



**US Army Corps
of Engineers**

Hydrologic Engineering Center

HEC-WAT Hydrologic Sampler

User's Manual

Version 1.0
November 2018

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
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1. REPORT DATE (DD-MM-YYYY)		2. REPORT TYPE		3. DATES COVERED (From - To)	
November 2018		Computer Program Document			
4. TITLE AND SUBTITLE HEC-WAT Hydrologic Sampler User's Manual Version 1.0				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Beth Faber, CEIWR-HEC Julia Slaughter, CEIWR-HEC Lea Adams, CEIWR-HEC Others at CEIWR-HEC				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) US Army Corps of Engineers Institute for Water Resources Hydrologic Engineering Center (CEIWR-HEC) 609 Second Street Davis, CA 95616-4687				8. PERFORMING ORGANIZATION REPORT NUMBER CPD-88b	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/ MONITOR'S ACRONYM(S)	
				11. SPONSOR/ MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT <p>The Hydrologic Sampler is a plug-in built for the HEC-WAT (Watershed Analysis Tool) software (refer to the HEC-WAT User's Manual). The purpose of the Hydrologic Sampler is to allow users to create hydrologic time series data necessary for a Flood Risk Analysis (FRA) compute in HEC-WAT. The FRA compute is a Monte Carlo simulation that evaluates thousands of sampled flood events within a watershed. Each flood event is initiated with a time series dataset of either flow hydrographs or precipitation hyetographs. The hydrologic sampling relies on hydrologic information such as flow or precipitation frequency curves, cross correlations between curves, and hydrograph or hyetograph shapes, or instead, historical and synthetic event hydrographs. This hydrologic information will be sampled to generate as many realizations of the lifecycle hydrologic sequence as necessary, with each generated sequence available as input boundary conditions to the other software applications in the program sequence, such as HEC-RAS, HEC-HMS or HEC-ResSim.</p>					
15. SUBJECT TERMS <p>HEC-WAT, software, plug-in, interface, integrate, analytical process, tools, USACE, watershed, lifecycle, realization, Monte Carlo, water resources study, study, graphical user interface, GUI, flow sampling, frequency curves, precipitation sampling, correlation, bootstrapping, Hydrologic Sampler, HEC-HMS, HEC-RAS, HEC-ResSim, HEC-FIA, computations, framework, hydrologic, hydraulic, sampling, modeling, results, models, reporting, visualization, data, sharing, statistical analysis, measures, alternatives, simulations, analysis periods, events, schematic, map windows, program order, common computation points, stream alignment, model linking, panes, panels, tabs, toolbars</p>					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 164	19a. NAME OF RESPONSIBLE PERSON
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19b. TELEPHONE NUMBER

HEC-WAT Hydrologic Sampler

User's Manual

November 2018

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CPD-88b

HEC-WAT, Hydrologic Sampler, User's Manual

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CHAPTER 1

Introduction

The Hydrologic Sampler is a plug-in built for the HEC-WAT (Hydrologic Engineering Center's (HEC) Watershed Analysis Tool) software (for further details refer to the HEC-WAT User's Manual). The purpose of the Hydrologic Sampler is to allow users to generate the hydrologic time series necessary for a Flood Risk Analysis (FRA) compute in HEC-WAT. The FRA compute is a Monte Carlo simulation that evaluates thousands of randomly sampled flood events within a watershed. Each flood event is initiated with time series of either flow or precipitation that are used as input boundary conditions in subsequent watershed models such as HEC-RAS (River Analysis System), HEC-HMS (Hydrologic Modeling Systems) or HEC-ResSim (Reservoir System Simulation).

The Hydrologic Sampler uses pseudo random number generation to create flow or precipitation input time series required for an FRA simulation. For flow sampling, two supported methods for generating hydrographs are available: **Correlated Flow Frequency Curves** and **Bootstrapping Historical/Synthetic Basin-wide Events**. For precipitation sampling, one method of generating hyetographs is available: **Basin Average Frequency Curve**. In each case, the Hydrologic Sampler randomly samples the hydrology, generating as many hydrologic time series (as hydrographs or hyetographs) as necessary for the FRA compute. Each generated time series is available to the other software applications in the HEC-WAT program.

HEC-WAT distinguishes between and separates sampling of natural variability (aleatory uncertainty) from knowledge uncertainty (epistemic uncertainty) using a nested Monte Carlo sampling structure, with inner and outer loops. Natural variability is sampled at an event level (inner loop), while knowledge uncertainty is sampled at a realization level (outer loop); where a realization contains enough flood events to fully characterize the natural variability. A realization contains many HEC-WAT "analysis periods" or lifecycles, with an event placed in each year of a lifecycle. At the event level, the Hydrologic Sampler generates each flow or precipitation event using a random instance of natural variability, such as peak flow or total precipitation magnitude, and date. The primary knowledge uncertainty captured in the Hydrologic Sampler is in the annual maximum flow or precipitation frequency curves. This uncertainty is defined by an equivalent record length, N , and at the realization level, N is randomized by re-estimating each frequency curve from an N -year bootstrap. Since each realization is based on one random instance of knowledge uncertainty, many realizations are required to capture the full distribution of possible outcomes.

1.1 Overview of Sampling Methods

HEC-WAT Version 1.0 provides three hydrologic sampling methods in the Hydrologic Sampler (Table 1-1). The user must specify only one of these methods per hydrologic sampling alternative (Section 1.3). Table 1-1 provides descriptions and data requirements for each hydrologic sampling method that might be helpful in selecting the appropriate sampling method.

Table 1-1 Methods Available in the Hydrologic Sampler

Method Data Type	Frequency Curves		Bootstrapping Historical/Synthetic Events
	Flow	Precipitation	Flow
Input(s)	Flow Frequency Curves, Spatial Correlations, Shape Hydrographs	Basin Average Precipitation Frequency Curve, Subbasin Areas, Shape Hyetographs	Historical/Synthetic Hydrographs
Advantages	<ul style="list-style-type: none"> Generates greater variety of events than historical record. Uses historical temporal patterns. Consistent record lengths across watershed unnecessary. 	<ul style="list-style-type: none"> Generates greater variety of events than historical. Uses historical temporal & spatial patterns. 	<ul style="list-style-type: none"> Do not need to simplify hydrology to frequency curves and correlations. Capture complex hydrology by example.
Limitations	<ul style="list-style-type: none"> Hydrology simplified into frequency curves. Estimating site-to-site correlation is difficult. 	Basin average frequencies might not reproduce station frequency curve.	<ul style="list-style-type: none"> Uses only Historical/Synthetic events. Need a consistent period of record for entire system.
Refer to...	Chapter 2	Chapter 4	Chapter 3

The following sections provide an overview of each available sampling option in the Hydrologic Sampler. Chapter 2 provides details on the **Correlated Flow Frequency Curves** sampling method; Chapter 3 provides details on the **Bootstrapping Historical/Synthetic Basin-wide Events** sampling method, and Chapter 4 provides details on the **Basin Average Frequency Curve** sampling method.

1.1.1 Flow - Correlated Flow Frequency Curves

The **Correlated Flow Frequency Curves** method generates randomly sampled flood events based on users providing a flow-frequency curve for each inflow location, cross-correlations between frequency curves, and hydrograph shapes. This method generates an array of flood magnitudes at hydrograph locations, with specified linear cross-correlations, that defines the spatial distribution throughout a watershed. Though more flexible in creating possible flood events, the set of frequency curves and linear spatial relationships can be a simplistic representation of extreme event hydrology for a complex watershed.

The user provides location-specific flow-frequency curves to capture the probability distributions of event magnitudes ranging from small to extremely large. Estimation of flow-frequency curves occurs (in general) from a historical record of annual maximum (or coincident) flows, as are the cross-correlations between locations within a watershed. The user provides scalable hydrograph shape sets to capture examples of possible event timing, both for a given location and in combination with other locations. Finally, the user provides the distribution of flood dates based on frequency analysis of historical flood dates. In this method, the Hydrologic Sampler generates a hydrograph for each specified inflow location using the following steps:

- (1) randomly samples a peak flow magnitude for each primary location with correlated sampling from the flow-frequency curves,

- (2) samples a shape set from the available basin-wide sets and scales each hydrograph shape to match the corresponding sampled flow magnitude, and
- (3) places the event on a randomly sampled date.

The resultant set of synthetic flood hydrographs for the watershed is then a combination of date, magnitude and timing of the event arrival.

1.1.2 Flow - Bootstrapping Historical/Synthetic Basin-wide Events

The **Bootstrapping Historical/Synthetic Basin-wide Events** (bootstrapping) flow sampling method re-samples a provided historical record (plus optional derived synthetic events), as watershed-wide flood events. The method is limited to a discrete set of known flood events that are reasonable, rather than a continuous array of possibilities, but a well-constructed set can capture a more complex spatial description of flood event probability in the watershed than the **Correlated Flow Frequency Curves** method.

The user can include, as many events in the historical record, but the record must contain data at every location for each event. The user may also choose to supplement the historical record with synthetic flood events that are greater or less than measured flows, or have a different spatial distribution, to ensure a good characterization of feasible extreme events is included. For each event, the user defines a flood hydrograph for each inflow location that encompasses the peak and as much of the hydrograph recession limb as they deem necessary, with all locations spanning the same event windows. The hydrographs can vary in length and shape from one event to the next. The user-defined set of historical and synthetic hydrographs should collectively capture the probabilistic relationships of magnitude and spatial distribution in the watershed.

In this method, the Hydrologic Sampler starts with a "bucket" of flood events filled with the user-defined, basin-wide historical record and additional synthetic flood events. The sampling method randomly samples the flood bucket; and each selected flood hydrograph, for the sampled event at all basin inflow locations, will be included in the event compute. The Hydrologic Sampler maintains flood event frequency by sampling events at the frequency they occurred or would occur, meaning an equal likelihood for each historical event and user-assigned frequency for synthetic events. This **Bootstrapping Historical/Synthetic Basin-wide Events** (bootstrapping) flow sampling method implicitly maintains cross-correlation of flood magnitudes between inflow locations as well as frequency, because the definition of each historical year and synthetic event is across the entire watershed.

1.1.3 Precipitation – Basin Average Frequency Curve

The **Basin Average Frequency Curve** method samples precipitation from flow-frequency curve values, and is very similar to the **Correlated Flow Frequency Curves** method for sampling flows. The method uses a basin average precipitation-depth frequency curve provided by the user, as well as various hyetograph shape sets and a flood season distribution. Precipitation hyetographs are generated by scaling randomly chosen shape sets to match randomly sampled

basin average precipitation depths. The primary difference in methodology compared to flow sampling, however, is that one precipitation depth is sampled from an area-weighted basin average frequency curve, then disaggregated by area and relative shape set depth at various subbasin locations, rather than sampling values directly for each subbasin location.

The user provides a basin average precipitation-frequency curve to capture the probability distribution of event magnitudes, ranging from small to extremely large. This curve has generally been estimated from historical gaged precipitation records across the watershed. The user also develops sets of location-specific scalable hyetograph shapes (shape sets) that together capture the array of possible event timing and spatial distribution of rainfall throughout the watershed, with each set usually based on a large event from the historical record. Finally, the user provides a distribution of possible flood dates based on frequency analysis of the historical flood dates.

In this method, the Hydrologic Sampler generates a hyetograph for each subbasin location for each event using the following steps:

- (1) randomly samples an annual maximum precipitation depth from an aggregated basin average depth-duration frequency curve,
- (2) randomly selects a shape set,
- (3) disaggregates the basin average precipitation depth among the subbasin locations based on subbasin area and shape set depth,
- (4) scales every hyetograph in the shape set to the subbasin depth, and
- (5) places the scaled hyetographs on a peak date randomly sampled from the flood season distribution.

1.2 Hydrologic Sampling Editor Interface

In HEC-WAT Version 1.0, the **Hydrologic Sampling Editor** allows the user to apply one of the three available hydrologic sampling methods (Table 1-1) per hydrologic sampling alternative (Section 1.3) for use in an FRA study. The **Hydrologic Sampling Editor** graphical user interface (GUI) will adjust depending on the selected hydrologic sampling method. The user selects a hydrologic sampling method from the **Data to be Sampled** and **Sampling Method** lists (Figure 1-1). For example, Figure 1-1, displays the **Hydrologic Sampling Editor** and highlights the components of the **Hydrologic Sampling Editor**. The following subsections provide detailed descriptions of the **Hydrologic Sampling Editor** components.

1.2.1 Navigation Bar

The navigation bar (Figure 1-1) is located next to a list of hydrologic sampling alternatives, which allows users to select a specific alternative by **Name** (e.g., *Test_HS*). The navigation bar allows users to navigate through the list of alternatives by clicking the navigation buttons.

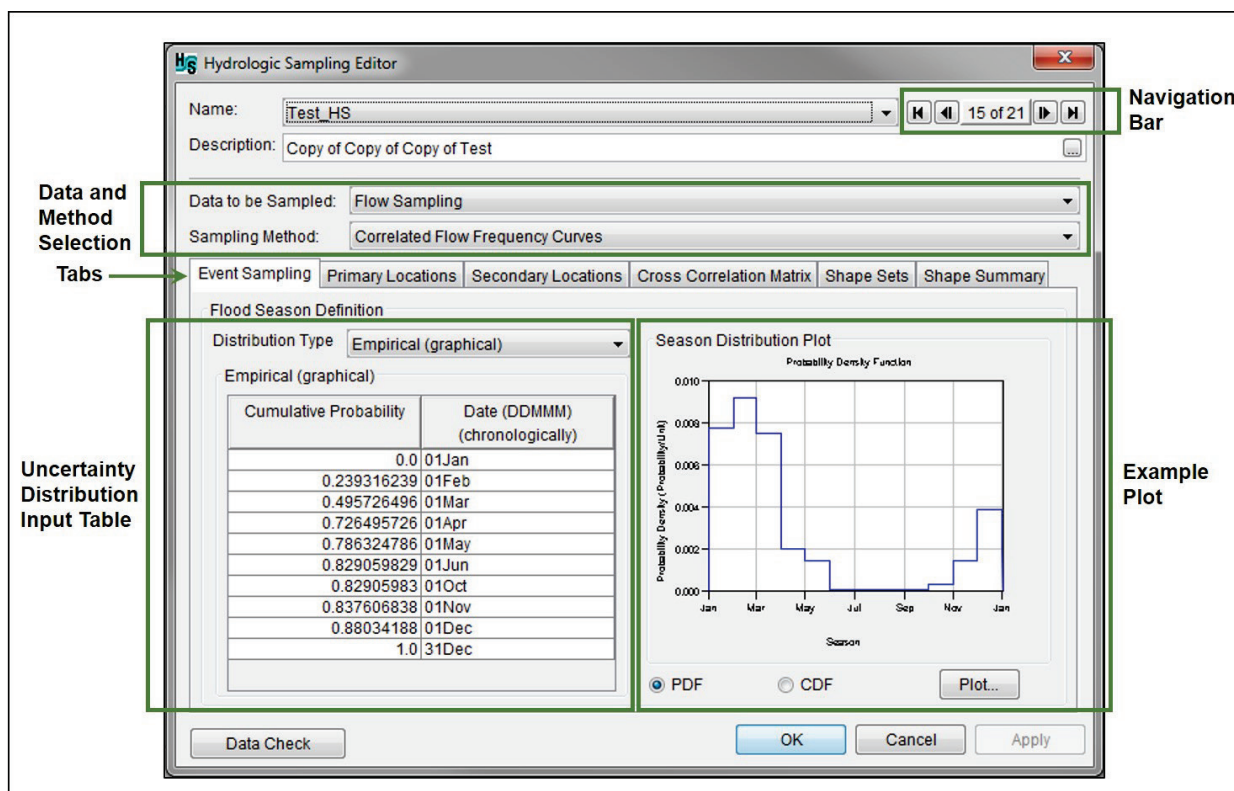






Figure 1-1 Hydrologic Sampling Editor

From left to right the navigator buttons (Figure 1-1) are:

- **First Record**  button – moves directly to the top alternative in the list of alternatives.
- **Last Record**  button – moves directly to the bottom alternative in the list.
- **Previous Record**  button – moves forward through the list one alternative at a time.
- **Next Record**  button – moves backward through the list one alternative at a time.

