop Grate and Slotted inlets)

Enter the length of this grate in feet.

---

**TIP** Set the Length to zero for automatic design. Hydraflow Express Extension sizes the inlet length for 100% capture. When Hydraflow Express Extension designs for grates in sags, including combination inlets, it sizes the grate opening area based on the Grate Design Depth of 0.3 ft.

---

### Gutter

**Sw** - Enter the transverse slope of the gutter section only, Sw in ft/ft. Equals Sx when modeling Drop or Slotted inlets. This item is not required for Drop inlets or Slotted.

**Sx** - Enter the transverse slope of the pavement section only, Sx in ft/ft. Equals Sw when modeling Drop or Slotted inlets.

**Depression** - (Curb type inlets only). Enter a local depression amount in inches. This value is measured from the projection of Sx.

---

**TIP** If you are unsure of the depression value, leave it blank. When you click Run, Hydraflow Express Extension prompts you to enter the depression value, but also calculates and enters it.

---

**Gutter Width** - Enter the width of the gutter section in feet. This is the width as it corresponds to the Sw value, if specified, and should not be less than any grate widths specified for this line. If this is a Drop Grate inlet, you should select a width wide enough to contain the entire grate width. This item is not required on Drop Curb or Slotted inlets.

**Longitudinal Slope** - Required for inlets on grade. Enter the gutter slope, or longitudinal slope of this inlet in percent (%). This item is not required for Drop Curb inlets or inlets in sags.

**Manning's n-Value** - Enter an n value for the gutter section. This is not required on any inlet in a sag or Drop Curb inlets. Default is 0.013.

### Calcs

**Compute by** - Hydraflow Express Extension allows you to calculate using a single flow rate or a range of Q vs. Depth. A range of Q vs. Depth allows Hydraflow Express Extension to create a rating or performance curve. A single Q does not.

**Q vs. Depth** - Q vs. Depth produces a rating curve at 0.25 cfs increments. The Results Grid populates its rows beginning at 0.25 cfs and computes for increasing Qs up to the point where the corresponding depth equals or exceeds the Max. Depth.

**Max Depth** - Enter the maximum depth in inches to be used for the rating table. Default = 6.

**Known Q** - For a known flow rate in cfs, Hydraflow Express Extension computes a corresponding depth, spread, etc. If a hydrograph exists in the Hydrology task and Known Q is equal to zero, Hydraflow Express Extension inserts the Q peak from the hydrograph.

**TIP** If you have set any parameters to zero for design, it is recommended that you use Known Q for the calculation method. Otherwise, if Q vs. Depth was specified, 0.25 cfs is used for the design flow.

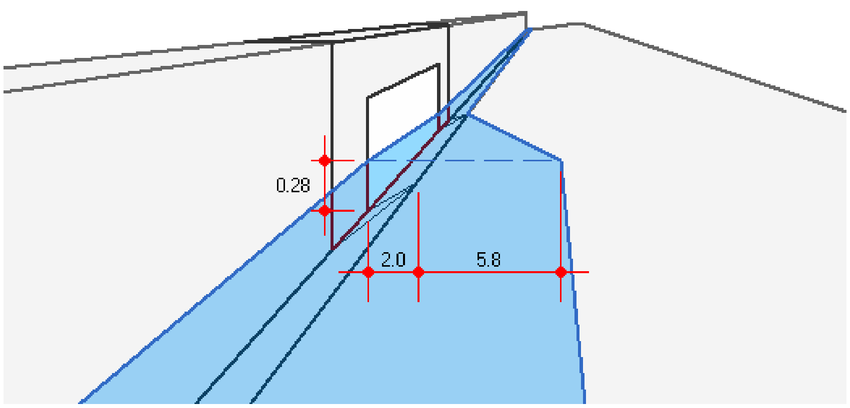
# Output

Click Run to generate the output. The graphic bar below the Help Assist box displays the progress. If any erroneous data is present, Hydraflow Express Extension prompts you before proceeding. Once completed, the Graphic Display and Results Grid are drawn and populated. If Q vs. Depth was specified, the Maximum Depth specified and a 0.25 cfs increment is the basis for the data in the Results Grid. The Graphic Display plots corresponding to the selected row in the Results Grid. For example, to plot a section corresponding to a flow of 1.25 cfs, click on the row that contains Q of 1.25.

### Graphic Display

Hydraflow Express Extension can plot inlet sections in either 3-D or 2-D.

The following illustration shows a three-dimensional graphic display of a Curb Inlet with bypass flow. In this illustration, all dimensions indicated are in feet.




### Image Controls

These controls allow you to manipulate the views of the drawing. They function differently, however, depending on whether you are in 2D or 3D mode. From left to right these are as follows:

**Two or Three-Dimensional** - To switch between 2D and 3D view, click the left-mouse button.

**Spin Buttons** - In 2D view, independently increase or decrease the X and Y scales. In 3D view, move the location of the center of projection. The allowed magnitude of movement is limited for practical reasons.

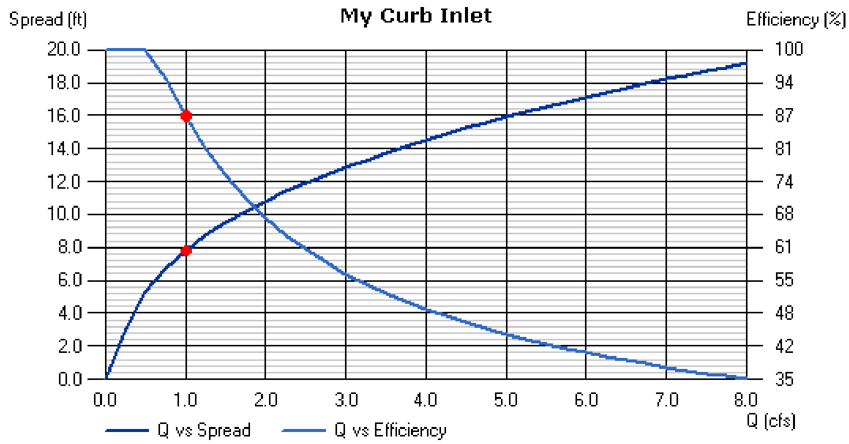
**TIP** You may modify the X or Y scales of the 3D view by first changing them in the 2D mode and then switching to 3D.

**Reset** - Resets the drawing scale to the default.

### Performance Curve

If Q vs. Depth was specified, Hydraflow Express Extension builds a rating curve that can be displayed by clicking P-Curve located at the upper left of the graph.

The following illustration shows a performance curve for a Curb Inlet.




The Q shown is the total Q, not necessarily the Captured Q. Spread refers to the spread in the Gutter. If the inlet is on grade the rating curve includes an efficiency curve. The dots on the curve correspond to the currently selected row on the Results Grid. To remove the dots, click the graph.

### Results Grid

| Q | | Inlet | | Gutter | | Bypass | | |
|---|---|---|---|---|---|---|---|---|
| Total | Captured | Depth | Efficiency | Spread | Velocity | Q | Spread | Depth |
| (cfs) | (cfs) | (in) | (%) | (ft) | (ft/s) | (cfs) | (ft) | (in) |
| 0.25 | 0.25 | 2.17 | 100 | 3.05 | 1.17 | 0.00 | 0.00 | 0.00 |
| 0.50 | 0.50 | 2.71 | 100 | 5.30 | 1.25 | 0.00 | 0.13 | 0.12 |
| 0.75 | 0.71 | 3.05 | 94 | 6.70 | 1.32 | 0.04 | 1.25 | 1.20 |
| 1.00 | 0.87 | 3.31 | 87 | 7.80 | 1.37 | 0.13 | 1.88 | 1.80 |

Click on a row to plot the corresponding values. A brief description of the output variables follows.

Q Total - The total flow approaching the inlet.

Q Captured - The amount of flow intercepted by the inlet.

Inlet Depth - The computed depth at the face of the inlet.

Inlet Efficiency - The capture efficiency of the inlet expressed as a percentage of Q Total.

Gutter Spread - The width of flow in the gutter section, just upstream of the inlet face.

Gutter Velocity - The velocity of flow in the gutter section.

Bypass Q - The amount of uncaptured flow.

Bypass Spread - The width of flow in the gutter downstream of the inlet. For inlets on grade only.

Bypass Depth - The depth of flow downstream of inlets on grade.

# Computational Methods

The purpose of this analysis is to determine the amount of flow a particular inlet can capture, the pond depth, gutter spread widths, and the amount of flow that is bypassed. Hydraflow Express Extension has design features that size inlets to capture 100% of the flow. To simplify this process, Hydraflow Express Extension assumes that all inlets have common n-values of 0.016.

Hydraflow Express Extension follows the basic methodology of FHWA HEC-22 for inlet interception capacity calculations. Clogging factors are not used in this program. If necessary, you should adjust the inlet lengths to account for clogging factors.

**Inlets in Sags** - An inlet in a sag, or sump, has no longitudinal slope, meaning that the gutter slope equals zero. In addition, inlets in sags capture 100% of the flow and thus no bypass flow. Note that the Drop Curb inlet must be in a sag.

# Curb Inlets in Sags

Curb inlets operate as weirs to depths equal to the curb opening height and as orifices at depths greater than 1.4 times the throat height. At depths in between, flow is in a transition stage.

**Depressed Curb Opening**

The equation used for the interception capacity of the inlet operating as a weir is:

$$Q = Cw(L + 1.8W)d^{1.5}$$

Where:

Cw = 2.3

L = Length of curb opening in ft

W = Gutter width in ft

d = Depth at the face of curb measured from the cross slope, Sx, in ft

---

**NOTE** If L > 12 feet then the equation for non-depressed inlets is used, per HEC-22.

---

**Without Depression**

The following equation is used to determine the interception capacity of the inlet operating as a weir:

$$Q = CwLd^{1.5}$$

Where:

Cw = 3.0

The following equation is used to determine the interception capacity of the curb inlet (depressed and non-depressed) operating as an orifice:

$$Q = CohL\left(\sqrt{2gd_o}\right)$$

Where:

Co = 0.67

h = Total height of curb opening in ft

L = Length of curb opening in ft

g = 32.2 gravity

do = Depth measured to the center of the inlet opening in ft

In transition flow, Hydraflow Express Extension uses both equations and selects the smallest Q.

If the inlet length has been set to 0, Hydraflow Express Extension automatically computes a value using the above weir equations assuming the depth to be equal to the total curb opening and solving for L.

## Grate Inlets in Sags

Grate inlets in sags operate as weirs to a certain depth dependent on their bar configuration and operate as orifices at greater depths. Hydraflow Express Extension uses the procedure as described in HEC No. 22. Hydraflow Express Extension uses both orifice and weir equations at a given depth. The equation that produces the lowest discharge is used. The standard orifice equation used is:

$$Q = CoAg\sqrt{2gd}$$

Where:

Co = 0.67

Ag = Clear opening area in sqft

g = 32.16 gravity

d = Depth of water over the grate in ft

The weir equation used is:

$$Q = CwPd^{1.5}$$

Where:

Cw = 3.0

P = Perimeter of the grate in ft disregarding side

against curb

d = Depth of water over the grate in ft

If you set the grate area, A, to 0, Hydraflow Express Extension automatically computes a value using the orifice equation and by assuming d = Grate Design Depth = 0.3 feet. It is believed that when the depth of water over the grate = 0.3 ft, the inlet begins a transition to acting as an orifice.