Note, the text at the center of the navigation button (*15 of 21*), indicates the total number (21) of hydrologic sampling alternatives that have been defined (Figure 1-1), and which hydrologic sampling alternative is currently being accessed (e.g., *15*).

1.2.2 Data and Method Selection

From the data and method selection area (Figure 1-1) of the **Hydrologic Sampling Editor**, the user can select what data is to be sampled (i.e., *Flow Sampling*, *Precipitation Sampling*) from **Data to be Sampled** list (Figure 1-1). In addition, the user can select the sampling method to be used (i.e., *Correlated Flow Frequency Curves*, *Bootstrapping Historical/Synthetic Basin-wide Events*, *Basin Average Frequency Curve*) from the **Sampling Method** list (Figure 1-1). The three sampling methods are described in Table 1-1 and Section 1.1. Further details regarding the sampling methods are provided in Chapters 2 through 4. Depending on the **Data to be Sampled**

selection, the options listed in the **Sampling Method** list change. Selecting the sampling method is the first step towards defining a hydrologic sampling alternative.

1.2.3 Tabs

Tabs of the **Hydrologic Sampling Editor** (Figure 1-1) parse the required user input for the available sampling methods in a logical and methodological order. Specifically, the names and content of the tabs change based on the selected sampling method (Table 1-1). Furthermore, some tabs are disabled until user input in a tab is completed, which helps guide the user in providing key information necessary to complete the selected sampling method.

1.2.4 Tables

The **Hydrologic Sampling Editor** GUI (Figure 1-1) contains several tables for viewing and entering data. Some tables are directly visible in the **Hydrologic Sampling Editor** GUI (Figures 1-2 and 1-3), while other tables display in new dialog boxes when certain commands are selected (e.g., **Define Ordinates and Tabulate**, described in Section 2.3.3). This section provides a broad overview of the tables in the **Hydrologic Sampling Editor** GUI, including options when entering and editing data.

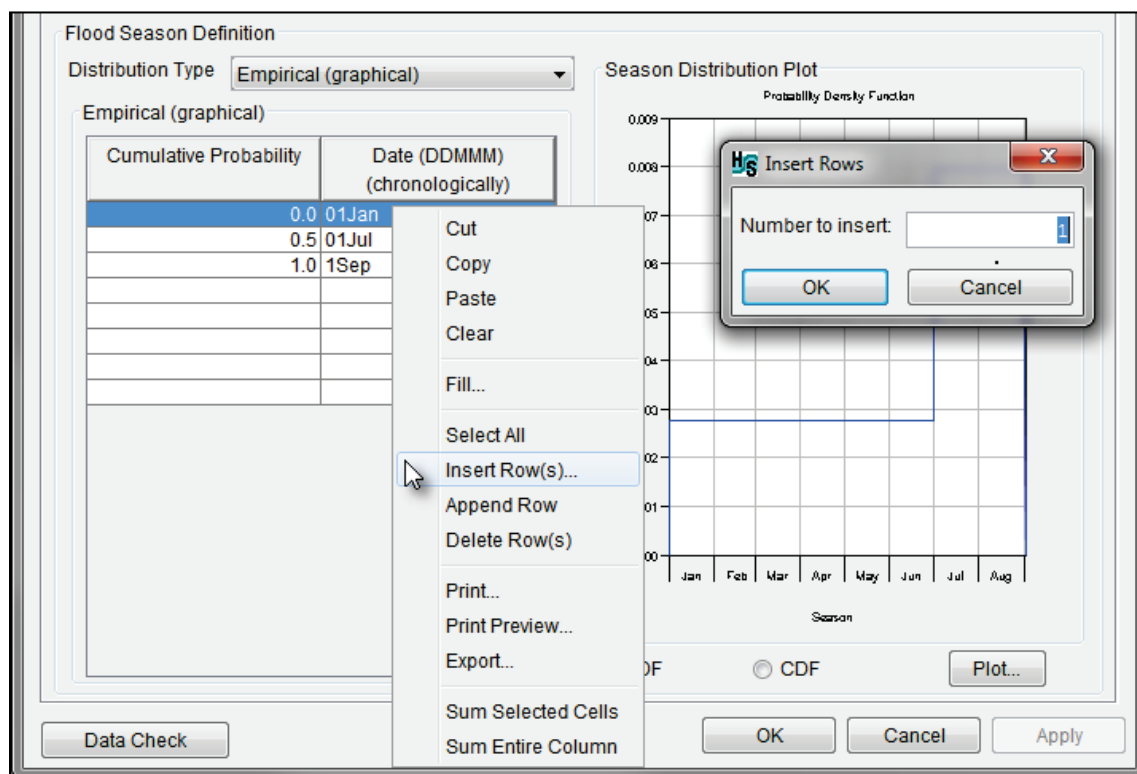


Figure 1-2 Example – Modifiable Table – Shortcut Menu Commands – Example Selection

Depending on the table, items from a shortcut menu (Figure 1-2) may be available. When a table is modifiable, a shortcut menu, in general, contains the items displayed in Figure 1-2. Several of the items open dialog boxes, from which the user will can complete the required information needed for the selected item. For example, the **Insert Row(s)** item opens the **Insert Rows** dialog

box (Figure 1-2). However, available shortcut items for modifiable tables (or sections of tables) will adjust based on the specific table. For example, the shape set summary table (Figure 1-3) does not allow for inserting, appending, or deleting row(s).

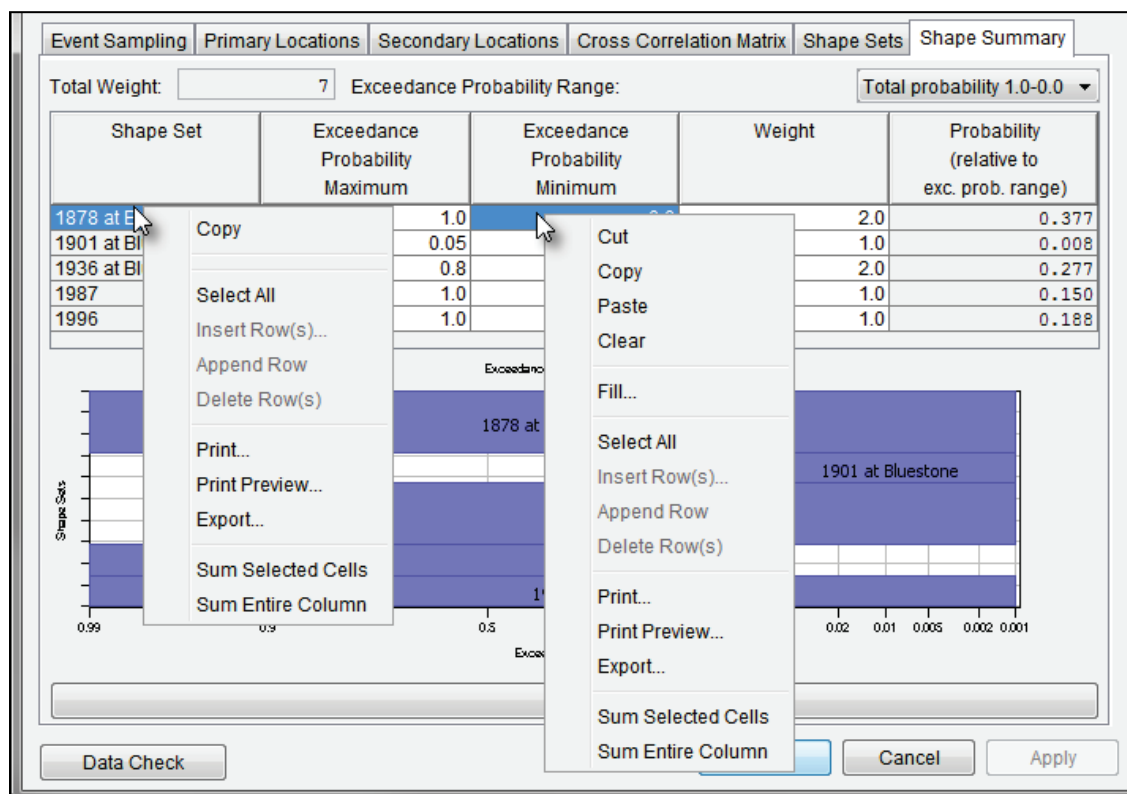


Figure 1-3 Examples – Non-Editable Table (Left Shortcut Menu) – Partially Editable Table (Right Shortcut Menu)

In general, the user enters data manually into a table by selecting a cell (one click) and entering the value in the cell. Use the Return key to move vertically down the table, the Tab key to move horizontally across (left to right), or the Arrow keys, or place with the mouse cursor. Users can copy (**C**opy shortcut command or Ctrl+C) and paste values (**P**aste shortcut command or Ctrl+V) from an outside source (e.g., Microsoft Excel® or a text editor), as long as the copied dataset is tab delimited or a spreadsheet. Several shortcut commands are available for editing tables (refer to Section 1.2.4 for more information).

In the **Hydrologic Sampling Editor**, light-gray shading (Figure 1-3) identifies non-editable tables (or sections of a table). In general, the shortcut commands for non-editable tables contain the commands displayed in Figure 1-3 (e.g., the first and last columns of the shape set summary table shaded in light gray). Unmodifiable tables (or sections of tables) are for informative purposes only, and display values calculated or automatically populated by the hydrologic sampling process.

1.2.5 Plots

The **Hydrologic Sampling Editor** GUI contains several plots for viewing entered data or resulting relationships. All plots contained in the **Hydrologic Sampling Editor** GUI are

viewable in a new dialog box by either (1) double-clicking inside a plot, or (2) click **Plot** (Figure 1-4). This section provides a broad overview of the plots in the **Hydrologic Sampling Editor**, including menu options in the plot dialog boxes. The subsequent chapters provide plot-specific information.

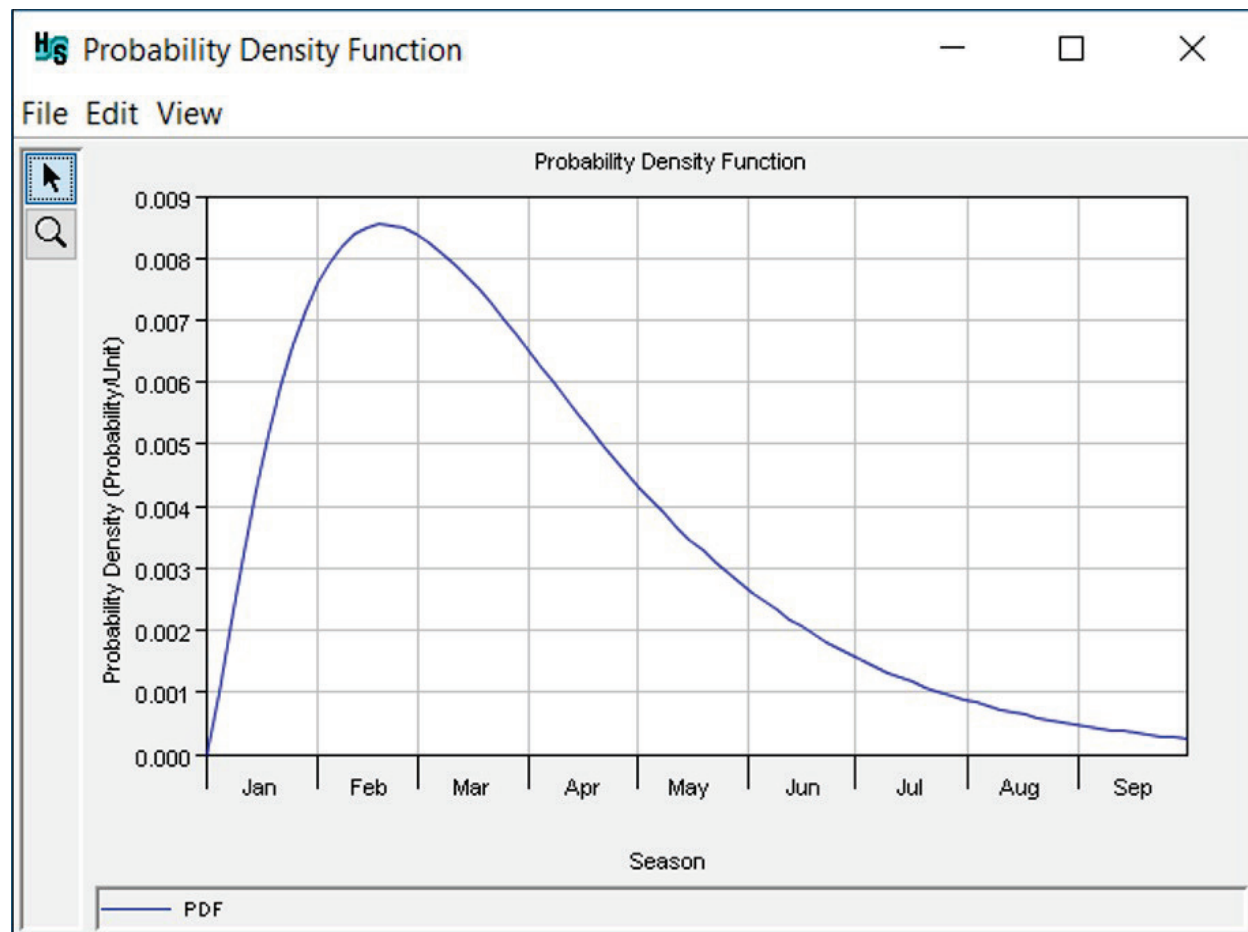


Figure 1-4 Hydrologic Sampling Editor – Plot Dialog Boxes

The plot dialog box includes three menus:

- | | |
|-------------|---|
| File | The File menu allows users to tabulate plotted data, save the plot, and print or close a plot dialog box. Available commands: Tabulate , Save As , Save Template , Apply Template , Save Specification , Print , Page Setup , Print Preview , Print Multiple , and Close . |
| Edit | The Edit menu allows users to modify the properties of a plot, configure the layout of a plot, and modify default settings. Available commands: Plot Properties , Configure Plot Layout , Default Line Styles , and Default Plot Properties . |
| View | The View menu allows users to change the view for a plot, and the legend placement and or presence in a plot. Available commands: Always On Top , Use Line Styles (default), Zoom to all , Legend Placement (Bottom of |

Panel, Right of Panel, Separate Window, Viewport Upper Left, or Viewport Upper Right), and Hide Legend.

1.2.6 Data Check

From the **Hydrologic Sampling Editor** (Figure 1-1), a data check can be performed to search for data consistency errors in the current hydrologic sampling alternative at any time. The data check option should generally be used after all required inputs have been defined to avoid generating a long list of as-yet undefined inputs.

From the **Hydrologic Sampling Editor** (Figure 1-1), click **Data Check**, the data check is performed and if no issues are experienced a message window opens (Figure 1-5) letting the user know that no data consistency errors were found. If user input is missing, incomplete or inconsistent, a **Data Consistency Errors** message window will open (Figure 1-6). The **Data Consistency Errors** window provides a list of all of the identifiable "Data consistency error(s)" for the selected hydrologic sampling alternative.