## Combination Inlets in Sags

The interception capacity of combination inlets in sags is equal to that of the grate alone in weir flow. In orifice flow, the capacity is equal to the capacity of the grate plus the capacity of the curb opening (Ref. HEC-22). Hydraflow Express Extension essentially uses the procedure described above for grate inlets in sag. However, when the depth at the curb creates orifice conditions for the grate, Hydraflow Express Extension uses both procedures, grate and curb inlets in sags, and adds their capacities to arrive at the total capacity. Note that both weir and orifice equations are used for the curb inlet analysis. In other words, the grate could be in orifice flow while the curb opening is in weir flow.

As with the single grate inlet, if you set the grate area, A, on the combination inlet to 0, Hydraflow Express Extension automatically computes the value using the orifice equation, d = Grate Design Depth at 0.30 feet and solving for Ag. There is not a design option for the curb opening length on combination inlets. By default, Hydraflow Express Extension sets it equal to the grate length, if found to be 0.

## Slotted Inlets in Sags

Slotted inlets in sag locations act as weirs to a depth of about 0.2 feet and begin to act as orifices at about 0.40 feet. Depths in between are in a transition and Hydraflow Express Extension computes both and uses the largest depth.

The interception capacity of a slotted inlet in a sag acting as a weir is computed using the following equation:

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

Where:

Cw = 2.48

L = Length of slot in ft

D = Depth in ft

The interception capacity of a slotted inlet in a sag acting as an orifice is computed using the following equation:

$$Q = 0.8LW\sqrt{2gd}$$

Where:

L = Length of the slot in ft

W = Width of the slot in ft

d = Depth in ft

**Inlets on Grade**

An inlet on grade has a positive longitudinal gutter slope. Hydraflow Express Extension uses the methods in HEC-22. For depressed inlets, the quantity of flow reaching the inlet is dependent on the upstream gutter section geometry and not the depressed section.

## Curb Inlets on Grade

The interception capacity for curb inlets is computed using the following equation. The equation also applies to slotted inlets.

$$Lt = Kt\,Q^{0.42} S_L^{0.3} \left(\frac{1}{nSe}\right)^{0.6}$$

Where:

Lt = Curb opening length for 100% capture in ft

Kt = 0.6

Q = Gutter flow in cfs

SL = Gutter slope, longitudinal in ft/ft

n = Manning's n-value

Se = Equivalent cross slope

$$Se = Sx + S'wE_o$$

Where:

Sx = Cross slope of pavement in ft/ft

S'w = Depression in ft / gutter width in ft or, for

non-depressed inlets, cross slope Sw - cross slope Sx

Eo = Ratio of flow in the gutter section to total gutter flow

If you set the inlet length to 0 (design), Hydraflow Express Extension automatically sets the inlet length equal to LT. If the specified inlet length is larger than LT, it captures 100% of the flow and Q captured equals Q. If the specified inlet length is less than the computed LT, then Q captured is computed as follows:

$$Qcaptured = Q_T \times E_F$$

Where:

Qt = Q catchment + Q carryover

Ef = 1 - (1 - L/LT)1.8 = Efficiency

Q bypassed equals Qt - Q captured

# Grate Inlets on Grade

The interception capacity of grate inlets on grade is computed using the following equations per HEC-22:

$$E = R_f E_o + R_s(1 - E_o)$$

Where:

E = Efficiency of the grate

Rf = Ratio of intercepted frontal flow to total gutter flow

Eo = Ratio of frontal flow to total gutter flow

Rs = Side flow interception efficiency

Because the Rf term in the previous equation is dependent on the specific grate properties illustrated in HEC-22, do not match every situation. Hydraflow Express Extension assumes Rf = 1, and that all frontal flow is intercepted without any loss of flow due to splash-over effects. All grate on grade examples given in HEC-22 compute an Rf = 1.

$$Rs = \frac{1}{\left[1 + \left(\frac{Kc\,V^{1.8}}{Sx\,L^{2.3}}\right)\right]}$$

Where:

Kc = 0.15

V = Velocity of flow in the gutter in ft/s

L = Grate length in ft

The amount of intercepted flow for grates on grade = E x Q and any non-intercepted flow is bypassed.

If the grate length is set to 0 for design, Hydraflow Express Extension uses the following weir equation:

$$Q = CwP\,d^{1.5}$$

Where:

Cw = 3.0

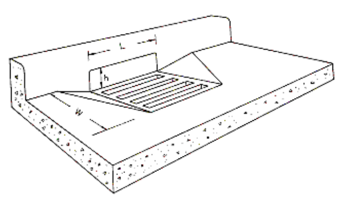
P = Perimeter of the grate in ft disregarding side against curb

d = Depth of water over the grate in ft

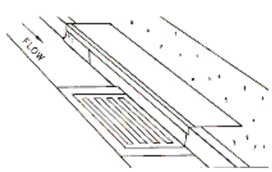
It solves for P and then sets the grate length, L, equal to P - 2 x (grate width). This design does not guarantee 100% capture.

# Combination Inlets on Grade

The interception capacity of combination inlets on grade is essentially equal to that of the grate alone. Hydraflow Express Extension computes this capacity by neglecting the curb opening and using the methods described above.



Sweeper Inlets



When the curb opening length is longer than the grate length, Hydraflow Express Extension assumes the open curb portion is located upstream of the grate, and called a sweeper inlet. The sweeper inlet has an interception capacity equal to the sum of the curb opening upstream of the grate plus the grate capacity. The grate capacity in this case is reduced by the interception of the upstream curb opening.

## Slotted Inlets on Grade

Since HEC-22 relies on a chart for slotted inlets on grade, Hydraflow Express Extension uses a weir equation prescribed in WinStorm 3.05.

$$L_r = \frac{0.706\,Q^{0.442}\,S^{E}\,z^{0.849}}{n^{0.384}}$$

Where:

Lr = Length required for 100% capture

Q = Flow in gutter in cfs

S = Longitudinal gutter slope in ft/ft

z = Reciprocal of cross slope, Sx

n = Gutter n-value

and

$$E = 0.207 - 19.084\,S^2 + 2.613S - 0.0001\,z^2 + 0.007z - 0.049Sz$$

It should be noted that the total Q cannot exceed 5.5 cfs and the longitudinal gutter slope should not exceed 0.09 ft/ft for slotted inlets on grade.

## Gutter Spread

Hydraflow Express Extension uses the following modified Manning's equation to compute the depth of flow in the gutter:

$$D = \left(\frac{Qn}{KcZ\sqrt{S}}\right)^{0.375}$$

Where:

D = Depth of flow in gutter in ft

Q = Flow in gutter in cfs

Z = Reciprocal of the cross slope

S = Longitudinal gutter slope in ft/ft

Kc = 0.56

For compound cross slopes, Hydraflow Express Extension uses a trial and error procedure and computes D in the gutter, (Sw) and (Sx) sections separately. From this depth, and cross section geometry, Hydraflow Express Extension computes the gutter spread.

# Hydrology

# 5

Whether you are modeling a culvert, channel, inlet, or weir, at some point you need a known flow rate. All hydraulic studies begin with hydrology. Hydrology is simply a flow vs. time relationship. Usually, we are most concerned with the peak flow (Qp). As environmental concerns have matured, so have hydrologic methods. As a result, peak flow is no longer the most important output. The volume and quality of flow are now considered equally important when performing hydrology tasks.

Hydraflow Express Extension provides you with a quick and easy way to meet the following objectives:

- Develop surface runoff hydrographs
- Use SCS, Rational and Modified Rational methods
- Use built-in design storms, including all SCS 24- and 6-hour
- Dynamically create IDF-based synthetic design storms
- Compute composite runoff coefficients and curve numbers
- Compute Tc with a variety of methods or user-defined
- Compute required storage with user-defined target Q
- Compute required outlet size vs. pond depth rating curve
- Compute estimated drawdown time
- Compute Mod. Rational Storm Duration Factor which maximizes required storage

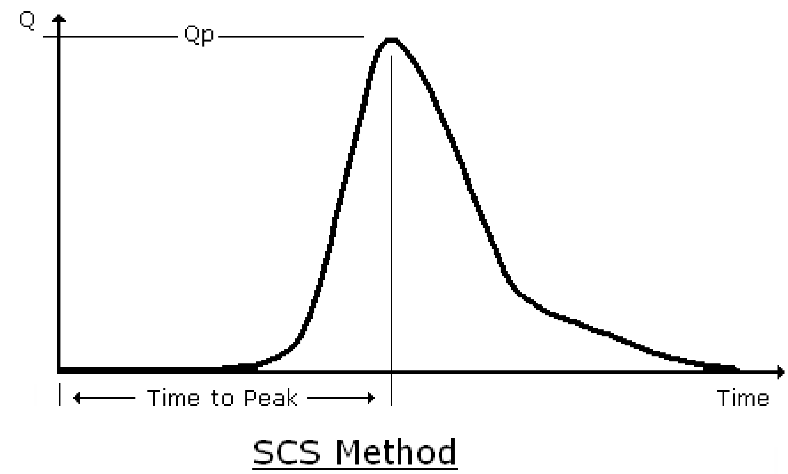
The purpose of this application is to not only provide you with a fast tool for developing flow rates for the variety of tasks contained within, but also to quickly establish preliminary designs for detention ponds, without having to create extensive, final design models.

While Hydraflow Express Extension can create runoff hydrographs using the Rational or SCS methods, engineers are often unsure about which method to use. Both are widely used in this industry, but can yield different results when given similar input parameters. Each method is described in the following section. Ultimately, it is up to you, and or your local drainage authority, to determine which method is most suitable for a given project.

Typically the Rational method has been used on smaller acreages (20 acres or less), while the SCS method is used on just about everything else. The SCS method, using the IDF-based Synthetic storm, is also a popular method. It uses the sophistication of the unit hydrograph method, however, it escapes the one-size-fits-all (24-hr) design storms. Rather than using the 24-hour storms, the synthetic distribution allows you to specify the total storm duration. It uses your IDF curves to construct the storm.

# SCS Hydrographs

Hydrologic methods developed by the Soil Conservation Service (SCS), now known as National Resources Conservation Service (NRCS), are widely used for the analysis of large and small watersheds. These methods are popular because of their easy to apply approach. The unit hydrograph method, coupled with any known design storm, allows one to generate an accurate hydrograph, without any other concerns.