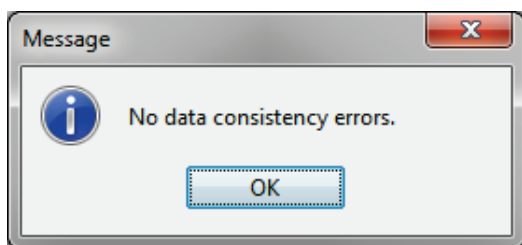


Figure 1-5 Message Window – No Data Consistency Errors

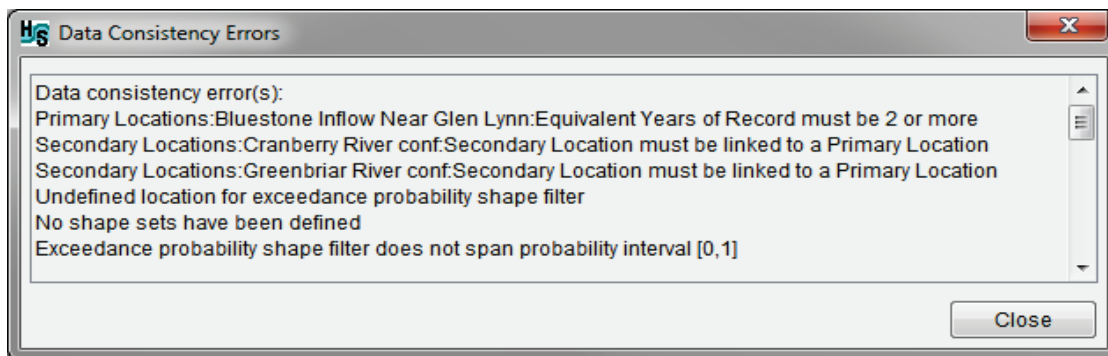


Figure 1-6 Data Check – Data Consistency Errors Message Window

The **Data Consistency Errors** message window (Figure 1-6) displays the name of the **Hydrologic Sampling Editor** tab (e.g., **Primary Locations** and **Shape Sets** tabs) when an issue with the hydrologic sampling data is found. The error report also provides the specific **Location** (e.g., *Bluestone Inflow Near Glen Lynn*), and the user input (e.g., *Equivalent Years of Record*) when data needs to be corrected or added.

1.2.7 Standard Buttons

Three standard buttons (**OK**, **Cancel**, **Apply**) are located at the bottom of the **Hydrologic Sampling Editor** (Figure 1-1). The standard buttons allow users to click **OK** to save edits and

close the editor/dialog box; click **Cancel** to close the editor/dialog box without saving edits; or, click **Apply** to save changes without closing the editor/dialog box.

In general, it is a good practice to click **Apply** to save (to disk) modifications made before switching between tabs or between hydrologic sampling alternatives. However, the **Hydrologic Sampling Editor** automatically retains modifications (in memory) when switching between tabs until **Apply** or **OK** is clicked to save changes to disk. When editing several hydrologic sampling alternatives, click **Apply** to save changes to the current hydrologic sampling alternative before navigating to the next hydrologic sampling alternative. If the user does not save edits when editing several hydrologic sampling alternatives, a **Confirm Changes** window (Figure 1-7) will display, asking the user if they want to save the edits of the hydrologic sampling alternative that was being edited.

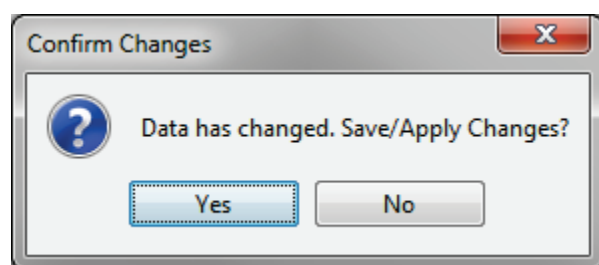



Figure 1-7 Confirm Changes Window

1.3 Create a Hydrologic Sampling Alternative

Prior to creating a hydrologic sampling alternative, users must create an HEC-WAT study. Refer to the HEC-WAT User's Manual for a detailed discussion of the HEC-WAT software, including comprehensive instructions on how to build an HEC-WAT study for an FRA simulation. To create a hydrologic sampling alternative:

1. From the HEC-WAT main window (Figure 1-8), from the **Study Pane** (which provides a view of the study data listed in the **Study Tree**), from the **Models** node, right-click on **Hydrologic Sampling**, click **New**. The **Create New Hydrologic Sampling Alternative** dialog box will open (Figure 1-9).

Alternatively, from the HEC-WAT main window (Figure 1-9), from the **Programs** toolbar, click . Note, this option only opens the **Create New Hydrologic Sampling Alternative** dialog box when no existing hydrologic sampling alternatives are available; otherwise, the **Hydrologic Sampling Editor** will open.

2. Enter a name in the **Name** field (e.g., *Test_HS*). Enter a description (optional, but recommended) in the **Description** field. Click **OK**, the **Create New Hydrologic Sampling Alternative** dialog box closes (Figure 1-9).
3. The **Hydrologic Sampling Editor** will open (Figure 1-10). From the **Data to be Sampled** list select the appropriate data that will be sampled (default – *flow sampling*). From the **Sampling Method** list (Figure 1-10); select the appropriate sampling method to be used for the hydrologic sampling alternative (default – *Correlated Flow Frequency Curves*).

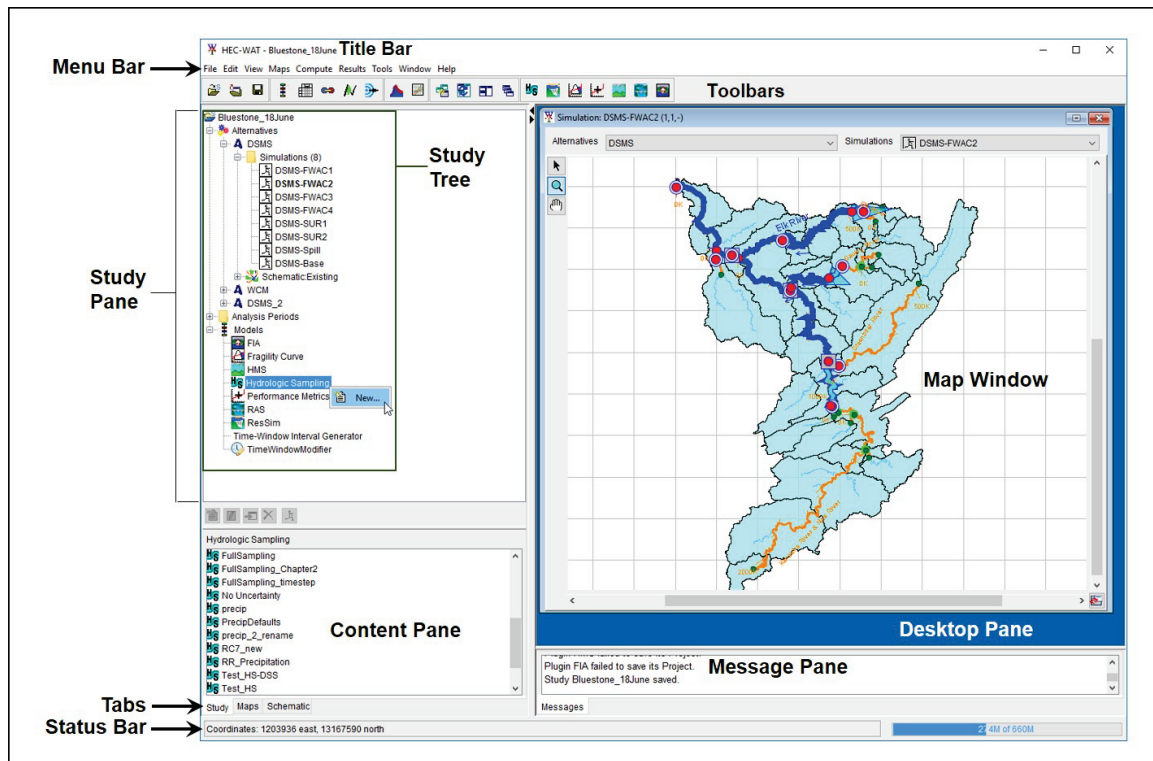


Figure 1-8 HEC-WAT Main Window

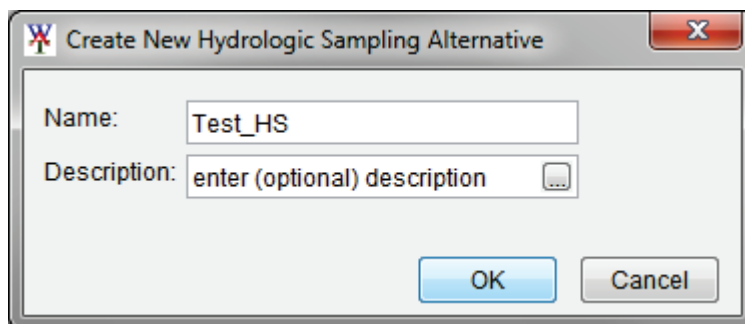


Figure 1-9 Create New Hydrologic Sampling Alternative Dialog Box

- The HEC-WAT study now contains a hydrologic sampling alternative (e.g., *Test_HS*). In the study directory, under the *hs* folder, an **.hs* file (e.g., *Test_HS.hs*) has been created. Section 1.2 provides an overview of the **Hydrologic Sampling Editor** structure, navigation, and various shortcut options. Users can edit, save, copy, rename, and delete existing hydrologic sampling alternatives (refer to Section 1.4 for more information).

1.4 Individual Hydrologic Sampling Alternatives

From the HEC-WAT main window (Figure 1-11), from the **Study Tree**, from the **Models** node (expanded), select **Hydrologic Sampling** (Figure 1-11). In the **Content Pane** (Figure 1-11), a list of the available individual hydrologic sampling alternatives for the study will display. Right-click on a hydrologic sampling alternative (e.g., *Ex_Bootstrap*), a shortcut menu will display (Figure 1-11). From the shortcut menu, users can perform various functions on individual

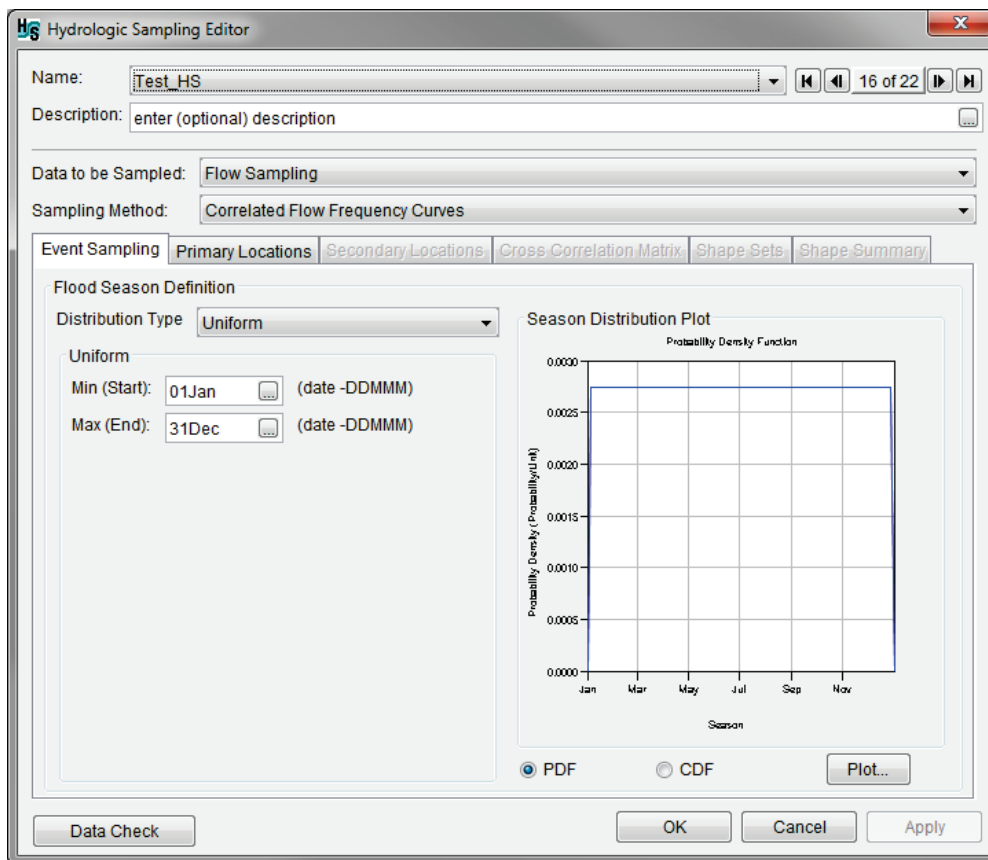


Figure 1-10 Hydrologic Sampling Editor - Default

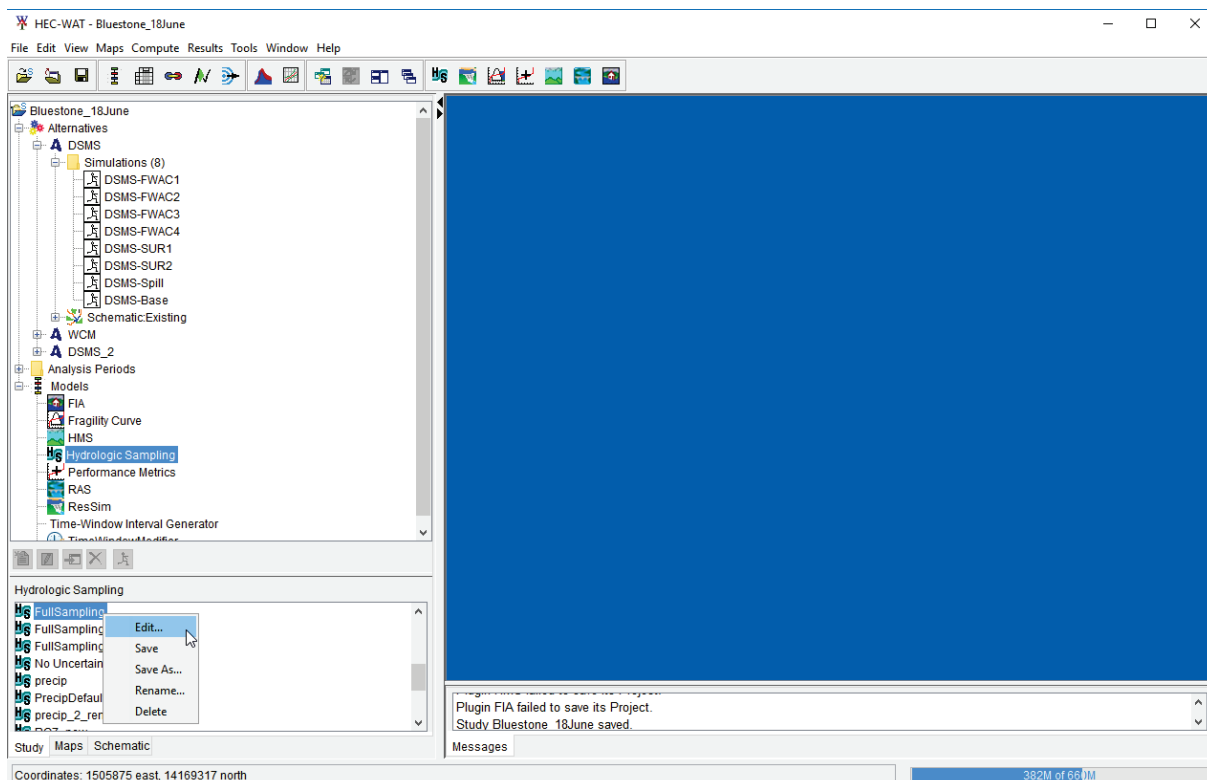



Figure 1-11 HEC-WAT Main Window – Content Pane – Individual Hydrologic Sampling Alternative(s)

hydrologic sampling alternatives. Available options include: edit an existing hydrologic sampling alternative; save a hydrologic sampling alternative; create a copy of an existing hydrologic sampling alternative (**Save As**); rename a hydrologic sampling alternative; and, delete a hydrologic sampling alternative.

1.4.1 Edit a Hydrologic Sampling Alternative

From the HEC-WAT interface, several ways are available to access the **Hydrologic Sampling Editor**. One way is from the HEC-WAT main window (Figure 1-11), from the **Programs** toolbar, click , the **Hydrologic Sampling Editor** will open (Figure 1-10) with the first hydrologic sampling alternative automatically selected. Another way, is from the **Edit** menu (Figure 1-11), point to **Hydrologic Sampling**, click **Open Hydrologic Sampling**, the **Hydrologic Sampling Editor** will open (Figure 1-10) with the first hydrologic sampling alternative automatically selected.