**The Unit Hydrograph Theory**

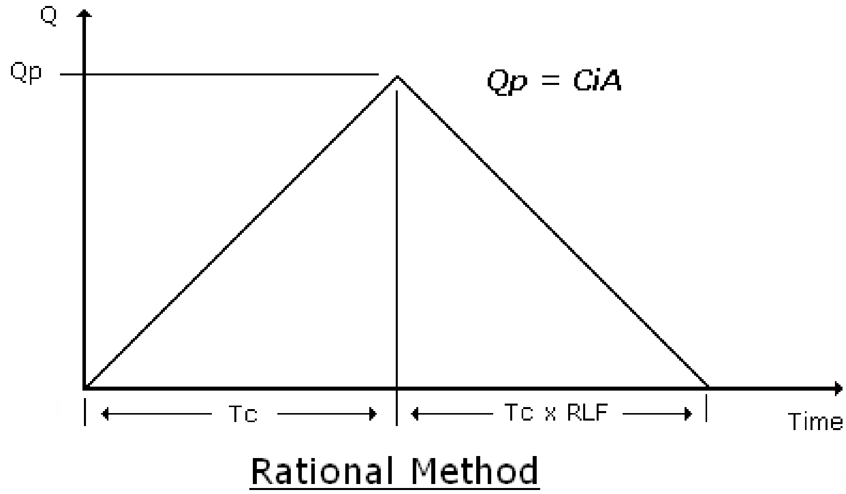
A unit hydrograph displays the results from 1 inch of rainfall excess on a watershed over a given time interval. It merely reflects the watershed characteristics and geologic factors. Once a unit hydrograph of a particular watershed is known, any design storm can be applied to it for computing the final runoff hydrograph. Many hydrologists use the SCS 24-hour storms, but storms of any length can be used with the unit hydrograph method. Hydraflow Express Extension Synthetic distribution is a good example and is gaining popularity.

# Rational Method Hydrographs

The rational method has been adopted by designers of urban hydrology and hydraulics because it is relatively simple to implement and to understand.

The Rational Method uses only three terms. You input acres and inches per hour on one side of an equation, and you get cubic feet per second on the other side. Although this method is accurate up to 200 acres, most governing authorities limit its use to 20 acres or less.

### The Rational Method




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 an impervious surface, C equals 1.00, 1 in/hr rainfall over 1 acre produces 1 cfs peak flow rate. If the duration of the rainfall equals Tc, the hydrograph reaches a peak of Ci expressed as cfs 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.

The time to rise and recess are always equal to Tc, making the shape of this hydrograph an isosceles triangle, with a time base equal to twice Tc. This simple theoretical basis led to this method being named the Rational Method.

Hydraflow Express Extension uses the Standard Rational method, as described above with optional receding limb factor, and the Modified Rational method.

#### Modified Rational Method

This method adapts the Standard Rational method to yield a hydrograph that can be used in detention pond design. According to the Rational method, the highest Qp occurs when the rainfall duration equals Tc. When the rainfall duration is greater than Tc, 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. The user simply modifies the Storm Duration Factor between successive routings to arrive at the critical event. Hydraflow Express Extension can compute this Storm Duration Factor automatically.

## Input

The input requirements are minimal and can be easily entered into Hydraflow Express Extensions Input Grid, as described in Chapter 2, Overview on page 1. To enter data, type in the value or select from a list, and press the Enter or Tab keys on your keyboard. Following is a description of those required items. While entering data, on-screen instructions are provided below the Input Grid, and a basic drawing is shown in the Graphic Display. After inputting data, compute the results by clicking the Run button.

Some cells on the input grid are marked with -0-. This indicates that data is not required for that particular junction.

**Basin**

**Hydrograph Type** - Select the hydrograph method by clicking one of the selector buttons - Std. Rational, Modified Rational or SCS.


**Drainage Area** - Enter the drainage area in acres. Enter zero to enable the Composite C/CN dialog box.

**Runoff Coefficient / Curve Number -** Enter a runoff coefficient (C) for rational method hydrographs or curve number (CN) for SCS. If Drainage Area was set to zero, click the ellipsis button [...] to open the Composite dialog box.

Up to six drainage areas and corresponding CNs can be entered for a composite CN.

**Tc Method**

There are many options for specifying the time of concentration, Tc. Select the desired option from the drop-down list, and then press the TAB key to move to the next item, Tc (min).

| Tc Method | Description |
|---|---|
| User-defined Tc | This is the default method. Simply enter the Tc in minutes. Tc is the time it takes for water to flow from the most remote point in the drainage area to its downstream end. |
| FAA method | Rational method only. Airfield drainage data collected by the Army Corps of Engineers that was used to develop this method and is now widely used in urban drainage design. Click [...] to open the FAA dialog box.<br>**Flow Length** - Enter the hydraulic flow length in feet.<br>**Watercourse Slope** - Enter the slope of Flow Length as a percentage.<br>Click Compute to calculate Tc, and then click Exit. |
| Lag method | This is the TR-20 default method and is used for SCS only. Click [...] to open the Lag method dialog box.<br>**Basin Slope** - Enter the slope of this drainage area as a percentage.<br>**Hydraulic Length** - Enter the distance from the most remote point in the drainage area to the catchment point in feet.<br>Click Compute to calculate Tc and then click Exit. |
| TR-55 method | This selection allows you to compute Tc by using the 3-component Tc as used by TR-55. Hydraflow Express Extension has a built-in TR-55 worksheet that computes Tc. Click [...] to open the TR-55 worksheet dialog box. See Computing Tc by TR-55 in the following section. |
| 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 gives shorter times compared to the Lag method. Click [...] to open the Kirpich method dialog box.<br>**Basin Slope** - Enter the slope of this drainage area as a percentage.<br>**Hydraulic Length** - Enter the distance from the most remote point in the drainage area to the catchment point in feet.<br>Click Compute to calculate Tc, and then click Exit. |

| Tc Method | Description |
|---|---|
| | Hydraflow Express Extension automatically computes Tc and enters it in the Time of Concentration input cell, unless you select User as the method. |

### Storm

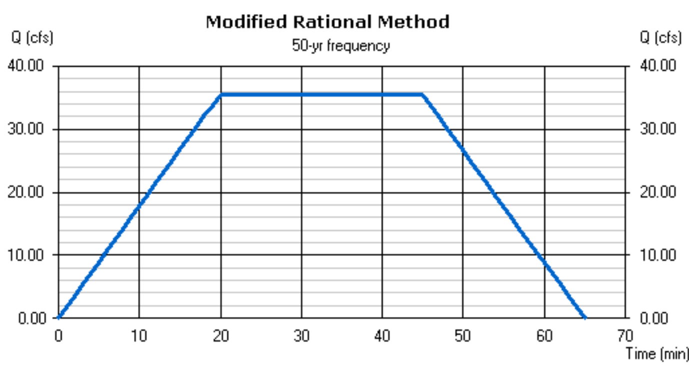
**Distribution** - SCS hydrographs only. Select the storm distribution from the list.

| Storm Name | Duration (hrs) | Description |
|---|---|---|
| SCS Type I, IA, II and III | 24 | Dimensionless distributions developed by SCS using Weather Bureau Rainfall Frequency Atlases for different geographic regions. |
| 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. |

**Duration** - If you are using the Synthetic storm distribution, then enter the total storm duration in hours. (Typically about twice Tc.) This item defaults to 24 or 6 hours when any of the SCS distributions are chosen as the distribution type. Must be >= 0.25 and <=24 hours.

**Receding Limb Factor** - Standard Rational only. 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. For example, if the RLF = 2 then the receding side of the hydrograph would be 2 x Tc.

**Storm Duration Factor** - Modified Rational only. This factor is multiplied by Tc and determines the total storm duration. For example, the following hydrograph was produced using a Tc of 20 minutes and a Storm Duration Factor of 2.25. (20 + 2.25 x 20 = 65min).



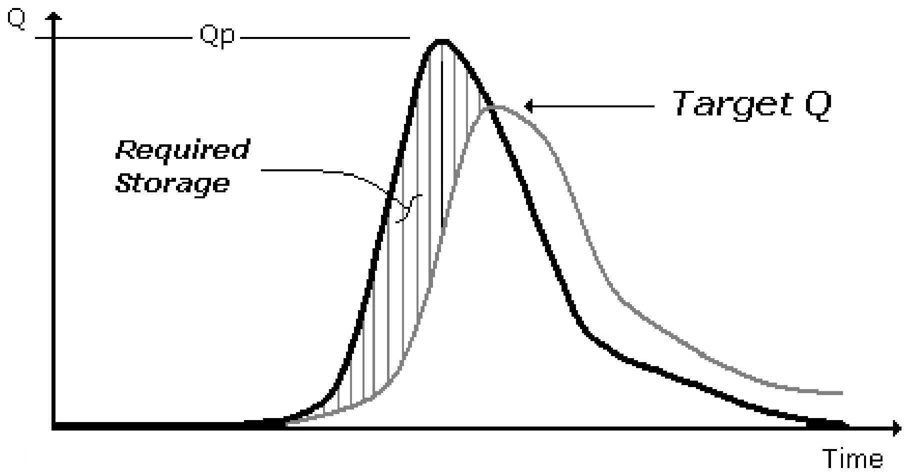

**TIP** Set the Storm Duration Factor to zero and Hydraflow Express Extension can automatically compute a value to maximize required storage. See Target Q in the following section.

**Shape Factor** - SCS only. The shape factor is usually 484. This value can become smaller in coastal regions. For example, 284 in Delmarva, NJ. Check local ordinances, but this value should typically stay at 484.

### Calcs

**Frequency** - Select the return period for this hydrograph from the list. Hydraflow Express Extension allows you to store your SCS rainfall precipitation in a file so that it is readily available without re-entering it each time. For more information, see Setting Up Your Precip Manager on page 52 and Setting Up IDF Curves on page 53. For the location of sample files, see Support and Sample File Locations on page 1.

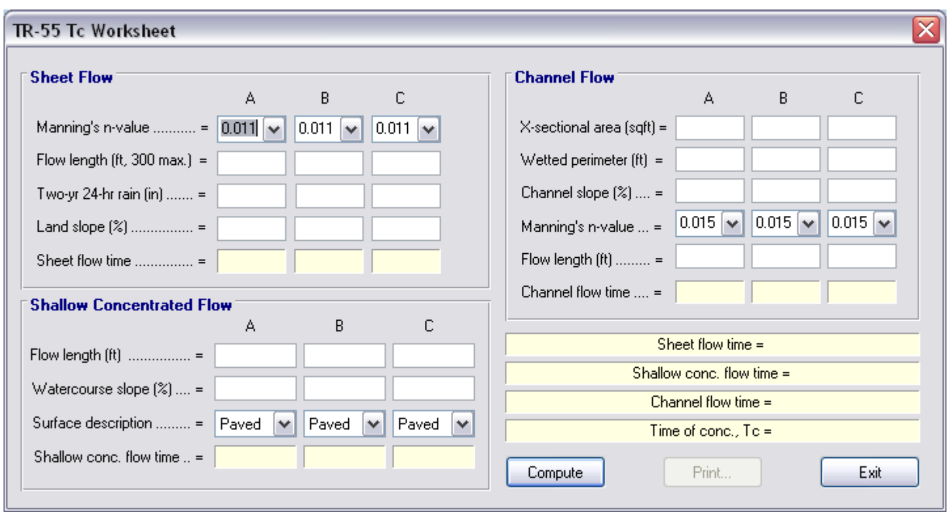
**Target Q** - Optional. Hydraflow Express Extension can automatically compute an estimated required storage from a Target outflow.




In addition, if using the Modified Rational, it computes the Storm Duration Factor (if left blank or zero) that maximizes storage.

### Computing Tc by TR-55

Hydraflow Express Extension has a built-in TR-55 worksheet that computes Tc. To use this feature, click [...] at the Tc input cell. The following dialog box is displayed:




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. Flow types are described in the following section. For more information, see TR-55.