Another way to access the **Hydrologic Sampling Editor** is:

1. From the HEC-WAT main window, from the **Study Tree**, from the **Models** node, select **Hydrologic Sampling** (Figure 1-11). The **Content Pane** will display a list of all available hydrologic sampling alternatives for the study.
2. From the **Content Pane**, right-click on a hydrologic sampling alternative (e.g., *Ex_Bootstrap*), from the shortcut menu, click **Edit** (Figure 1-11). The **Hydrologic Sampling Editor** will open (Figure 1-10) for the selected hydrologic sampling alternative.

Another way to access the **Hydrologic Sampling Editor** is:

1. From the HEC-WAT main window, from the **Study Tree**, from the **Simulations** folder (Figure 1-12), select a simulation of interest (e.g., *DSMS-FWAC1*). The simulation needs to be a flood risk analysis (FRA) simulation.

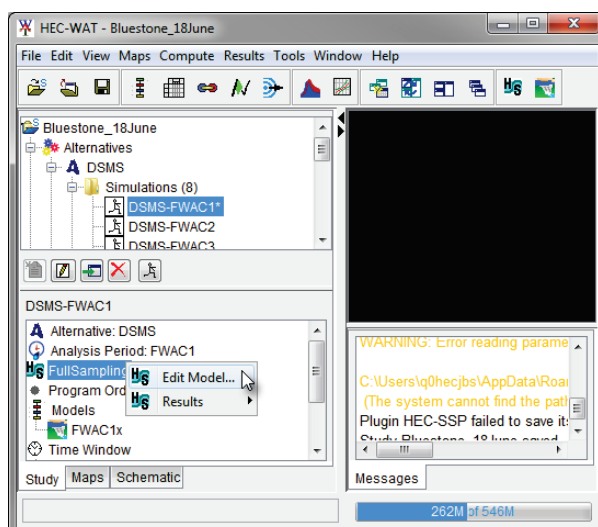


Figure 1-12 HEC-WAT Main Window – Study Tree and Content Pane

2. In the **Content Pane** (Figure 1-12), information about the selected simulation is provided, including the hydrologic sampling alternative that is part of the selected simulation.
3. Right-click the hydrologic sampling alternative of interest (e.g., *FullSampling*), from the shortcut menu (Figure 1-12), click **Edit Model**. The **Hydrologic Sampling Editor** will open (Figure 1-10).

1.4.2 Save a Hydrologic Sampling Alternative

To save a hydrologic sampling alternative, from the **Content Pane**, right-click on a hydrologic sampling alternative (e.g., *Ex_Bootstrap*), from the shortcut menu, click **Save** (Figure 1-11). The **Save** command creates a new backup or updates an existing backup (*.hs.bak) file for the selected hydrologic sampling alternative in the HEC-WAT study directory.

1.4.3 Copy an Existing Hydrologic Sampling Alternative

To create a copy of an existing hydrologic sampling alternative:

1. From the HEC-WAT main window, from the **Study Tree**, from the **Models** node, select **Hydrologic Sampling** (Figure 1-11). The **Content Pane** will display a list of all available hydrologic sampling alternatives for the study.
2. From the **Content Pane**, right-click on a hydrologic sampling alternative of interest (e.g., *Ex_Bootstrap*), from the shortcut menu (Figure 1-11), click **Save As**. The **Save Hydrologic Sampling As** dialog box will open (Figure 1-13). The **Old Name** box will contain the name of the selected hydrologic sampling alternative.

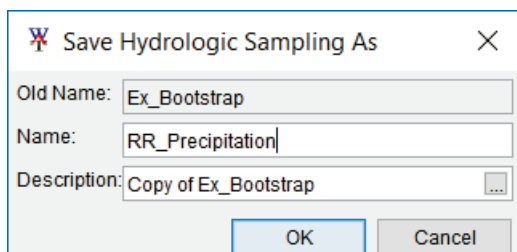


Figure 1-13 Save Hydrologic Sampling As Dialog Box

3. In the **Name** field, enter the name of the new hydrologic sampling alternative (e.g., *RR_Precipitation*).
4. In the **Description** field, a default description has been provided (e.g., *Copy of Ex_Bootstrap*), the user can enter a new description.
5. Click **OK**, the **Save Hydrologic Sampling As** dialog box will close (Figure 1-13), and a new hydrologic sampling alternative will be created based on the selected hydrologic sampling alternative.

1.4.4 Rename an Existing Hydrologic Sampling Alternative

Rename an existing hydrologic sampling alternative:

1. From the HEC-WAT main window, from the **Study Tree**, from the **Models** node, select **Hydrologic Sampling** (Figure 1-11). The **Content Pane** will display a list of all available hydrologic sampling alternatives for the study.
2. From the **Content Pane**, right-click on a hydrologic sampling alternative of interest (e.g., *Ex_Bootstrap*), from the shortcut menu (Figure 1-11), click **Rename**. The **Rename Hydrologic Sampling** dialog box will open (Figure 1-14).

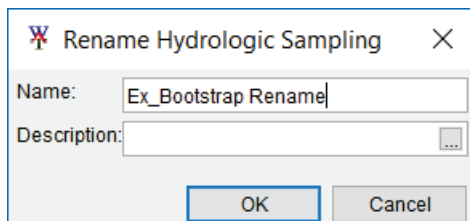


Figure 1-14 Rename Hydrologic Sampling Dialog Box

3. By default, in the **Name** field, the selected hydrologic sampling alternative name will display. The user will enter a new name (Figure 1-14) for the existing hydrologic sampling alternative (e.g., *Ex_Bootstrap Rename*).
4. Enter a description (optional, but recommended) in the **Description** field. Click **OK**, the **Rename Hydrologic Sampling** dialog box will close (Figure 1-14), and the selected hydrologic sampling alternative will now display a new name.

1.4.5 Delete an Existing Hydrologic Sampling Alternative

To delete an existing hydrologic sampling alternative:

1. From the HEC-WAT main window, from the **Study Tree**, from the **Models** node, select **Hydrologic Sampling** (Figure 1-11). The **Content Pane** will display a list of all available hydrologic sampling alternatives for the study.
2. From the **Content Pane**, right-click on a hydrologic sampling alternative of interest (e.g., *Ex_Bootstrap*), from the shortcut menu (Figure 1-11), click **Delete**. A Confirm Delete window will open (Figure 1-15).

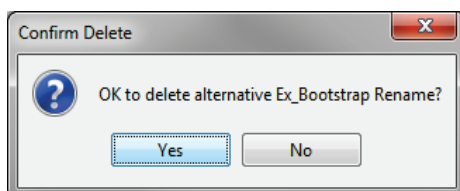


Figure 1-15 Confirm Delete Message Window

- Click **Yes**, the Confirm Delete message window will close (Figure 1-15), and the selected hydrologic sampling alternative will be deleted.

1.5 Select DSS Time Series

In order for a hydrologic sampling alternative to work in an HEC-WAT study, DSS time series dataset(s) of either flow hydrographs or precipitation hyetographs must be defined in the **Hydrologic Sampling Editor** (Figure 1-10). Figure 1-16 provides an example view of the standard DSS time series panel in the **Hydrologic Sampling Editor**.

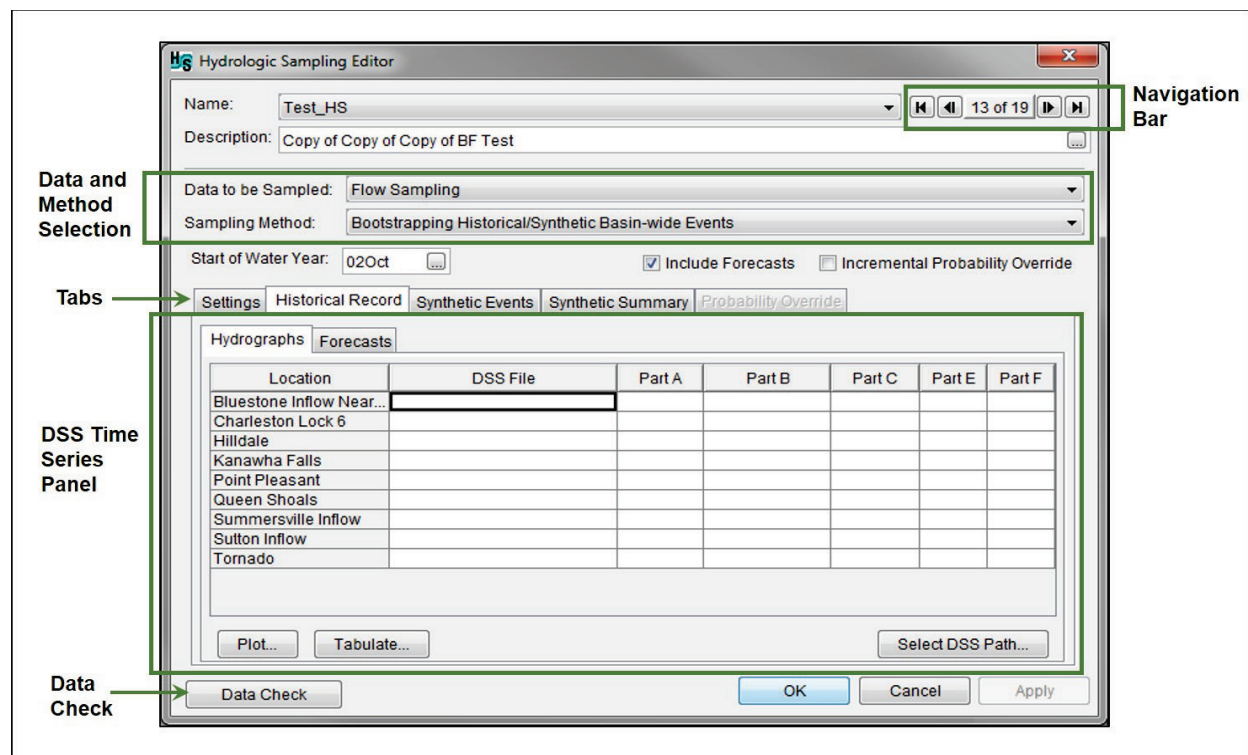


Figure 1-16 Hydrologic Sampling Editor – Define DSS Time Series Panel

The DSS time series panel allows the user to define DSS time series of data, and depending on the data and method selected (refer to Section 1.2.2) the following user inputs require DSS time series records:

- Shape Sets: hydrograph or hyetograph (see Section 2.6.3 or 4.5.3, respectively),
- Hydrographs: historic and/or synthetic (see Section 3.3.1 and/or 3.4.2, respectively), and
- Forecasts: historic and/or synthetic (see Section 3.3.2 and/or 3.4.6, respectively).

The standard DSS time series panel consists of a DSS input table that contains seven columns: **Location**, **DSS File**, and **Part A** through **Part F** (Figure 1-16). The **Hydrologic Sampling Editor** will automatically populate the information displayed in the **Location** column (Figure 1-16) based on previously entered user inputs. The users must complete the remaining columns in the DSS input table. Incomplete DSS input tables can result in data consistency error(s) (refer

to Section 1.2.6). Instructions for completing the DSS input table is provided in the method specific chapters (Table 1-1).

Note, **Plot** and **Tabulate** (Figure 1-16) can be used to view (plot, tabular) assigned DSS time series for a selected **Location**. The **Select DSS Path** button is used to assign a DSS time series record to a selected location.

1.6 Organization of Manual

The organization of this manual is displayed in Table 1-2. A brief description of the hydrologic sampling methods is provided at the beginning of this chapter, while each method is described in detail in the following chapters.

Table 1-2 Summary of Contents of the Hydrologic Sampling User's Manual

If the user wants to find out...	Refer to...
Overview of the Hydrologic Sampling methods	Section 1.1
Overview of the Hydrologic Sampling Editor	Section 1.2
Overview of the creating a hydrologic sampling alternative	Section 1.3
Managing individual hydrologic sampling alternatives	Section 1.4
How to setup a Correlated Flow Frequency Curves alternative	Chapter 2
How to setup a Bootstrapping Historical/Synthetic Basin-wide Events flow sampling alternative	Chapter 3
How to include forecasts in a Bootstrapping Historical/Synthetic Basin-wide Events flow sampling alternative	Section 3.1.1
How to include incremental probability overrides in a Bootstrapping Historical/Synthetic Basin-wide Events flow sampling alternative	Section 3.1.2
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CHAPTER 2

Correlated Flow Frequency Curves

This chapter describes how to set up a hydrologic sampling alternative using the **Correlated Flow Frequency Curves** sampling method for flow data. This sampling method generates hydrographs for all necessary inflow locations within the modeled watershed for each sampled flood event, based on user-defined flow-frequency curves, hydrograph shape sets and a distribution of flood event dates. The Correlated Flow Frequency Curves event generation method is described in the following paragraphs, and the user input steps are described starting in Section 2.1.

The Correlated Flow Frequency Curves sampling method is similar to the Basin Average Frequency Curve (basin average precipitation frequency curve) sampling method (refer to Chapter 4), as event magnitudes are randomly sampled from frequency curves, and event time series are scaled to those values from user-provided shape sets. To use the Correlated Flow Frequency Curves sampling method, an annual maximum flow frequency curve and its uncertainty must be specified for every significant inflow location in the watershed (primary location). Less significant inflow locations can be defined as secondary locations, and are based on a ratio of the flow at a selected primary location. Flow frequency curves used for this method are often the result of a statistical analysis for a record of gaged stream flows, or, can be the result of a series of frequency-based precipitation events simulated in a rainfall/runoff model. In an actual flood event, the flows at the various locations have some similarity in relative magnitude or return period. This similarity can be captured within the flood event generation by specifying a cross-correlation between the locations. Correlated random sampling maintains this similarity in relative magnitude (or return period) of flows between locations across a watershed.

All locations in the watershed that require an inflow hydrograph must be specified as either a primary or a secondary location. A peak flow magnitude is sampled at each primary location from its uncertainty-adjusted flow frequency curve, based on a generated pseudo random number. Each secondary location is tied to a specified primary location, receiving a flow magnitude based on a simple ratio of the flow at that primary location. Therefore, flows at a secondary location have perfect correlation with its corresponding primary location, while primary locations maintain user-defined correlations with each other due to correlated random sampling. The uncertainty in the flow frequency curves is incorporated by parametrically bootstrapping each flow frequency curve once per realization, sampling N flow magnitudes from the curve (where N is equal to the specified equivalent record length) and then re-fitting a new frequency curve to that sample. All event flows for that realization are sampled from these uncertainty-adjusted flow frequency curves, rather than the original user-specified flow frequency curves.

To create a hydrograph for each primary and secondary location, the flow magnitudes randomly sampled from frequency curves are used to scale user-defined sets of hydrograph shapes. A set of hydrograph shapes for all inflow locations is called a shape set, and the user may define

multiple shape sets in one hydrologic sampling alternative. Each shape set captures the temporal distribution of a flood event, including the event duration, arrival of event volume across that duration, and the relative timing of the event between one watershed location and another. The shape sets are typically based on historical flood events and are each suitable for a specific range of event magnitudes, ranging from small to large events. The exceedance probability range specified for each shape set defines a range of relative magnitudes, which will be used for a given shape set. In generating a flood event, the shape set is randomly selected, and the hydrograph for each location is scaled to its randomly sampled event flow magnitude. Each hydrograph is scaled by a single factor, and that factor is computed such that the average flow over the frequency curve's specified duration matches the sampled flow magnitude. The entire hydrograph is scaled with that computed factor.

The last step within the Correlated Flow Frequency Curves event generation algorithm is to sample a date for the flood event from a flood season defined by the user. The flood season is a probability distribution of event month and day, estimated from the dates of significant events in the watershed in the historical record, sometimes including those that are not the annual maximum. In the absence of a gage record, familiarity with local hydrology can suggest a flood season probability distribution. Once the date for a flood event is randomly sampled, the peak of the final scaled hydrograph is placed on that date. The hydrograph peaks in a shape set are likely on different dates at different locations, the primary location with most extreme relative magnitude (the smallest sampled exceedance probability) is used to place the event.