Hydraflow Express Extension allows you to specify up to 3 components for each flow type, areas A, B and C. In addition, these values are saved with the project *.hxp* file.

Once you have completed the data items, click Compute. Hydraflow Express Extension computes Tc and travel times for each segment.

To print a hard copy worksheet report, click Print.

When finished, click Exit. Hydraflow Express Extension returns to the input grid and inserts the computed Tc.

**NOTE** All land slopes are entered as a percentage (ft/100) rather than in ft/ft as in TR55. Hydraflow Express Extension converts them as needed.

### Sheet Flow

Sheet flow is flow over plane surfaces, usually in the upper reaches of the drainage area. A typical n-value used is .011 for smooth surfaces such as concrete, asphalt or bare soil. Dense grasses yield .24, Bermuda grass is .41 while woods range from .40 to .80 depending on the underbrush.

**NOTE** This method for computing sheet flow is limited to a flow length of not more than 300 feet. After 300 feet, sheet flow turns to shallow concentrated flow.

### Shallow Concentrated Flow

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

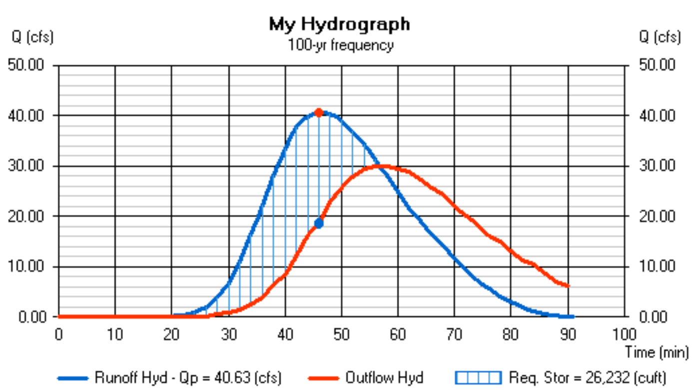
### Open Channel Flow

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

## Output

Click Run to generate the output. The graphic bar below the Help Assist box displays the progress. If any erroneous data is present, Hydraflow Express Extension prompts you before proceeding. Once completed, the Graphic Display and Results Grid are drawn and populated. The Graphic display data from the selected row in the Results Grid.

### Graphic Display

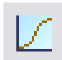



In the plot shown above, an SCS hydrograph was created using a Synthetic design storm of 1 hour with a 20-minute Tc. A target Q of 30cfs was also input.

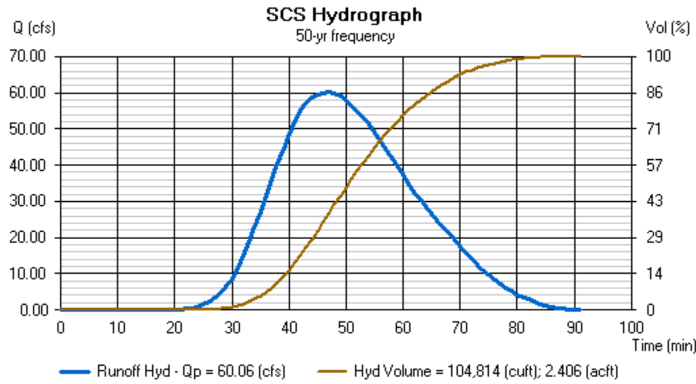
Note that Hydraflow Express Extension builds all hydrographs in one-minute time intervals for maximum accuracy. If the hydrograph duration is less than 6 hours, it plots the time scale in minutes. A longer duration is plotted in hour units.

The dots overlaying the graph indicate the selected row on the Results Grid. To remove, click the graph.

### Hydrograph Volume



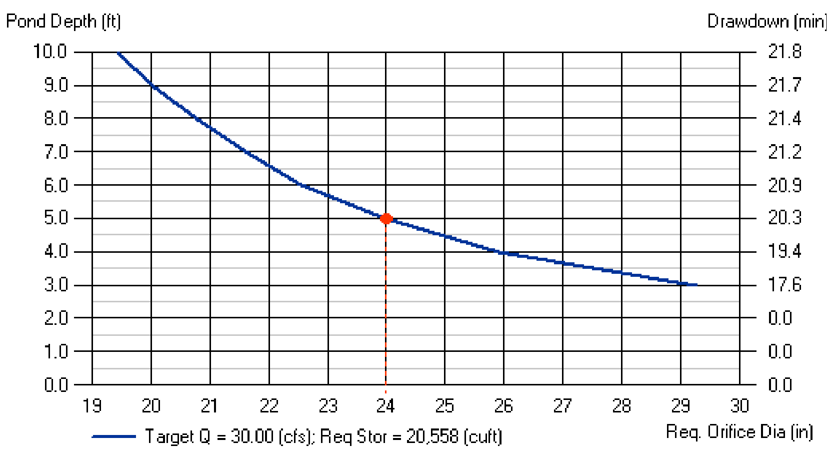
Hydraflow Express Extension can plot an overlay that indicates volume in percent of total volume vs. time. To toggle this overlay on/off, click the Volume button on the Graphic Toolbar.




Volume vs. time overlay

### Performance Curve

Hydraflow Express Extension creates a performance curve if a Target Q was specified. This curve provides a useful relationship between pond depth, required outlet orifice size, and estimated drawdown time.




For example, the plot above indicates that with a Target Q equal to 30 cfs, a 24-inch orifice would be required if the pond depth were 5.0 feet, and it would take approximately 20 minutes for the pond to empty from its peak. If the pond depth were 7.5 feet, a 21-inch orifice would be required with a slightly higher drawdown time of 21 minutes.

Using this information, one can get a good idea of pond size requirements. For example, if the orifice size chosen was 24-inches, the pond depth would be 5 feet. Using the required storage of 20,558 cuft shown above, it can be determined that a pond area could be:

$$PondArea = \frac{ReqStorage}{PondDepth} = \frac{20{,}558}{5} = 4{,}111.6 sqft$$

This assumes vertical side slopes and is a good preliminary estimate. The pond must be 5 feet deep to obtain the required Target Q from the 24-inch outflow, and also needs approximately 4,111 square feet to achieve the required storage.

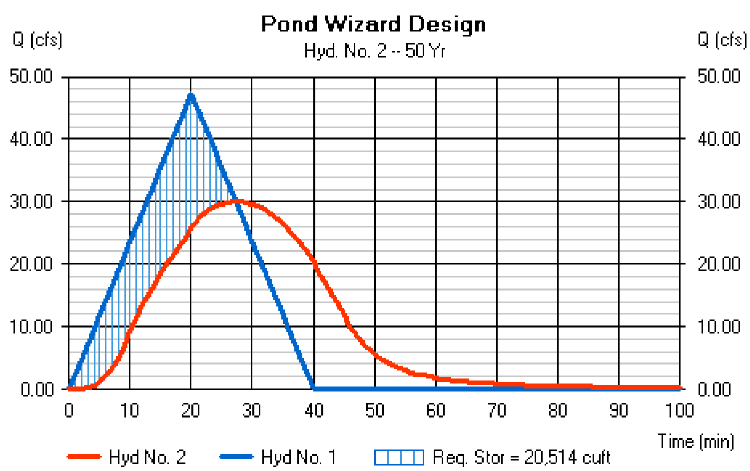
### How Accurate is Hydraflow Express Extension?

A final pond sizeor orifice size, cannot be finally determined without performing an actual routing by the Storage Indication Method. As a comparison, identical Rational method hydrograph inputs were entered into Hydraflow Hydrographs Extension where it was designed and routed using the Storage Indication Method. Here are the results:

| Hydraflow | Express Extension | Hydrographs Extension | % Difference |
|---|---|---|---|
| Peak Inflow (cfs) | 47.37 | 47.37 | 0 |
| Peak Outflow (cfs) | 30 | 30.04 | 0 |
| Req. Storage (cuft) | 20,558 | 20,514 | 0.2 |
| Max. Stage (ft) | 5.0 | 4.94 | 1.2 |
| Req. Orifice Size (in) | 24 | 24 | 0 |
| Bottom Area (sqft) | 4,111 | 4,096 | 0.38 |

Inflow and outflow after routing in Hydraflow Hydrographs Extension reveals similar results. It can be concluded that Hydraflow Express Extension estimates required storage volumes less than 1 percent of actual, and is on the conservative side.

The following graph illustrates comparison routing by Hydraflow Hydrographs Extension.




Results vary with different types of hydrographs. SCS method hydrographs may not be as close in comparison. Further testing reveals Hydraflow Express Extension to be within10 percent on design storms less than 24-hours and approaching 20 percent on 24-hour storms. Hydraflow Express Extension tends to be on the conservative side.

It should be noted that the drawdown time given by Hydraflow Express Extension is only a theoretical time from the peak stage. It does not consider the fact that inflow persists after that and adds to the actual routing time. The Hydraflow Express Extension drawdown time is typically short compared to actual.

**Results Grid**

| Runoff Hydrograph | | | Outflow Hydrograph | | Detention |
|---|---|---|---|---|---|
| Time | Q | Volume | Q | Volume | Required Storage |
| (min) | (cfs) | (cuft) | (cfs) | (cuft) | (cuft) |
| 46 | 60.03 | 38,200 | 23.86 | 8,856 | 31,145 |
| **47** | **60.06** | **41,803** | 25.34 | 10,377 | 33,228 |
| 48 | 59.69 | 45,396 | 26.82 | 11,986 | 35,200 |

Click on a row to plot the corresponding values.

**Runoff Hydrograph**

**Time** - Time increments are displayed in whole minutes when the hydrograph duration is less than 6 hours and in hours when greater than or equal to 6.

**Q** - The runoff at the corresponding time in cfs. It is formatted to the nearest 0.001 cfs if less than 10 and the nearest 0.01 when greater than or equal to 10.

**Volume** - The total accumulated volume under the curve up to this time increment in cuft.

**Outflow Hydrograph**

The following output requires a Target Q.

**Q** - The estimated outflow at the corresponding time in cfs when a Target Q was input. It is formatted to the nearest 0.001 cfs if less than 10, and the nearest 0.01 when greater than or equal to 10.

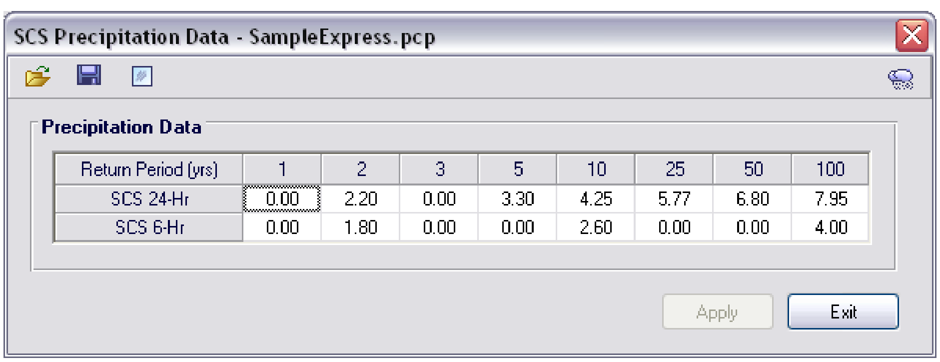
**Volume** - The total accumulated volume under the curve up to this time increment in cuft.

**Required Storage** - The accumulated storage required at the corresponding time in cuft.

# Setting Up Your Precip Manager

While creating hydrographs for the SCS method, Hydraflow Express Extension needs to know the precipitation amounts for each return period you intend to use. Rather than require you to enter this data each time, Hydraflow Express Extension has a built-in module that stores this for you.

The following illustration shows the SCS Precipitation Data dialog box, which illustrates how Hydraflow Express Extension stores SCS precipitation data.




Each hydrograph you create is calculated for the frequency using the precipitation values entered in this dialog box. Like the IDF curves, you can save the values as a file for loading at a later time. Also, like the IDF curves, these files are automatically saved when you exit the program, and reloaded upon its start. In addition, these files become part of all project files. If you are sharing a file with an associate, you do not need to send them the precip (*.pcp*) file, it is embedded in the *.gpw* file.

To begin, click Precip in the top tool bar.

### Entering Precipitation Values

Enter the precipitation values you typically use for the return periods for each of the storm distribution types you plan to use. Note that Rational method hydrographs uses the IDF curves, so there is no need to enter anything here. For example, when you want to compute an SCS hydrograph using the SCS-24-hour storms, Hydraflow Express Extension uses the precipitation values entered here. In the case sample table shown in the figure, the application uses 2.2 inches for the 2-year and 7.95 inches for the 100-year frequency. When using SCS method hydrographs with the Synthetic storm, it uses the IDF curves.

When finished, click Apply.

### Save File

Once the dialog box is complete, save the file. Hydraflow Express Extension allows you to save as many different precipitation files as your disk space allows. When you save, enter a name for the file in the Filename text box. If necessary, change the drive and directory, to the location where you want to save the file. Also note that all precipitation file names are e assigned a *.pcp* extension.

### Open File

To open a previously saved event file, click Open. Note that you may open any event files saved in Hydraflow Hydrographs Extension because they are compatible.

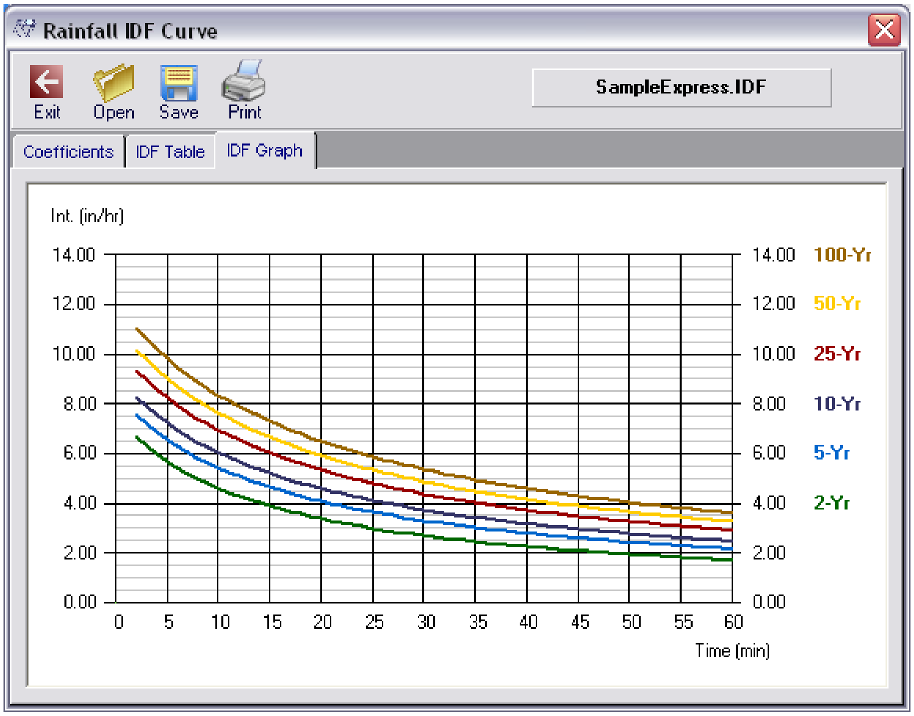
## Setting Up IDF Curves

Hydraflow Express Extension can develop any number of intensity-duration-frequency (IDF) curves, that is, any number of geographic locations, with up to eight return periods. Once created, these files are managed by Hydraflow Express Extension, without the need for any user intervention. They are always loaded upon startup and remembered upon exit.

During calculations for the Rational method, Hydraflow Express Extension automatically computes the rainfall intensity from the currently loaded IDF curves. But first, you must provide data so that these curves match those that you are presently using. This program ships with sample IDF curve files called SampleExpress.idf and FLZone1.IDF. You can use these while getting to know the program.

The rainfall data file, regardless of the type of data used initially, is set up from the Main Menu. Once the IDF data has been entered, Hydraflow Express Extension stores the IDF curves under a user-definable file name. This file is loaded each time Hydraflow Express Extension is started. During design, Hydraflow Express Extension uses it along with the Tc to compute the intensity.

You have a choice of entering points from your existing IDF curves or creating them from map data. In either case, Hydraflow Express Extension generates coefficients from this data for use in its intensity equations. These equation coefficients can be later modified and/or entered directly if you already have them.




IDF curves are automatically loaded at startup.

## Using Existing Data

This method should be your last choice in setting up your curves. The preferred method is to use the Hydro-35 or NOAA Atlas 14 map data, explained in the following section. When entering existing data, Hydraflow Express Extension attempts to plot these points on a best-fit straight line using log scale. The equation coefficients are derived from that line. This method is usually not problematic unless your existing points plot in a concave fashion on log scale. In these cases, the resulting equation may deviate from the original data. Sometimes you can modify the 5-min value up or down to allow for a better fit.

To set up your curves to match existing IDF data, click the IDF button on the top tool bar. The IDF graph appears, showing the current IDF curve. Next click the IDF Table tab. The following table should appear:

| Intermediate Intensity Values (In/hr) | | | | |
|---|---|---|---|---|
| Return Period | 5-Minute | 15-Minute | 30-Minute | 60-Minute |
| 1-Yr | 0.00 | 0.00 | 0.00 | 0.00 |
| 2-Yr | 5.70 | 4.00 | 2.69 | 1.70 |
| 3-Yr | 0.00 | 0.00 | 0.00 | 0.00 |
| 5-Yr | 6.58 | 4.70 | 3.30 | 2.15 |
| 10-Yr | 7.25 | 5.22 | 3.74 | 2.46 |
| 25-Yr | 8.25 | 5.99 | 4.38 | 2.91 |
| 50-Yr | 9.05 | 6.60 | 4.87 | 3.25 |
| 100-Yr | 9.84 | 7.20 | 5.36 | 3.60 |

The required data, consists of the intensity values, in in/hr, 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.

To enter your own data, click Clear, or just edit the table with new data.

**2-Yr / 5 MIN ... 100-Yr / 60 MIN**

Enter the corresponding intensity amounts in inches per hour from your IDF curves. You must enter all of the data for each return period used.

When finished, click OK. Hydraflow Express Extension then calculates the corresponding rainfall intensity equation coefficients. For more informatin, see Viewing IDF Curves on page 57.

## Entering Rainfall Data at a Constant Rate

If 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 per hour. The resulting graph is a straight-line graph that you would expect from a constant rate.

## Creating from Map Data

Hydraflow Express Extension has the ability to generate new IDF curves from National Weather Service precipitation data. The computational procedure is that as described in FHA Circular No. 12, "Drainage of Highway Pavements."

Technically, when using Hydro-35 data or existing curves, Hydraflow Express Extension manipulates your input data to generate coefficients B, D and E, for use in an intensity vs. Tc equation.

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

Where:

I = rainfall intensity in in/hr

Tc = time duration

B, D and E = coefficients

The required data can be precipitation values from NWS Hydro-35 (Eastern United States) or NOAA Atlas (Western United States) Hydro-35. The NOAA Atlases may be available at National Technical Information Service (NTIS) 1-800-553-6847. Ask for publication number PB272112. (Hydro-35).

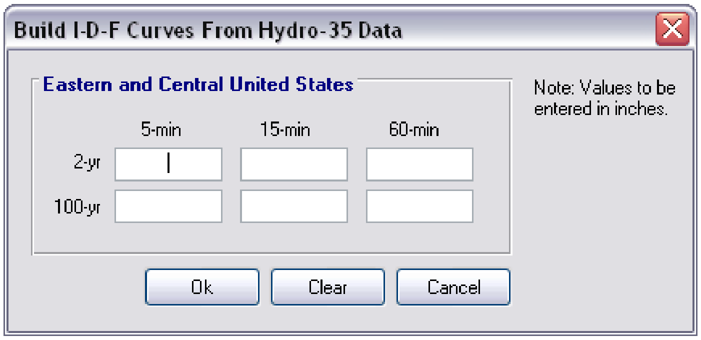
These new estimates replace those contained in TP-40 and NWS Hydro-35. This is the latest published data from the NWS. Using this data is as easy as clicking your mouse on your map location. The server then provides the six precipitation values needed for entry here. Not all states were updated at the time this manual was written.

**To generate IDF curves from map data**

- Click Edit menu ➤ IDF Curves ➤ Create New From Map Data ➤ Eastern States or Western States.

**If you are in the Eastern States**

If located in the Eastern and Central United States, the precipitation data from NWS Hydro-35 is needed. The values are in total inches, not inches per hour (in/hr) and consist of the 5, 15 and 60 - minute durations corresponding to the 2 and 100-year frequencies.



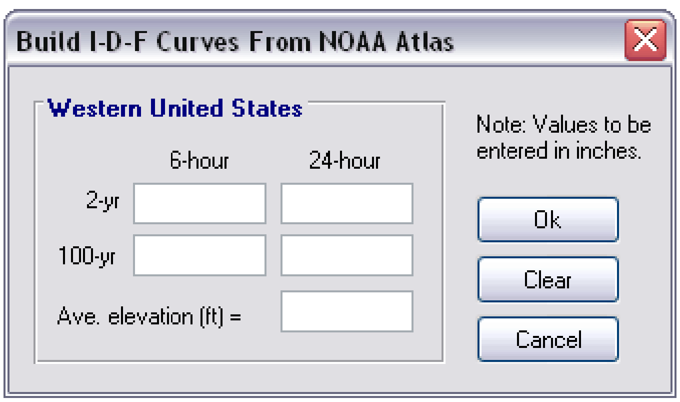

To get your local rainfall data, visit the NWS website.

**2-Yr / 5 MIN ... 100-Yr / 60 MIN**

Enter the corresponding precipitation amounts in total inches. When finished, click OK. Hydraflow Express Extension then calculates the corresponding rainfall intensity equation coefficients.

**If you are in the Western States**

If located in the Western United States, you need the precipitation data from your state's NOAA Atlas is needed. The values are in total inches, not inches per hour (in/hr) and consist of the 6 and 24-hour durations corresponding to the 2 and 100-year frequencies. You also need the average elevation in feet.




**2-Yr / 6 Hr ... 100-Yr / 24 Hr**

Enter the corresponding precipitation amounts in total inches.