With the Correlated Flow Frequency Curves sampling method selected (Figure 2-1), the **Hydrologic Sampling Editor** contains the following six method-specific tabs:

Event Sampling	This tab allows the user to define the Flood Season from which event dates are sampled. Users define the flood season with a probability distribution, choosing one of five available distribution types and entering the corresponding user inputs and seasonal bounds.
Primary Locations	This tab allows the user to Select Primary Locations and define a maximum flow frequency curve for each location, including its duration and uncertainty. The user specifies the Duration , Duration Output (optional), and Maximum Flow Frequency Curve , choosing a distribution type and specifying its corresponding user inputs. The user also defines the frequency curve Uncertainty .
Secondary Locations	The Secondary Locations tab allows the user to select the Secondary Locations , link each secondary location to a Primary Location , and define a value for the Ratio with Maximum at Primary Flow Location .
Cross Correlation Matrix	The Cross Correlation Matrix tab requires the user to specify a matrix of cross correlation values between all Primary Locations identified in the Primary Locations tab.

Shape Sets

In the **Shape Sets** tab, the user defines one or more hydrograph shape sets. A hydrograph shape set is a group of hydrographs representing all inflow locations that, when selected, are separately scaled to the randomly sampled flow magnitudes. Each shape set has a user-specified **Exceedance Probability Filter** (minimum and maximum) that defines the probability range to which each shape set applies; a **Weight**, which defines the relative likelihood of the shape set; and the **DSS Pathnames** where hydrographs for all **Primary** and **Secondary Flow Locations** are provided. Users must also set the **Location for Exceedance Probability Filter** to specify the **Primary Location**, which is used to filter the shape sets available to generate any given event.

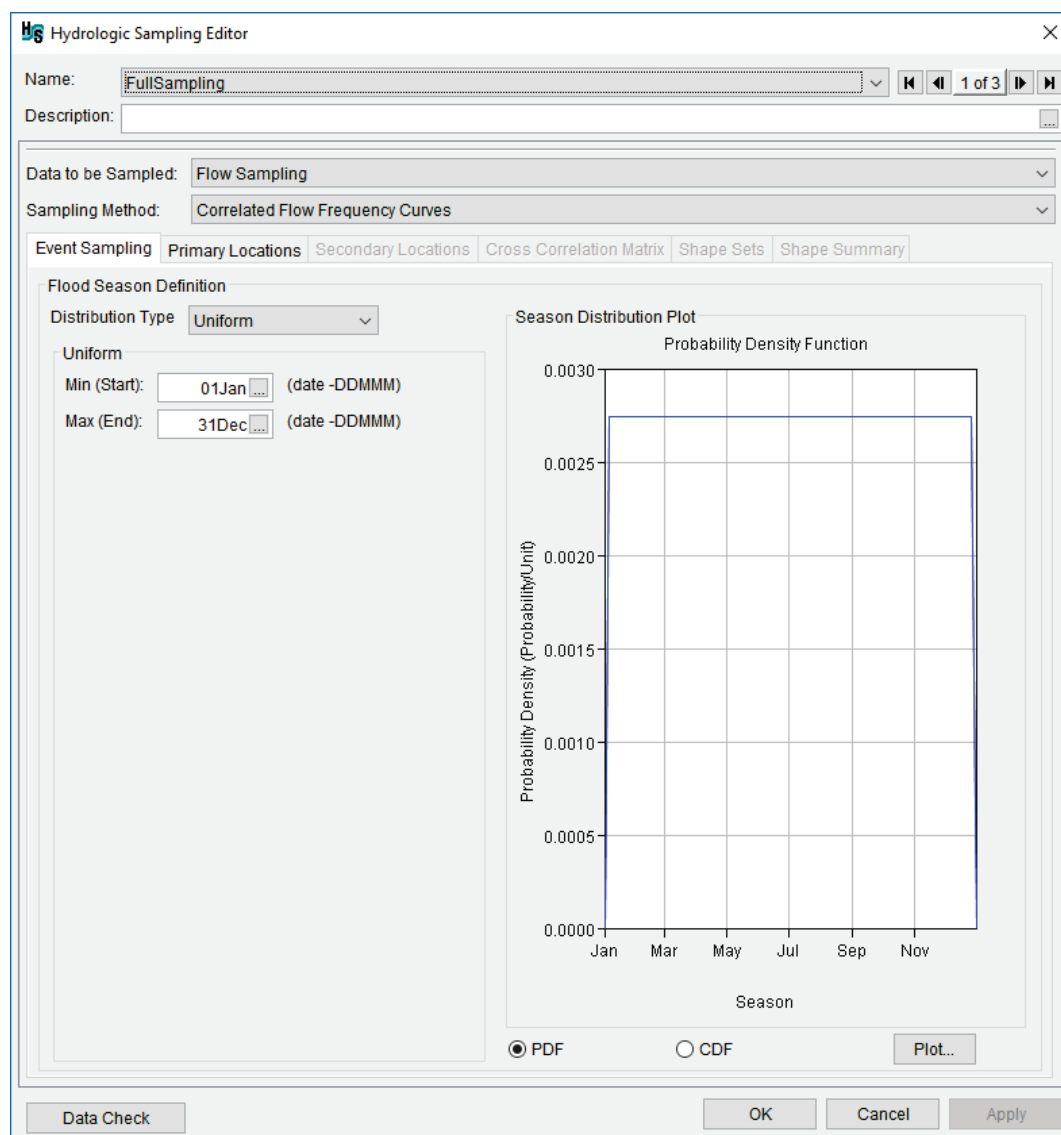


Figure 2-1 Hydrologic Sampling Editor – Correlated Flow Frequency Curves

Shape Summary

The **Shape Summary** tab displays all defined shape sets together in a summary table and plot. The summary table also allows the user to

modify the **Exceedance Probability Maximum**, **Exceedance Probability Minimum**, and **Weight** for the shape sets created in the **Shape Sets** tab.

2.1 Sampled Data Type and Sampling Method Selection

First, either create a new hydrologic sampling alternative (refer to Section 1.3), or edit an existing hydrologic sampling alternative (refer to Section 1.4.1). From the **Hydrologic Sampling Editor**, from the **Data to be Sampled** list, select **Flow Sampling** (Figure 2-1). From the **Sampling Method** list, select **Correlated Flow Frequency Curves** (Figure 2-1).

2.2 Event Sampling Tab

From the **Event Sampling** tab (Figure 2-1), a user can identify the flood season. The flood season defines when flood events might occur within a year. The flood season is described by a probability distribution of the peak flood dates using one of five distribution types (**Uniform** (default), **Triangular**, **Normal**, **Gamma** and **Empirical**).

The flood season can be as simple as a Uniform distribution between a minimum and a maximum date, allowing any date in the range with equal likelihood. The flood season can be a more complex distribution with some dates more likely than other dates. When an analytical distribution is chosen (Uniform, Triangular, Normal or Gamma), the user inputs of that distribution must be entered.

The default values for minimum (start) and maximum (end) dates are 1 January (01Jan) and 31 December (31Dec), respectively, though the user may enter their own values to define the flood season bounds. For Normal and Gamma distributions, which do not have explicit upper and lower bounds, user-specified start and end dates may truncate the tails of the distribution. **Note:** When the defined flood season distribution spans 1 January, minimum and maximum dates must be re-defined from the defaults. Another distribution option is to create a user-defined non-parametric empirical (graphical) distribution, which requires a table of cumulative probability versus date entered by the user.

The flood season distribution is used by the hydrologic sampling algorithm in the final step when creating a flood event. A randomly sampled date from the flood season distribution is used as the month and day of the flood event peak flow, as defined by the sampled shape set (refer to Section 2.6). Because different locations within a watershed shape set might have different relative peak dates within a time-window, the location with the extreme relative magnitude (smallest sampled exceedance probability) is the location for which the peak is matched to the sampled date.


Once the user is done with edits on the **Event Sampling** tab, click **Apply**. This will save the edits and the **Hydrologic Sampling Editor** (Figure 2-1) remains open so the user can proceed with the definition of a hydrologic sampling alternative. Alternatively, the user can click **OK**, which saves the hydrologic sampling alternative and closes the **Hydrologic Sampling Editor** (Figure 2-1).

2.2.1 Flood Season Definition

The **Flood Season Definition** box of the **Hydrologic Sampling Editor** (Figure 2-1) allows the user to select a probability distribution type from five options (**Uniform** (default), **Triangular**, **Normal**, **Gamma** and **Empirical**), specify the distribution's corresponding user inputs, as well as set the season start, and end dates. The **Start** and **End** dates are user inputs, which function differently for the various distribution types. For the first two distributions, **Uniform** and **Triangular**, the start and end dates are explicit distribution inputs. However, for the next two distributions, **Normal** and **Gamma**, the start and end dates can be used to truncate the season distribution.

Default start and end dates are *01Jan* and *31Dec*, and these dates must be re-defined if the flood season spans 1 January (e.g., when using a standard water year, from 1 October to 30 September). As the last step in the event generation algorithm, the hydrologic sampling algorithm randomly samples this user-defined flood season distribution to set the date (as day and month) of each flood event. The user must select the most representative distribution and define its corresponding user inputs accordingly.

Uniform Distribution

Uniform distribution is the default uncertainty distribution for the Correlated Flow Frequency Curves sampling method. The Uniform distribution includes two inputs - **Min (Start)** and **Max (End)** (Figure 2-2). Defaults are 01Jan (**Min**) and 31Dec (**Max**). The user can edit these values manually (DDMMM), or by clicking . The **Select Date** dialog box will open (Figure 2-3) that will allow the user to select a day and month. When the defined flood season distribution spans 1 January, minimum and maximum dates must be redefined. Changes made to the inputs immediately updates the **Season Distribution Plot** box of the **Hydrologic Sampling Editor** (Figure 2-2).

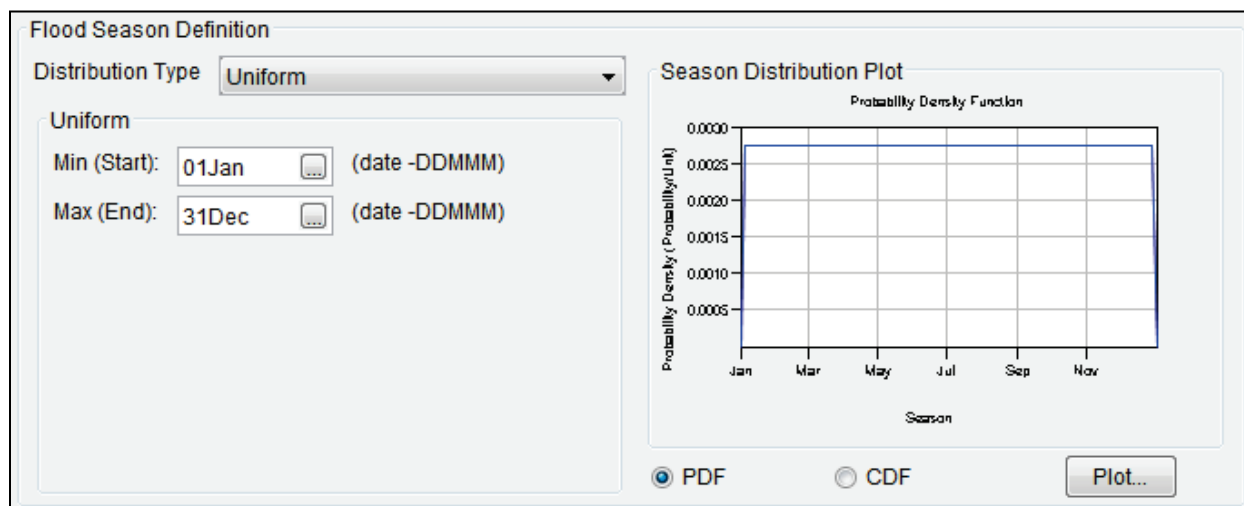


Figure 2-2 Correlated Flow Frequency – Flood Season Definition – Uniform Distribution

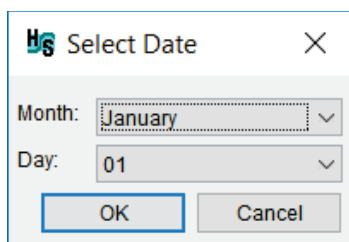


Figure 2-3 Select Date Dialog Box

Triangular Distribution

The Triangular distribution includes three inputs – **Min (Start)**, **Mode**, and **Max (End)** dates (Figure 2-4). Defaults are 01Jan (**Min**), 01Jul (**Mode**), and 31Dec (**Max**). The user can edit these values manually (DDMMM), or by clicking . The **Select Date** dialog box will open (Figure 2-3) that will allow the user to select a day and month. When the defined flood season distribution spans 1 January, minimum and maximum dates must be redefined from the defaults. Changes made to the inputs immediately updates the **Season Distribution Plot** box of the **Hydrologic Sampling Editor** (Figure 2-4).

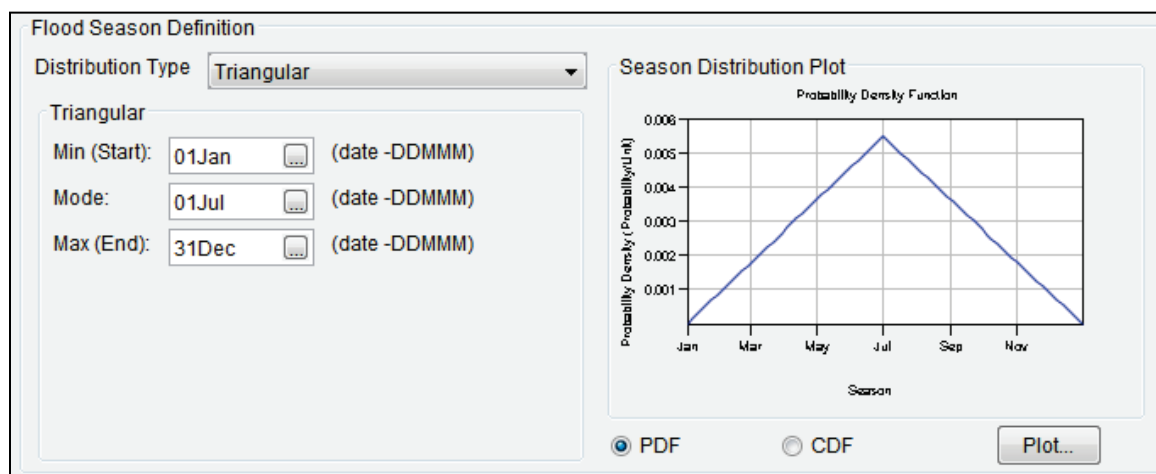


Figure 2-4 Correlated Flow Frequency – Flood Season Definition – Triangular Distribution

Normal Distribution

The Normal distribution includes four inputs – **Mean**, standard deviation (**Std Dev.**), **Min (Start)**, and **Max (End)** (Figure 2-5). Defaults are 01 Jul (**Mean**), 20 (**Std Dev.**), 01Jan (**Min**), and 31Dec (**Max**). The user can edit the **Mean**, **Min**, and **Max** values manually (DDMMM); or by clicking . The **Select Date** dialog box will open (Figure 2-3) that will allow the user to select a day and month. **Std Dev.** is entered in days. Changes made to the inputs immediately updates the **Season Distribution Plot** box of the **Hydrologic Sampling Editor** (Figure 2-5).

The Normal distribution does not have explicit upper and lower bounds; therefore, the user-specified start and end dates can optionally be used to truncate the tails of the distribution resulting from the user-defined mean and standard deviation. However, the start and end dates must be redefined when the season spans 1 January; an example is provided in Figure 2-6.