**Average Elevation**

Enter the average ground elevation for this area. For example, the average ground elevation for Colorado Springs, Colo. could be 6000.

When finished, click OK. Hydraflow Express Extension then calculates the corresponding rainfall intensity equation coefficients.

# Third Degree Polynomial

Some IDF curves are polynomial-based. For example, the state of Florida has poly-based zoned rainfall curves and publishes these coefficients for direct entry into Hydraflow Express Extension. The third degree polynomial equation used is as follows:

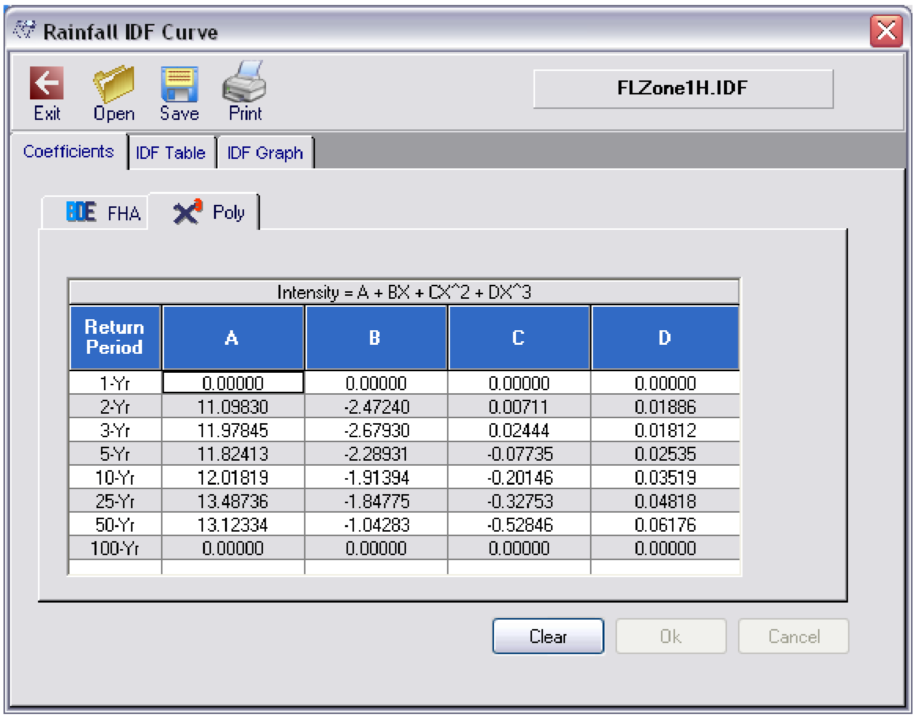
$$I = A + BX + CX^2 + DX^3$$

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

X = Ln(time duration in minutes)

A, B, C, D = coefficients

To create polynomial-based curves click IDF on the top toolbar. A graph is displayed showing the current IDF curve. Next click the Coefficients tab. Then click Poly to make sure the table is in the Polynomial mode. The following dialog box is displayed:




| Return Period | A | B | C | D |
|---|---|---|---|---|
| 1-Yr | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2-Yr | 11.09830 | -2.47240 | 0.00711 | 0.01886 |
| 3-Yr | 11.97845 | -2.67930 | 0.02444 | 0.01812 |
| 5-Yr | 11.82413 | -2.28931 | -0.07735 | 0.02535 |
| 10-Yr | 12.01819 | -1.91394 | -0.20146 | 0.03519 |
| 25-Yr | 13.48736 | -1.84775 | -0.32753 | 0.04818 |
| 50-Yr | 13.12334 | -1.04283 | -0.52846 | 0.06176 |
| 100-Yr | 0.00000 | 0.00000 | 0.00000 | 0.00000 |

Click Clear to erase existing data and then enter the appropriate coefficients. When done, click OK. Click the IDF Graph tab to view the curves.

# Viewing IDF Curves

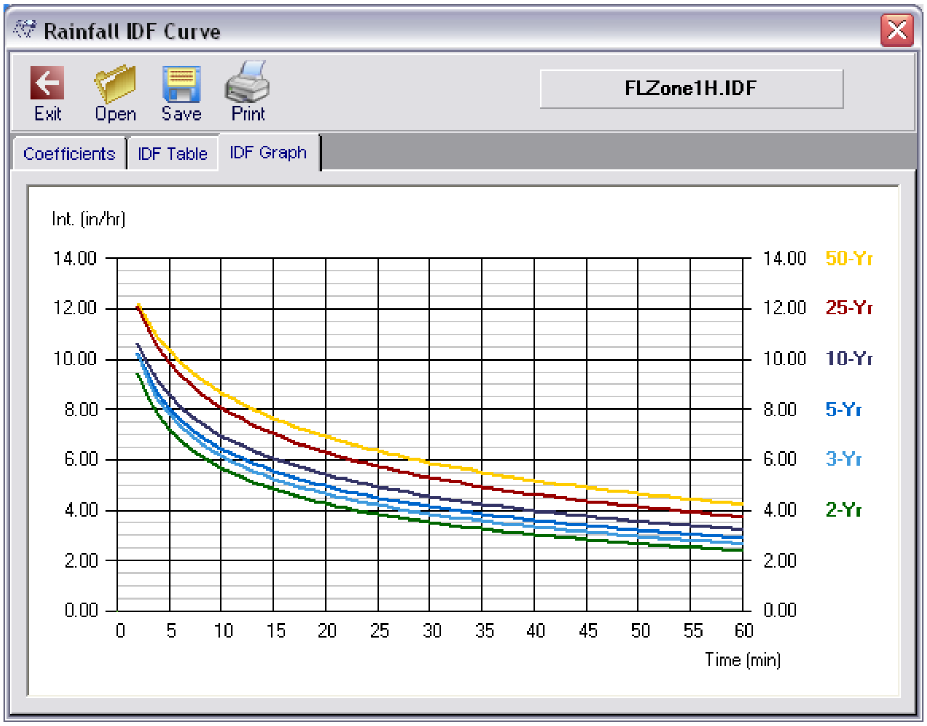
Regardless of the method used to create your new curves, Hydraflow Express Extension always generates equation coefficients and a graphical display of the curves. To view this data, click IDF on the upper toolbar.

This dialog box allows you to the following tasks:

- 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

It is also important to note that these curves are polynomial-based.



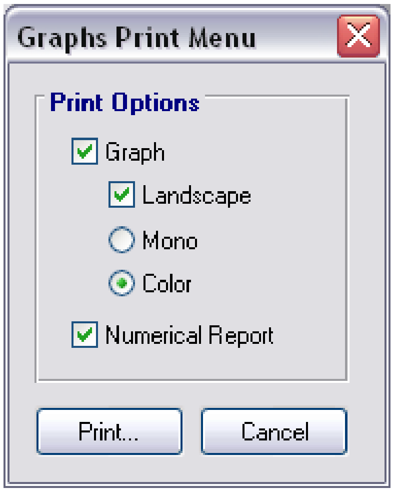

Editing Coefficients: Click the Coefficients tab. To change any of the coefficients, click the table cell and enter the new number. Click OK when finished. To see the effect of the change on the plot, click the IDF Graph tab.

## Save File

Once the IDF curve has been generated, you should save the file. Hydraflow Express Extension allows you to save as many different IDF curves as your disk space allows. When you save, enter a name for the file in the Filename text box. If necessary, change the drive and directory, to the location where you want to save the document. All IDF file names is assigned an *.IDF* extension.

## Printing the Curves

To print a hard copy of this plot, click Print.




Separate IDF reports can be printed in either graphic or numeric formats. Check the appropriate boxes and then click Print. Check the Numerical Report box to get a printed report of the numeric data.

## Opening an Existing Curve

Click Open. In the Open dialog box select the name of the file you wish to load. Its name should then appear in the File Name text box. Click OK. The new plot is shown along with its corresponding numeric data.

---

**NOTE** These files are compatible with all Hydraflow Express Extension *.idf* files. For example, an idf file saved in Hydraflow Storm Sewers Extension can be opened in Hydraflow Express Extension or vice versa.

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When you are finished viewing, click Exit to return to the Main Menu. Hydraflow Express Extension uses the currently loaded IDF curve in all subsequent calculations. The name of the current IDF curve is displayed on appropriate printed reports. When you exit Hydraflow Express Extension, it remembers this file and reloads it the next time it is started.

# Computational Methods

Hydraflow Express Extension uses the 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 because of their easy-to-apply approach. The intent of this section is to provide a summary of the concepts used by Hydraflow Express Extension.

## SCS Unit Hydrograph

Hydraflow Express Extension uses the Unit Hydrograph Method for calculating runoff hydrographs. More specifically, it uses the triangular D-hour Unit Hydrograph approach. The peak discharge for the unit graph is computed using the following equation:

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

Where:

Qp = peak outflow (cfs)

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 set to 484 and reflects a unit hydrograph that has 3/8 of its area under the rising limb. This factor is greater in mountainous watersheds, for example, 600, while in flat, swampy areas, this factor is lower, around 300. Unless you are certain as what this value should be leave it set to 484, the default.

The time to peak, Tp and the time base, Tb are what determines the characteristics of the unit hydrograph. Hydraflow Express 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 Lag Time (L)

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

Where:

L = lag time (hrs)

l = hydraulic length (ft)

S = (1000 / CN) - 10

Y = basin slope (%)

CN = SCS curve number

Time Base:

*Tb = 2.67Tp*

Where:

Tb = time base (hrs)

Tp = time to peak (hrs)

## Design Storms

To calculate the direct runoff hydrograph, you need an excess precipitation hyetograph. Hydraflow Express Extension offers many different ways to specify the design storm. Most of these are the SCS 24-hr and 6-hr distributions. Another option is the Synthetic Storm.

## SCS 24-Hour Distributions

Hydraflow Express Extension provides the SCS 24-hr distributions in one-minute time intervals. The incremental rainfall amounts are computed from a polynomial equation. This equation is used with coefficients that vary with the elapsed time of the storm. The following equation is used to determine the distribution:

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

Where:

Pt = Fraction of 24-hour precipitation

T = Elapsed time (hrs)

C0 = Coefficient

C1 = Coefficient

C2 = Coefficient

C3 = Coefficient

The list of coefficients is quite lengthy and therefore is not shown here.

## Synthetic Storms

This option can produce an infinite number of design storm hyetographs. Hydraflow Express Extension uses the rainfall IDF curves to compute depth increments over the time intervals. From this 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. This is the same method used by the SCS to construct their 24-hour storms.

The Synthetic Storm option can be perfectly matched to the site, with its total duration specified to best fit the computed Tc. For example, if Tc is 30 minutes, you could specify a one-hour storm rather than struggle with a 24-hr 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.

## Excess Precipitation Hyetograph

The precipitation increments of the design storm 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 that are used for the final excess precipitation hyetograph.

After computing the excess precipitation hyetograph, Hydraflow Express Extension computes the direct runoff hydrograph using the concept of convolution or linear super positioning. 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.