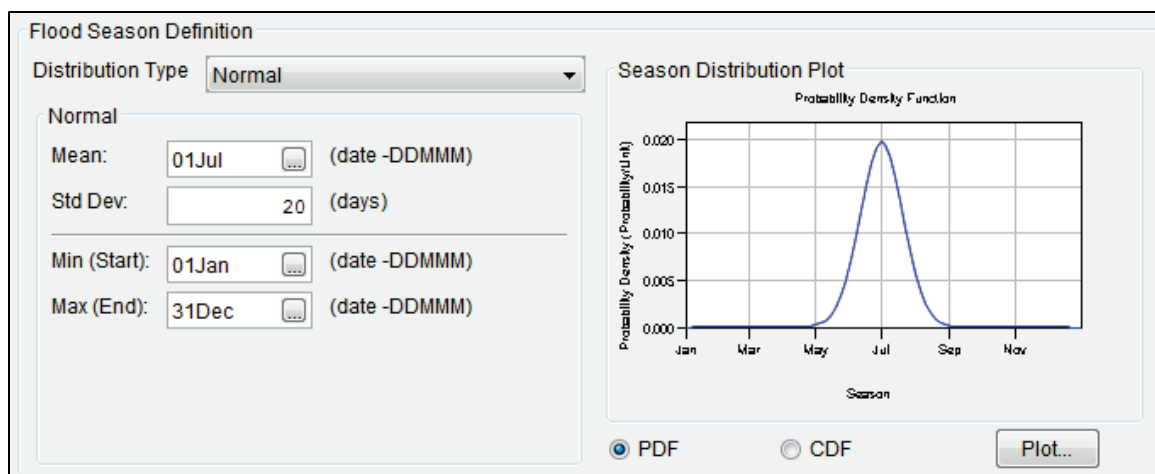


Figure 2-5 Correlated Flow Frequency – Flood Season Definition – Normal Distribution

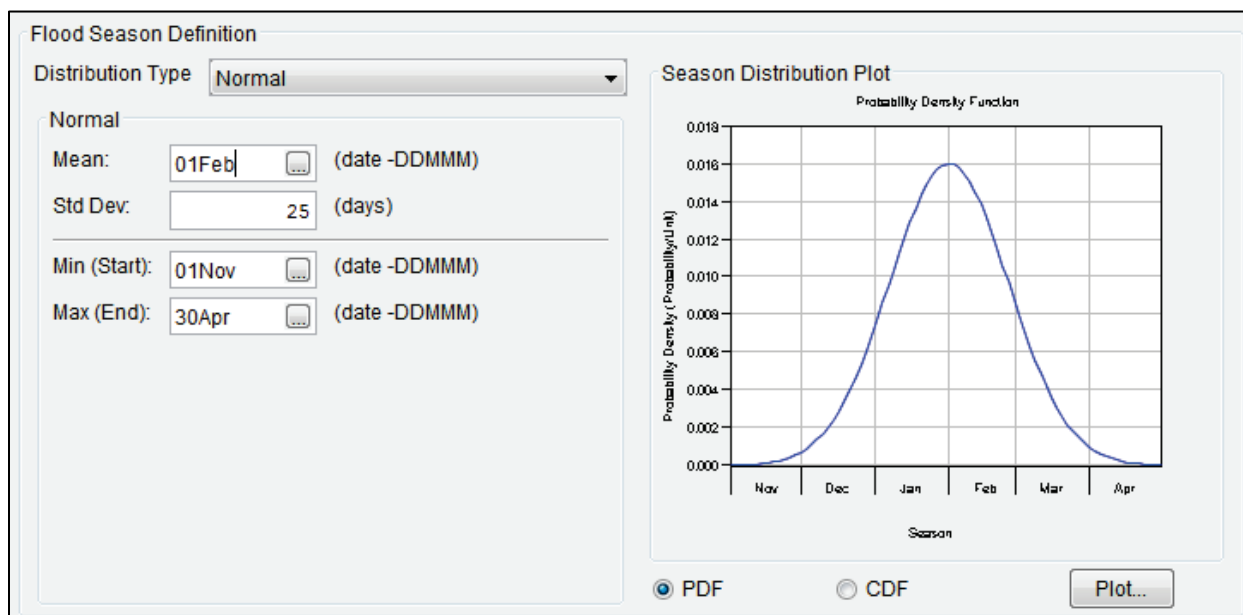


Figure 2-6 Example Normal Distribution

Gamma Distribution

The Gamma distribution includes five inputs – **Shape**, **Scale**, **Shift**, **Min (Start)**, and **Max (End)** (Figure 2-7). Defaults are 2 (Shape), 20 (Scale), 0 (Shift), 01Jan (**Min**), and 31Dec (**Max**). The user can edit the **Mean** and **Max** values manually (DDMMM); or by clicking . A calendar window will open (Figure 2-3) that will allow the user to select a day and month. **Shape**, **Scale**, and **Shift** are entered in days. Changes made to the inputs immediately updates the **Season Distribution Plot** box of the **Hydrologic Sampling Editor** (Figure 2-7).

The Gamma distribution type does not have explicit upper and lower bounds; therefore, the user-specified start and end dates can optionally be used to truncate the season distribution resulting from the user inputs. However, the start and end dates must be redefined when the flood season spans 1 January.

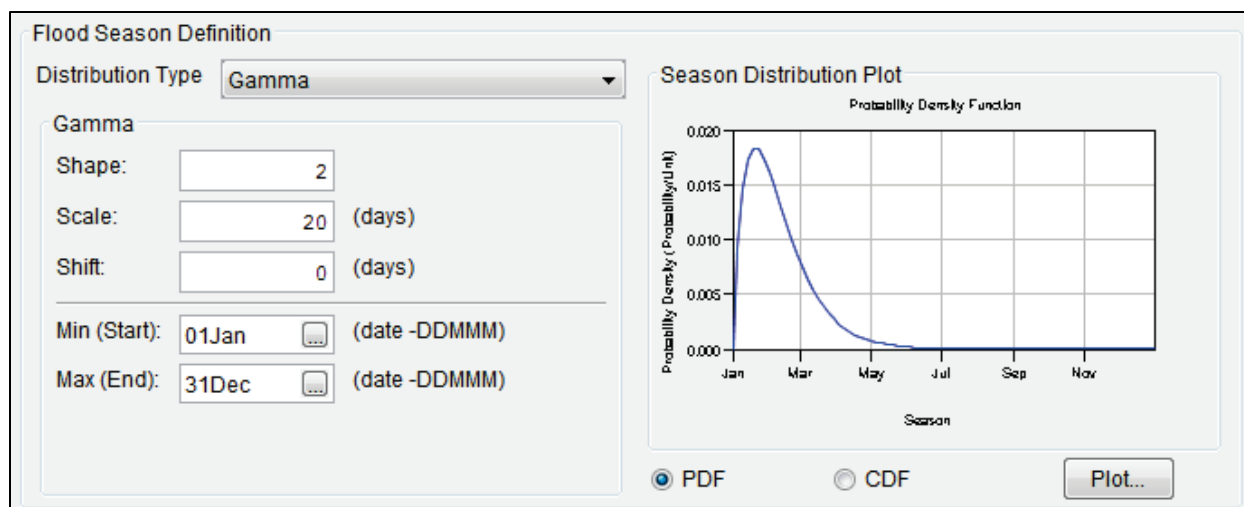



Figure 2-7 Correlated Flow Frequency – Flood Season Definition – Gamma Distribution

Empirical (graphical) Distribution

For an Empirical, distribution a default Cumulative Probability function is provided (Figure 2-8). If necessary, the user can edit the Cumulative Probability function, the **Cumulative Probability** column (Figure 2-8) values must span from 0.0 to 1.0. The **Date** column values should be entered in the DDMM format, or by clicking . The **Select Date** dialog box will open (Figure 2-3) that will allow the user to select a day and month. Changes made to the user inputs immediately update the **Season Distribution Plot** (Figure 2-8).

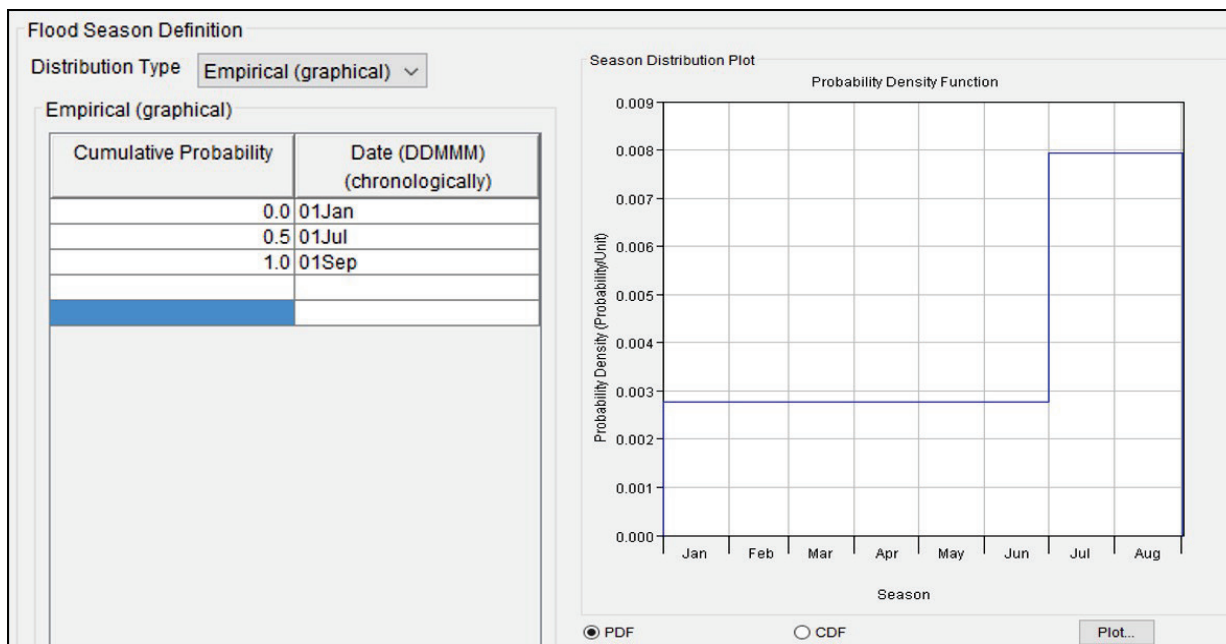


Figure 2-8 Correlated Flow Frequency – Flood Season Definition – Empirical Distribution

The **Cumulative Probability** function can be copied from an outside source (e.g., Microsoft® Excel or a text editor) and pasted into the table (Figure 2-8). Right-clicking on the table to

display a shortcut menu with various commands for editing tables (refer to Section 1.2.4 for further details).

2.2.2 Season Distribution Plot

A **Season Distribution Plot** (Figure 2-9) displays the defined season distribution. The plot has two viewing options: **PDF** (probability density function) or **CDF** (cumulative distribution function). Toggling between **PDF** and **CDF**, changes the plot in the **Season Distribution Plot** box (Figure 2-9). In addition, to view the season distribution plot in a new window, the user can click **Plot**, or double-click on the plot displayed in the **Season Distribution Plot** box, to open the plot in a new window. Figure 2-9 displays an example of a PDF (Figure 2-9a) and a CDF (Figure 2-9b) plots, respectively.

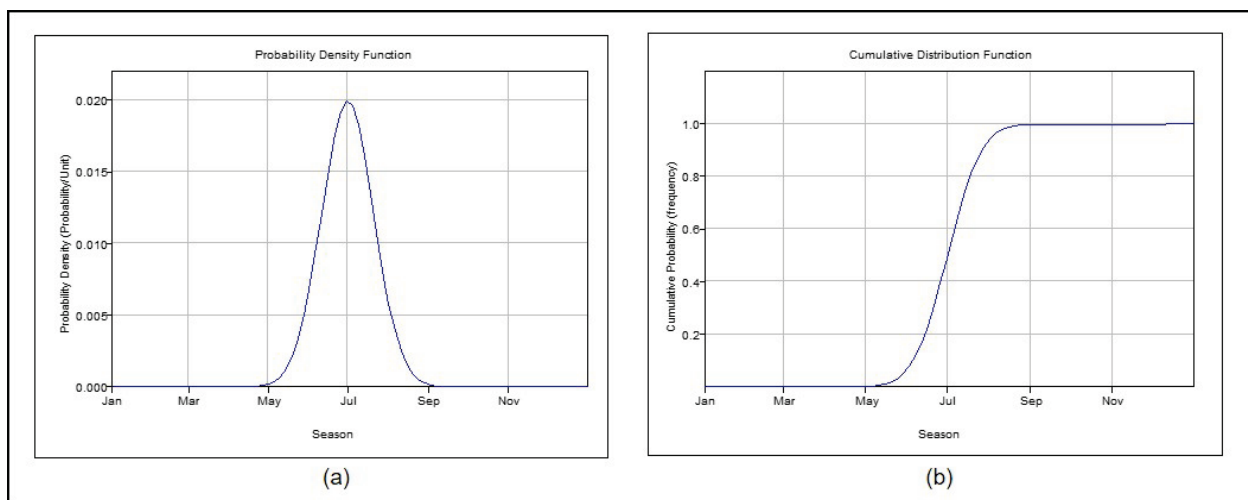


Figure 2-9 Example Season Distribution Plots – Probability Density Function (PDF) and Cumulative Distribution Function (CDF)

2.3 Primary Locations Tab

The **Primary Locations** tab (Figure 2-10) allows the user to select the primary inflow locations and define an annual **Maximum Flow Frequency Curve**, with **Duration** and **Uncertainty**, for each selected location. The list of available primary locations are derived from the common computation points (CCPs) defined in the watershed (for further details on CCPS, refer to the HEC-WAT User's Manual). The hydrologic sampling algorithm in HEC-WAT uses correlated random sampling to generate a random flow magnitude from an uncertainty-adjusted probability distribution (maximum flow frequency curve) for each defined primary location for each event.

The structure of the **Primary Locations** tab consists of three panels that change with **Location**, **Duration**, **Maximum Flow Frequency Curve**, and **Uncertainty**. As described in the following subsection, users create a list of primary locations and then enter information specific to each primary location.

Important: Each primary location has a separately defined **Duration**, **Maximum Flow Frequency Curve**, and **Uncertainty** that the user must specify. Modifying the default **Duration**

Output is optional. **Data Check** (Section 1.2.6) notifies the user if primary locations are incomplete (missing any required user inputs). When input data for a primary location has not been completed, and data check has been run (clicked **Data Check**), a **Message** window will display listing issues for a primary location.

2.3.1 Creating Primary Locations

The first step is to select the primary inflow locations:

1. From the **Primary Locations** tab (Figure 2-10), click **Select Primary Locations**, the **Selection Editor** will open (Figure 2-11). From the **Selection Editor**, users will identify

Hydrologic Sampling Editor

Name: FullSampling

Description:

Data to be Sampled: Flow Sampling

Sampling Method: Correlated Flow Frequency Curves

Event Sampling | **Primary Locations** | Secondary Locations | Cross Correlation Matrix | Shape Sets | Shape Summary

Locations with defined probability distribution (frequency curve) and sampled random number

Location: Select Primary Locations

Duration

Duration of maximum average flow: Inst. Peak

Duration Output...

Maximum Flow Frequency Curve

Distribution Type: Log Pearson type III

Log Pearson type III

Mean (of log):

St. dev (of log):

Skew (of log):

☐ Clip Min Value:

Prob < Min:

☐ Clip Max Value:

Prob > Max:

Maximum Flow Frequency Curve

Return Period

Flow (cfs)

Exceedance Probability

Define Ordinates and Tabulate...

Plot...

Uncertainty

☐ No Uncertainty.

☒ Equiv. years of record: Randomize Skew

☐ User Defined Uncertainty:

Exceedance Probability	Standard Deviation (of log)

Data Check OK Cancel Apply

Figure 2-10 Hydrologic Sampling Editor - Correlated Flow Frequency – Primary Locations Tab

primary locations from the list of common computation points defined for the study watershed (e.g., *Bluestone Inflow Near Glen Lynn*).