## Rational Method Hydrographs

Hydraflow Express Extension computes both Standard and Modified Rational method hydrographs. In either method, the peak is equivalent to the peak discharge as determined by the Rational formula. That is:

$$Qp = CiA$$

Where:

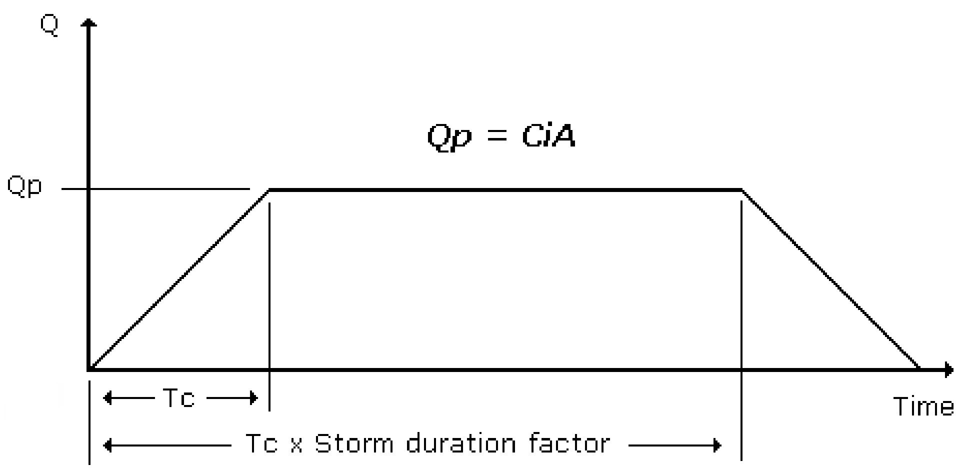
Qp = Hydrograph peak discharge (cfs)

C = Runoff coefficient

A = Basin area (ac)

i = Intensity (in/hr)

The time-to-peak of the hydrograph is equal to the time of concentration. 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 RLF = 1.




Modified Rational

When using the Modified rational method, the time base is stretched out by the Storm Duration Factor as shown above. The intensity used to compute Qp is based on Tc x Storm Duration Factor.

Hydraflow Express Extension uses the following standard orifice equation to estimate orifice sizes:

$$Q = 0.6A\sqrt{2gh}$$

Where:

Q = Target Q in cfs

A = Cross-sectional area of the orifice in sqft

h = Depth to the center of the orifice in ft

Drawdown times are computed using the following equation:

$$T = \frac{2A}{0.6\sqrt{2g}}\left(\sqrt{PondDepth}\right)$$

Where:

T = Drawdown time in seconds

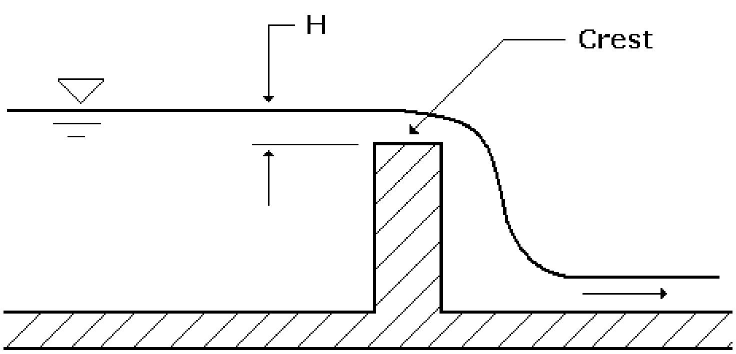
A = Orifice area in sqft

# Weirs

# 6

Traditionally used for flow measurement, weirs have become standard features in detention pond outlets. They typically are notches in the sides of concrete walls or riser structures (sharp-crested) as well as those with long, nearly horizontal crests, used as overflow spillways (broad crested).

Any weir formed so that water springs clear of the crest as it flows over it is called a sharp crested weir. If the crest is long enough in the direction of flow to where hydrostatic pressures fully develop, it is considered a broad crested weir.




Hydraflow Express Extension can model the following six weir types:

- Rectangular (sharp or broad crested)
- Compound or two stage (sharp or broad crested)
- Circular (sharp crested)
- V-notch (sharp or broad crested)
- Trapezoidal (sharp crested)
- Proportional (sharp crested)

Working within these parameters Hydraflow Express Extension can quickly compute the following values:

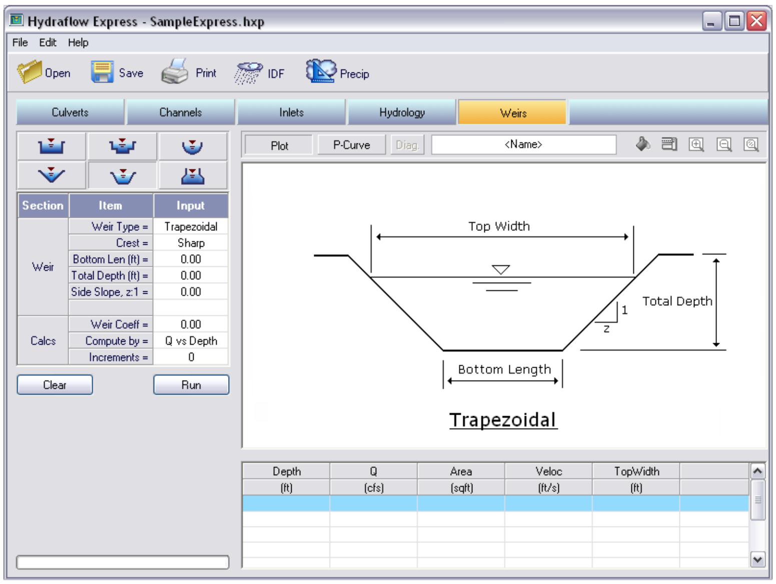
- A rating table of Q vs. depth based on a range of user-defined depth increments
- Weir depth from a single known Q
- Q from a user-defined depth

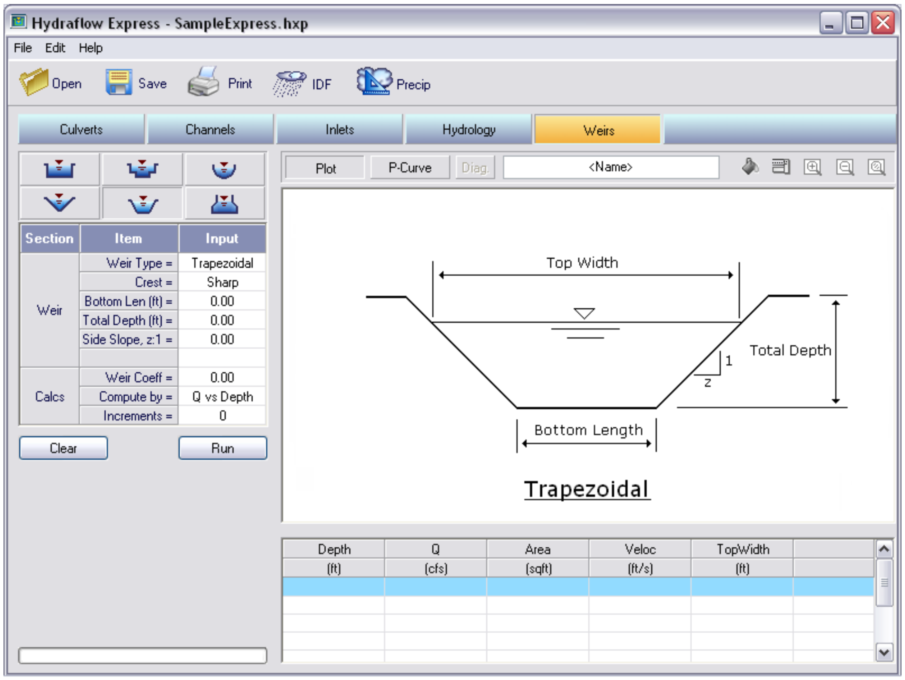
In all cases, Hydraflow Express Extension provides plots of cross sections, performance curves, numerical tables, and report-style print-outs.

# Input

The input requirements are minimal and are easy to enter. For more information, see Common User Interface on page 3. This grid works like any other spreadsheet style data entry. Enter values or select from a list under the Input column and press Enter or Tab. The cursor advances to the next item. While doing this, Hydraflow Express Extension displays a Help Diagram in the Graphic Display as well as tips in the Input Assist box. To edit an item, double-click the cell or press F2. Once the data is input, compute the results by clicking Run.

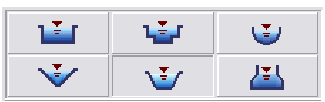
**NOTE** Some data items are not required or do not apply to that particular channel section. These cells display a 0 or a blank.






## Weir

**Weir Type** - Choose weir type



Hydraflow Express Extension offers a variety of weir types. Select the weir by clicking on the corresponding button. A cross section drawing of each is shown on the graphic display to assist in data entry. A brief discussion of each weir type follows.

**Rectangular** - The most basic type of weir is the rectangular and is usually sharp crested. You can also use this type of weir for any riser structure, circular or rectangular in plan view. The crest length is the perimeter of the riser.

**Compound** - This is the same as the rectangular weir but can have a second weir below the first. Also called a two-stage weir.

**Circular** - This weir type has a circular section and is evaluated at depths up to the diameter.

**V-notch** - Use this weir when you anticipate low quantities of flow. Hydraflow Express Extension models v-notch weirs up to 120 degrees.

**Trapezoidal** - Also known as a Cipoletti weir, is trapezoidal in shape and was devised to minimize loss of flow due to the vertical side contractions of rectangular weirs. Cipoletti weirs have 4 to 1 side slopes but Hydraflow Express Extension can model smaller side slopes up to 4:1.

**Proportional** - This weir is also known as a Sutro weir and is designed so that when the total head exceeds a certain level, Depth a, the discharge is linearly proportional to the total head. As you'll see on the Performance curve, the Q vs. Depth line is straight. The equation defining the curved sides is described in, Computational Methods later in this chapter.

**Crest** - Choose the crest type from the list. Note that certain weir types are limited to sharp only.

**Bottom Length** - Enter the length of the weir crest, perpendicular to the flow.

**Diameter** - Enter the diameter of the circular shaped weir in feet. Note that the total depth is limited to the diameter.

**Angle** - Enter the total angle for the V-notch weir in degrees. It cannot exceed 120.

**Total Depth** - Enter the total depth to be modeled. Circular weirs defaults to their diameter.

**Length, x** - Enter the bottom-most length of a Compound weir. Must be less than Bottom Length.

**Depth, a** - Enter the depth associated with Length, x for Compound weirs. Must be less than Total Depth. This is the initial bottom depth for Proportional weirs.

### Calcs

**Weir Coefficient** - Hydraflow Express Extension automatically computes the appropriate weir coefficient and uses it as the default. To accept, simply tab through this item. You can override the default by entering a known coefficient. To reset to auto default, enter zero.

**Compute by** - Select a computation method from the drop-down list.

**Q vs. Depth** - This produces a rating table of Q vs. Depth based on a range of user-defined depth increments.

**Known Q** - Use this to compute a depth corresponding to a known flow rate.

**Known Depth** - Use this to compute a flow rate corresponding to a known depth. Must be less than Total Depth.

**Increments** - If Q vs. Depth was selected above, enter the number of increments or points to be computed. The default is 10. For example, the Results Table is populated with 10 rows of computed data in increments of Total Depth / 10. The maximum is 50.