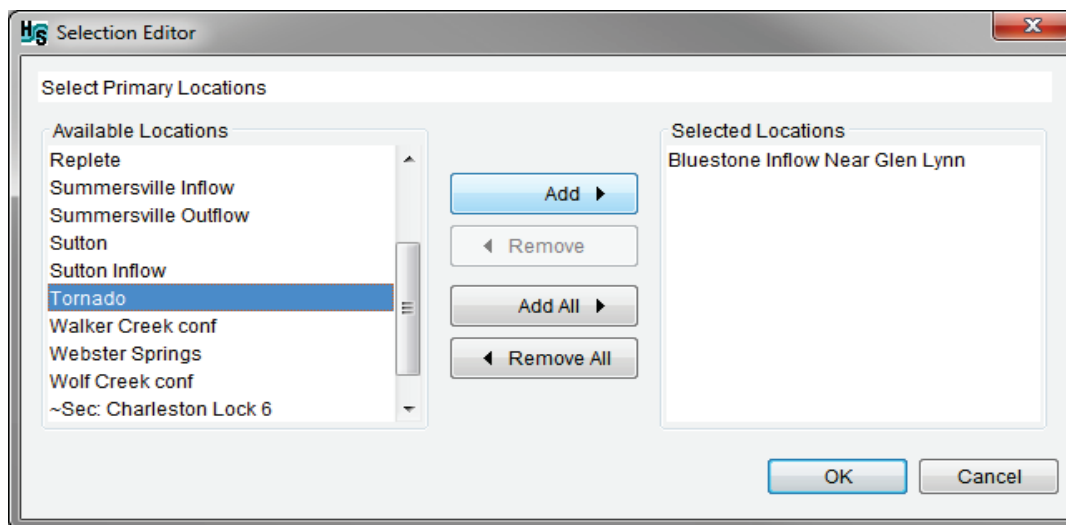


Figure 2-11 Selection Editor

- From the Selection Editor (Figure 2-11), select the required primary locations from the **Available Locations** list (e.g., *Tornado*), click **Add**. This will move the selected locations to the **Selected Locations** list (Figure 2-11). The **Add All** button moves all **Available Locations** to the **Selected Locations** list. Alternatively, double-clicking on a location in the **Available Locations** list will move the selected location to the **Selected Locations** list.

Note, for users editing an existing hydrologic sampling alternative when secondary locations have previously been selected (Section 2.4.1), secondary locations previously added are displayed with "**~Sec:**" in front of the location name (e.g., *~Sec: Charleston Lock 6*) at the bottom of the **Available Locations** list, as displayed in Figure 2-11. The "**~Sec:**" indicates that those locations were already selected as secondary locations, and should therefore not be selected as primary locations.

- To remove locations from the **Selected Locations** list (Figure 2-11), either click **Remove** for individually selected locations, or click **Remove All** to remove all selected locations.

Note, users can add or remove selected locations at any time. However, if users attempt to remove primary locations, a **Location Selection Warning** message opens (Figure 2-12), and requires users to confirm the deletion of the primary location and all related information.

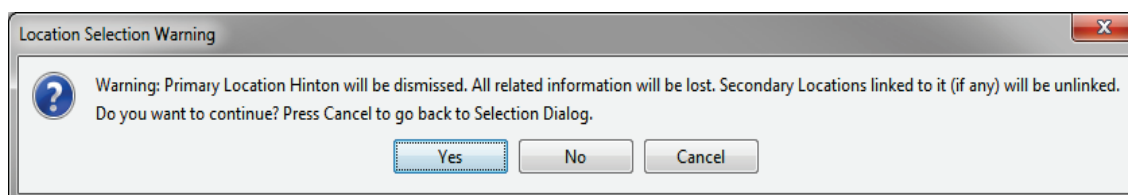


Figure 2-12 Location Selection Warning Message Window

4. Following the successful selection of the primary location(s), click **OK**, the **Selection Editor** will close (Figure 2-11).
5. A list of the primary locations will be available from the **Location** list (Figure 2-10).
6. For each primary location, the user must specify the location-specific **Duration**, **Maximum Flow Frequency Curve**, and the **Uncertainty** for each primary location.

2.3.2 Duration

A maximum flow frequency curve is the probability distribution of annual maximum or coincident flows that represents either an instantaneous peak or an average flow across some duration. From the **Duration** box of the **Hydrologic Sampling Editor** (Figure 2-10); from the **Duration of maximum average flow** list, the user can select either an instantaneous peak, number of days, or number hours of duration for the selected primary location.

The hydrologic sampling algorithm automatically stores outputs for the duration defined by the user from the **Duration of maximum average flow** list (Figure 2-10). The **Duration** box also contains an optional item, **Duration Output** (Figure 2-10). **Duration Output** allows users to store average event flows of additional durations, or an instantaneous peak, as output. The hydrologic sampling output variables and DSS output include the flow magnitude for the duration specified for the frequency curve as *MAX FLOW*, and all other durations as specified.

Note: users must access the HEC-WAT **Output Variable Editor** to select the desired duration outputs to save the provided hydrologic sampling DSS output (e.g., *MAX FLOW*, *PEAK FLOW*, *AVG 3 DAY MAX*). Refer to the HEC-WAT User's Manual for more information on the **Output Variable Editor**, accessing output variable results and accessing DSS (*.dss) result file(s).

One or more primary locations must be defined (Section 2.3.1) before a user can specify duration outputs. The duration outputs at each primary location are specified as follows:

1. From the **Location** list (Figure 2-10); select the primary location of interest.
2. From the **Duration** box (Figure 2-10), from the **Duration of maximum average flow** list (Figure 2-10) select one of the following:
 - **Inst. Peak** (Instantaneous Peak) – this option is the default.
 - **Days** – once selected to the right, in the box, enter the number of days for the duration.
 - **Hours** – once selected to the right, in the box, enter the number of hours for the duration.
3. Optionally, users can specify additional durations to include for each event in the hydrologic sampling output. To add durations, click **Duration Output**, the **Duration Output** dialog box (Figure 2-13) will open.

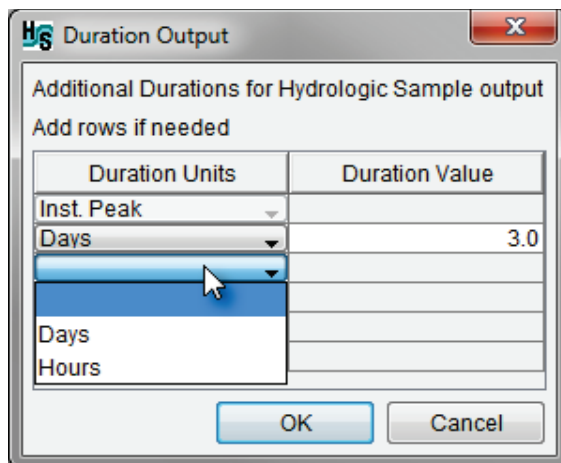


Figure 2-13 Duration Output Dialog Box

4. Note, the default additional duration output is *3.0 days*, which provides an output for the maximum three-day average flow. The preset default duration output can be retained, removed or changed to some other unit and/or value.
5. From the **Duration Output** dialog box (Figure 2-13), from the **Duration Units**, select one of the available options (**Days** or **Hours**) from the list in the cell (Figure 2-13). The selection will activate the corresponding **Duration Value** cell.
6. Next, in the activated **Duration Value** cell, enter the desired value (e.g., *72.0*, which adds a duration output for the maximum 72-hour average flow).
7. Repeat Steps 4 and 5 to enter the desired number of additional durations to include in the hydrologic sampling output.
8. To edit the **Duration Output** table, right-click on cells in the table on the **Duration Output** dialog box (Figure 2-13). Each column has its own unique shortcut menu (refer to Section 1.2.4 for shortcut options) with various options for editing the **Duration Output** table.
9. Click **OK**, the **Duration Output** dialog box will close (Figure 2-13), and the edits will be saved. The user is now returned to the **Hydrologic Sampling Editor; Primary Locations** tab (Figure 2-10).

2.3.3 Maximum Flow Frequency Curve

Next, users need to enter information for the maximum flow frequency curve (Figure 2-10). This information includes selecting a distribution type (Log Pearson Type III, Log Normal, GEV, Empirical) and defining the corresponding inputs for the selected distribution type. From the **Maximum Flow Frequency Curve** panel (Figure 2-14), from the **Distribution Type** list, select a distribution type.

The screenshot shows the 'Primary Locations' tab in the HEC-WAT Hydrologic Sampler. The 'Locations with defined probability distribution (frequency curve) and sampled random number' section has 'Bluestone Inflow Near Glen Lynn' selected. The 'Duration' section shows 'Inst. Peak' for 'Duration of maximum average flow'. The 'Maximum Flow Frequency Curve' section has a 'Distribution Type' dropdown menu open, showing options: 'Log Pearson type III' (selected), 'Log Normal (base 10)', 'GEV', and 'Empirical (graphical)'. Below this are fields for 'Mean (of log)', 'St. dev (of log)', and 'Skew (of log)'. There are also checkboxes for 'Clip Min Value' and 'Clip Max Value' with corresponding input fields. To the right is a plot titled 'Maximum Flow Frequency Curve' with 'Return Period' on the top x-axis (values: 1.1, 2, 5, 10, 50, 200) and 'Exceedance Probability' on the bottom x-axis (values: 0.99, 0.9, 0.5, 0.2, 0.02, 0.002). The y-axis is 'Flow (cfs)' on a log scale from 1 to 10. Buttons for 'Define Ordinates and Tabulate...' and 'Plot...' are at the bottom right.

Figure 2-14 Correlated Flow Frequency – Primary Locations Tab – Distribution Type List

When defining the maximum flow frequency curve (Figure 2-14), users must select a distribution type and define the corresponding distribution parameters. For the distribution types (other than **Empirical**), the user may choose to "clip", or constrain, the entered distribution to a defined minimum or maximum value, to limit the range of values sampled. The probability across the unconstrained range of the distribution is then increased by the excluded probability. Clipping limits are defined by selecting **Clip Min Value** and/or **Clip Max Value** (Figure 2-14), and entering a value for either the minimum or maximum value. HEC-WAT automatically creates the probability, which automatically updates the maximum flow frequency curve. The **Empirical** distribution requires users to enter a table of exceedance probability versus flow (cfs).

Viewing the Maximum Flow Frequency Curve

Whatever method the user chooses to generate a maximum flow frequency curve, a plot of the curve is displayed on the **Hydrologic Sampling Editor** (Figure 2-15). This plot automatically updates when user inputs are changed. In addition, by clicking **Plot**, the **Maximum Flow Frequency Curve** dialog box will open (Figure 2-16) displaying a plot of the current maximum flow frequency curve. This allows the user to examine the resultant plot of the defined curve in more detail. Refer to Section 1.2.5 for more details regarding plots in the **Hydrologic Sampling Editor**.

In addition, users can view a tabulated report that displays the calculated flow values and default exceedance probability ordinates of the maximum flow frequency curve. To view the table, click **Define Ordinates and Tabulate** (Figure 2-14), the **Define Ordinates and Tabulate Distribution** dialog box will open (Figure 2-16).

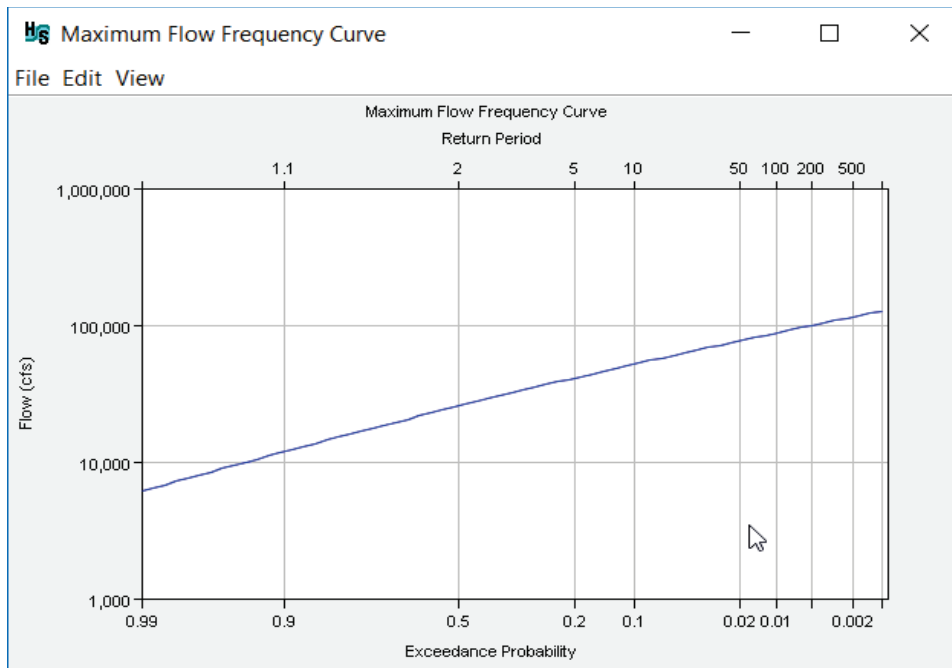


Figure 2-15 Maximum Flow Frequency Curve Plot

Define Ordinates and Tabulate Distribution

Add rows to define additional ordinates

Exceedance Probability	Flow (cfs)
0.001	126463.46
0.002	114598.66
0.005	99308.77
0.01	88023.86
0.02	76956.72
0.05	62591.89
0.1	51827.36
0.2	40969.92
0.5	25605.21
0.8	15573.64
0.9	11877.82
0.95	9442.17
0.99	6052.52

OK Cancel

Figure 2-16 Define Ordinates and Tabulate Distribution Dialog Box

Default Exceedance Probability Ordinates

The **Define Ordinates and Tabulate Distribution** dialog box (Figure 2-16) displays the probability versus flow table for the defined probability distribution. The displayed values represent both the original distribution and the result of imposed boundaries; i.e., the optional minimum or maximum clipping thresholds. The hydrologic sampling algorithm calculates flow (cfs) values based on the entered input parameters for the selected distribution and the default list of exceedance probability ordinates.

The user can modify/add/remove exceedance probability ordinates and the changes do not affect the entered distribution in any way. However, changes are reflected in the computed quantiles and the plot of the maximum flow frequency curve. Specifically, if the user adds or removes exceedance probability ordinates, the plot of the maximum flow frequency curve will update and display the values contained in the table at any given time. To modify, remove or add additional exceedance probability ordinates to the maximum flow frequency curve:

1. From **Maximum Flow Frequency Curve** panel (Figure 2-14); click **Define Ordinates and Tabulate**, the **Define Ordinates and Tabulate Distribution** dialog box will open (Figure 2-16).
2. It is not necessary to overwrite or add new exceedance probability ordinates in numerical order. When done with modifications, close the **Define Ordinates and Tabulate Distribution** dialog box (Figure 2-16). Upon reopening the dialog box, new/modified exceedance probabilities are automatically reordered, with corresponding flows generated.
3. To overwrite an existing **Exceedance Probability**, click inside the cell and enter the desired probability.
4. To remove existing exceedance probability ordinates, select the cell (or multiple cells) that contains the exceedance probability ordinate(s) to be deleted. Right-click on that cell, from the shortcut menu (Figure 1-3), click **Delete Row(s)**. The selected exceedance probability ordinate(s) are removed from the table.
5. To enter additional exceedance probability ordinates, right-click on a selected cell, from the shortcut menu (Figure 1-3), click **Insert Row(s)**. The **Insert Rows** dialog box (Figure 1-2) will open, in the **Number to insert** box, enter the number of new rows needed. Click **OK**, the **Insert Rows** dialog box will close, and blank cell(s) will display above the cell that was selected. Enter an exceedance probability ordinate(s) in the new cell(s), once the user leaves that cell(s), the associated flow value will automatically update based on the entered exceedance probability ordinates(s).
6. Manual edits to the values in the **Flow (cfs)** column (Figure 2-16) are not allowed as the flows are calculated based on the exceedance probability distribution. However, the user can manipulate the **Flow (cfs)** column, by right-clicking on the column, and accessing commands from the shortcut menu (Section 1.2.4).
7. Once editing is complete, click **OK**, the **Define Ordinates and Tabulate Distribution** dialog box will close (Figure 2-16). Modifications made to the exceedance probability ordinates(s) will automatically be saved, and the **Maximum Flow Frequency Curve** plot (Figure 2-14) will atomically update.