**Q** - Enter a known Q in cfs. If the resulting depth exceeds Total Depth, Hydraflow Express Extension prompts you to decrease Known Q.

**Depth** - Enter a depth in feet less than or equal to Total Depth.

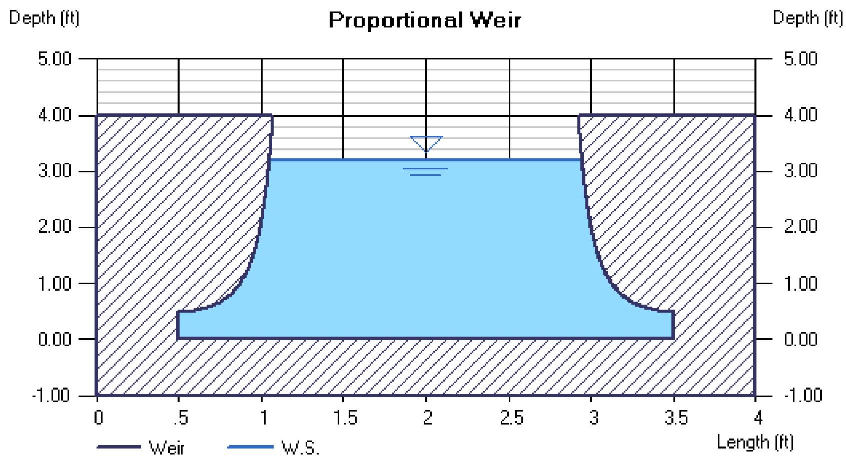
# Output

Click Run to generate the output. The graphic bar below the Help Assist box displays the progress. If any erroneous data is present, Hydraflow Express Extension prompts you before proceeding. Once completed the Graphic Display and Results Grid are drawn and populated. If Q vs. Depth was specified, that range and increment is the basis for the data in the Results Grid. The Graphic Display plots data from the selected row in the Results Grid. For example, to plot a profile corresponding to a depth of 1.5, click on the row that contains Depth of 1.5.

### Graphic Display

In the profile plot, each line type is indicated in the legend located at the bottom of the graph. The scale on the left and right indicates absolute depth above the crest.

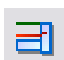
The following illustration shows a graphic display of a proportional weir:




### Fill

Use this button to turn on/off the color fill. This does not affect printed reports. They do not fill areas.

### EGL

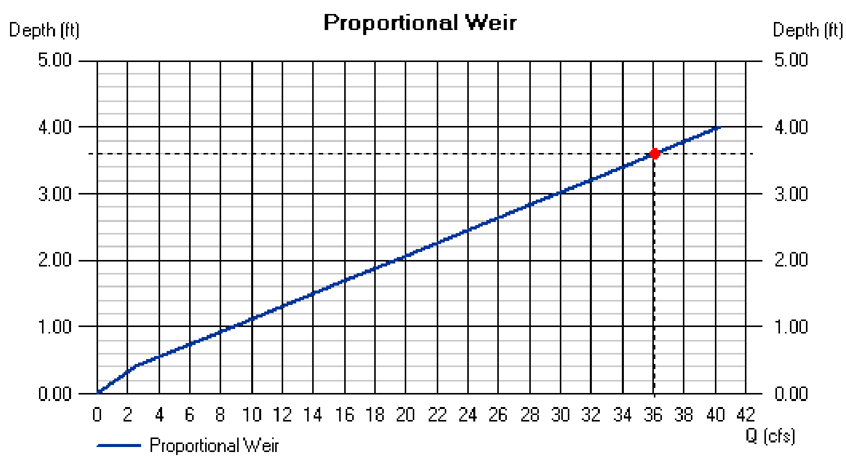


In the plot shown above, note the Energy Grade Line (EGL) is not shown. This can be toggled on or off using the EGL button located at the top of the graph. EGL = HGL + Velocity Head.

### Performance Curve

If Q vs. Depth was used as the Compute-by method, Hydraflow Express Extension builds a rating curve, which you can display by clicking P-Curve.

The following illustration shows a performance curve for a proportional weir. Note the linear relationship.




The dot on the curve corresponds to the currently selected row on the Results Grid. To remove this dot, click the graph.

### Results Grid

| Depth | Q | Area | Veloc | TopWidth | Energy |
|---|---|---|---|---|---|
| (ft) | (cfs) | (sqft) | (ft/s) | (ft) | (ft) |
| 1.60 | 15.08 | 4.05 | 3.73 | 2.08 | 1.82 |
| 2.00 | 19.29 | 4.86 | 3.97 | 2.01 | 2.24 |
| 2.40 | 23.50 | 5.66 | 4.15 | 1.96 | 2.67 |
| 2.80 | 27.71 | 6.44 | 4.31 | 1.93 | 3.09 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

Click on a row to plot the corresponding values. A brief description of the output variables follows.

**Depth** - The range of depth that is determined by the total depth of the weir and the number of increments specified. For example, if the total depth is 4 and increments equal 10, the Results Grid would be set up in 4/10ths or in 0.4 ft depths.

**Q** - The corresponding computed flow rate.

**Area** - The cross-sectional area of flow.

**Velocity** - The velocity in the weir, computed as Q / Area.

**Top Width** - Distance across the top water surface.

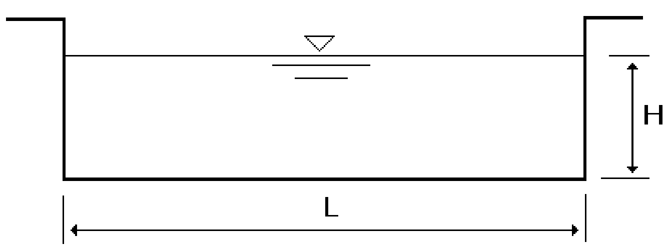
**Energy** - The energy grade line (EGL). Depth plus velocity head.

# Computational Methods

Hydraflow Express Extension uses a variety of forms of the fundamental weir equation to compute flow rates at varying depths of flow. Sources for these equations include HEC-22 and "Open Channel Hydraulics", Richard French.

When a known Q is specified, it solves for the depth using an iterative procedure.

**Rectangular and Compound Weirs**




The following equation is used for rectangular and compound weirs:

$$Q = CwL\,H^{1.5}$$

Where:

Q = Discharge in cfs

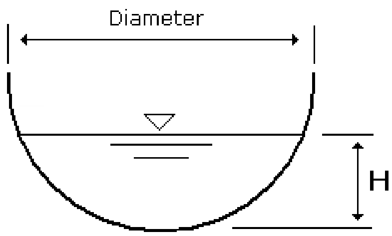
Cw = 3.33 for sharp crest; 2.6 for broad crest

L = Crest length in ft

H = Head above weir crest (excludes velocity head)

**Circular Weirs**

Hydraflow Express Extension uses the following fundamental weir equation for circular weirs:




$$Q = CwA\sqrt{H}$$

Where:

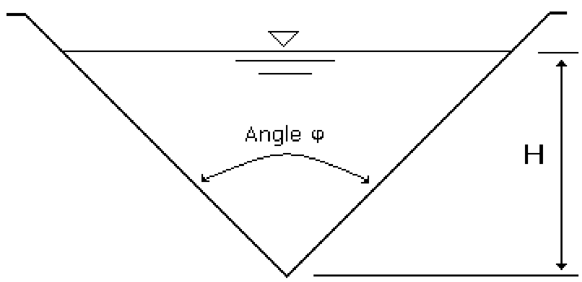
Q = Discharge in cfs

Cw = 3.33 (sharp crest)

A = Area at depth H in sqft

H = Depth in ft

**V-notch Weirs**




The following equation is used for V-notch weirs:

$$Q = Cw\,H^{2.5}$$

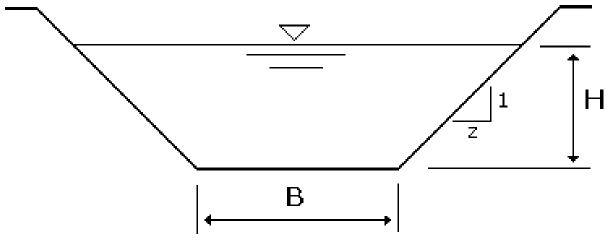
Where:

Q = Discharge in cfs

H = Depth in ft

$$Cw = 2.54 Tan\left(\frac{\phi}{2}\right)$$

**Trapezoidal Weirs**




Also known as Cipoletti weirs, Trapezoidal weir flow is computed using the following equation:

$$Q = 3.1\left[B + .8Hz\right]H^{1.5}$$

Where:

Q = Discharge in cfs

B = Bottom width in ft

z = Side slope (Cipoletti weirs, z = 4)

H = Depth in ft

**Proportional**

Also known as a Symmetrical Sutro weir, the Proportional weir produces a linear stage-discharge curve by using the following equation:

$$Q = 4.96\sqrt{a}B(H - a/3)$$

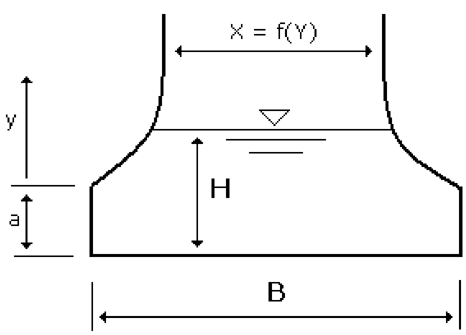
Where:

Q = Discharge in cfs

a = Initial depth in ft, see figure below

B = Bottom Length in ft

H = Depth in ft




The curved portion of the weir is constructed using the following the equation:

$$X = B\left[1 - \frac{2}{\Pi} Tan^{-1}\sqrt{\frac{y}{a}}\right]$$

# Reference Tables

# A

## Runoff Coefficients (C)

| Description of Area | Coefficient |
|---|---|
| **Business** | |
| Central business | 0.70 - 0.95 |
| District and local | 0.50 - 0.70 |
| **Residential** | |
| Single family | 0.35 - 0.45 |
| Multi-units | 0.40 - 0.75 |
| 1/2 acre lots or larger | 0.25 - 0.40 |
| **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 |
| Unimproved | 0.10 - 0.30 |
| Asphaltic | 0.70 - 0.95 |
| Concrete | 0.80 - 0.95 |

| Description of Area | Coefficient |
|---|---|
| Roofs | 0.75 - 0.95 |

# SCS Curve Numbers (CN)

| Land Use Description | Hydrologic Soil Group | | | |
|---|---|---|---|---|
| **Residential** | **A** | **B** | **C** | **D** |
| Average Lot Size | | | | |
| 1/8 acre or less | 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 |
| Paved parking lots, 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 |
| Open Spaces, Lawns, 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 = 0.25

# Mannings n-Values

| Item | Manning's n |
|---|---|
| **Pipes** | |
| 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 |
| **Miscellaneous** | |
| Smooth surfaces (concrete, asphalt, bare soil) | 0.011 |
| Fallow (no residue) | 0.05 |
| Cultivated soils | 0.06-0.17 |
| Short grass | 0.15 |
| Dense grass | 0.24 |
| Bermuda grass | 0.41 |
| Light underbrush woods | 0.40 |
| Dense underbrush woods | 0.80 |

# Index

## T



## U



## W



## Z