Distribution Type - Log Pearson Type III

The default distribution type is **Log Pearson type III** (Figure 2-14). To define a Log Pearson Type II distribution the user must enter the **Mean (of log)**, **St. dev (of log)** (standard deviation),

and the **Skew (of log)** distribution parameters (Figure 2-17).

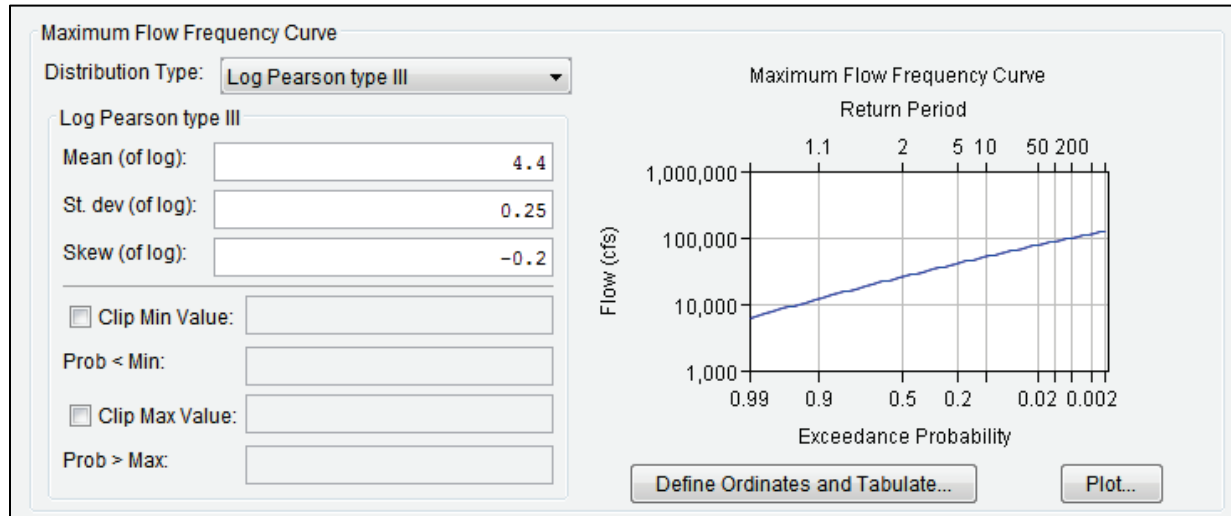


Figure 2-17 Correlated Flow Frequency – Distribution – Log Pearson Type III

An example of a completed Log Pearson Type III distribution and the resulting maximum frequency curve plot are displayed in Figure 2-17. Note, the user has the option to clip the lower or upper tail of the distribution using the **Clip Min Value**, or **Clip Max Value**, or both (see the section on *Clipping the Lower and/or Upper Tails of a Frequency Curve*).

Distribution Type – Log Normal (Base 10)

For the **Log Normal (base 10)** distribution (Figure 2-18), the user will the following parameters: **Mean (of log)** and **St. dev (of log)** (standard deviation). Figure 2-18 provides an example of a completed **Log Normal (base 10)** distribution and the resulting maximum frequency curve plot. Note, the user can has the option to clip the lower or upper tail of the distribution using the **Clip Min Value**, or **Clip Max Value**, or both (see the section on *Clipping the Lower and/or Upper Tails of a Frequency Curve*).

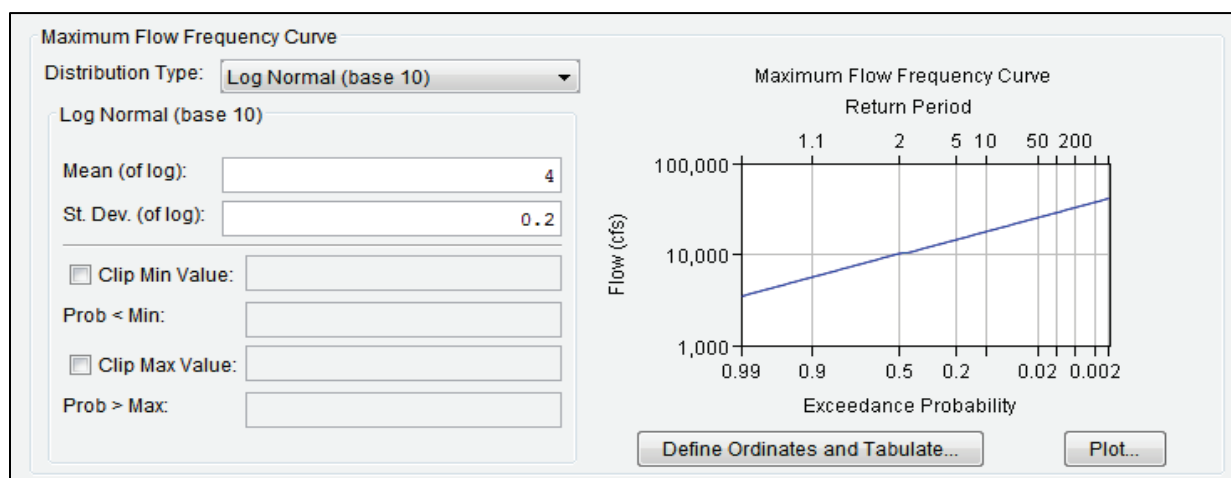


Figure 2-18 Correlated Flow Frequency – Distribution – Log Normal (base 10)

Distribution Type – Generalized Extreme Value (GEV)

The Generalized Extreme Value (GEV) distribution (Figure 2-19) require that the following distribution parameters be entered, **Location (ξ)**, **Scale (α)**, and **Shape (κ)**. Figure 2-19 provides an example of a completed GEV distribution and the resulting maximum frequency curve graph. Note, the user has the option to clip the lower or upper tail of the distribution using the **Clip Min Value**, or **Clip Max Value**, or both (see the section on *Clipping the Lower and/or Upper Tails of a Frequency Curve*).

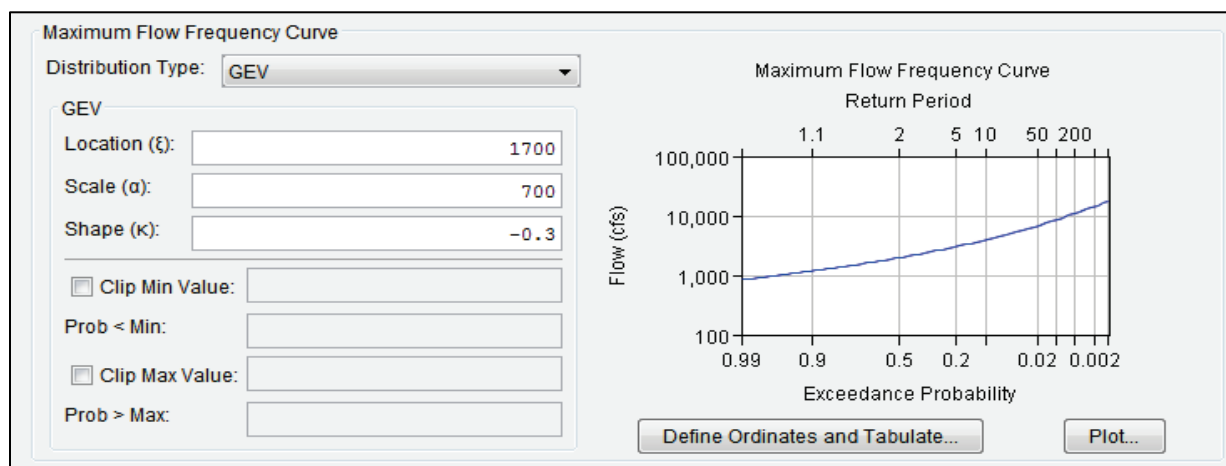


Figure 2-19 Correlated Flow Frequency – Distribution – GEV

Note, the GEV input parameters can be defined in more than one way. In the HEC-WAT (Version 1.0) and HEC-SSP (Version 2.2 or greater) software packages, the GEV input parameters follow the description in the *Handbook of Hydrology* (Maidment Ed., 1993) and *Regional Frequency Analysis* (Hosking et. al., 1997).

Distribution Type – Empirical (graphical)

The **Empirical (graphical)** distribution (Figure 2-20) requires that a user complete the **Exceedance Probability** and **Flow (cfs)** table. By right-clicking on a cell in the table, a shortcut

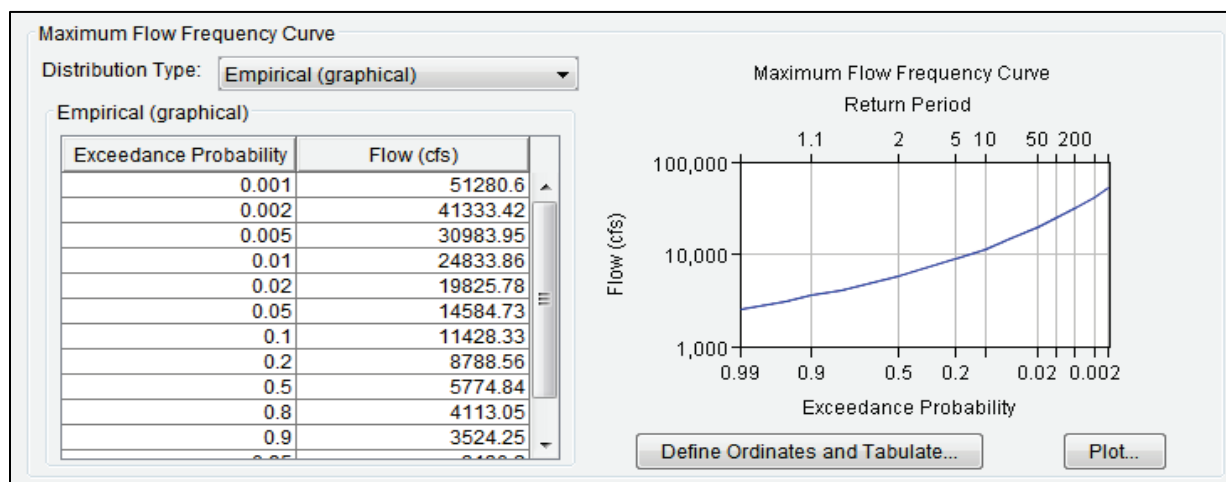


Figure 2-20 Correlated Flow Frequency – Distribution – Empirical (graphical)

menu will display with options (e.g., cut, copy, paste, etc.) for editing the table (Section 1.2.4). Note, extrapolation does not occur beyond the user-defined minimum and maximum flow. Figure 2-20 provides an example of a completed **Empirical** distribution and the resulting frequency curve graph.

Clipping the Lower and/or Upper Tails of a Frequency Curve

For the Log Pearson type III, Log Normal, and GEV distribution types, the user can clip the lower or upper tail of a distribution using the **Clip Min Value**, or **Clip Max Value**, or both (Figure 2-21). This clipping or constraining of the entered distribution, defines the minimum or maximum value, which limits the range of values sampled. The probability across the unconstrained range of the distribution is then increased by the excluded probability.

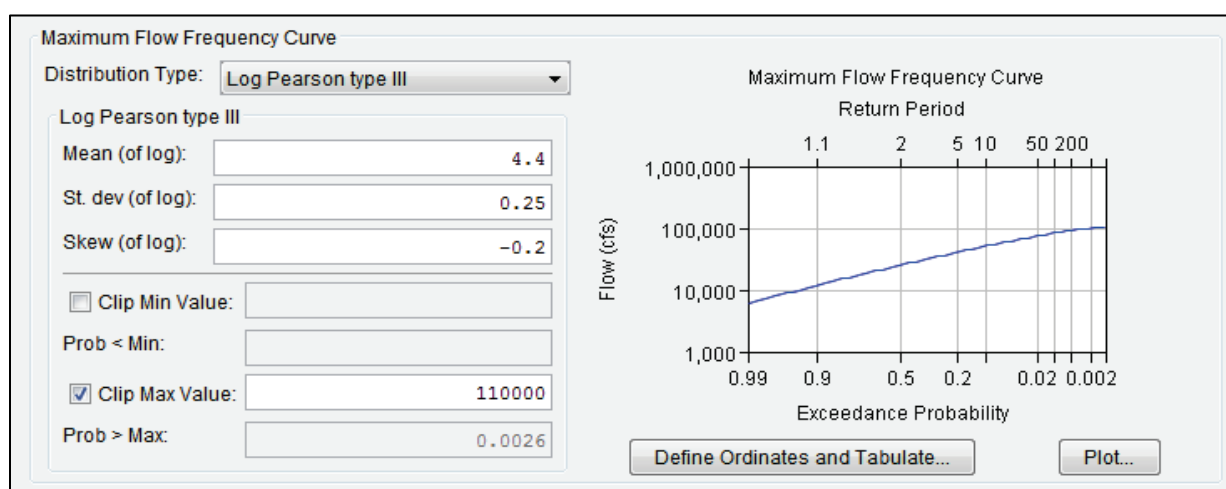


Figure 2-21 An Example of Clipping the Upper Tail

For example, to clip the upper tail of a **Log Pearson Type III** distribution (Figure 2-21), select **Clip Max Value** (Figure 2-21), enter the maximum flow (cfs) value (e.g., 11000). The **Prob > Max** box (Figure 2-21) will automatically update (e.g., 0.0026 or 0.26 percent) to show the probability (a value between 0.0 – 1.0, not a percent) of the original distribution having a value beyond the clip threshold (and thus being clipped or excluded). The probability distribution is then adjusted so that the remaining range spans the excluded probability.

2.3.4 Uncertainty

The maximum flow frequency curve specified for each primary location is not known precisely, because the estimated curve contains uncertainty due to limited available record length. A record length limitation is an example of "knowledge uncertainty", as described in the introduction to Chapter 1, and is randomized at the realization level (outer loop) of the HEC-WAT FRA nested Monte Carlo simulation, meaning it is sampled once per realization.

The uncertainty in the generated maximum flow frequency curve is incorporated by parametrically bootstrapping each curve once per realization. In other words, a new frequency curve is generated by randomly sampling N values (where N is the equivalent record length) from the original frequency curve, and then re-estimating the parameters from that N -value

sample. Individual flow magnitudes are then sampled for each event (via HEC-WAT's inner loop sampling) from a different uncertainty-adjusted frequency curve for each realization (via HEC-WAT's outer loop sampling).

Next, users need to enter information for about the uncertainty of the maximum flow frequency curve (Figure 2-22). Generally, two uncertainty options are available for all distribution types that users may choose from: **No Uncertainty**, or a specified **Equivalent Years of Record** (default). A third option is available to define uncertainty for an **Empirical** (graphical) frequency curve (**User Defined Uncertainty**), which uses a normal distribution at each ordinate with a user-defined standard deviation, entered as a table.

Exceedance Probability	Standard Deviation (of log)
0.9	10.0
0.1	100.0

Figure 2-22 Hydrologic Sampling Editor – Uncertainty Box

No Uncertainty

From the **Uncertainty** panel (Figure 2-22), select **No Uncertainty**. This option does not add uncertainty and the defined maximum flow frequency curve is used for sampling events in every realization.

Equivalent Years of Record

From the **Uncertainty** panel (Figure 2-22), select **Equiv. years of record** (default) and enter the number of years in the box next to **Equiv. years of record**. An equivalent record length parameterizes uncertainty due to a limited record length. This uncertainty value is either the actual record length used to estimate the flow frequency curve, or an equivalent length based on either (a) the addition of historical information, (b) use of a regional skew, or (c) development of the frequency curve from a method other than a statistical analysis of a gaged or modified flow record.

For analytical distributions (Log Pearson type III, Log Normal, GEV, Empirical), the **Equiv. years of record** defines N (where N equals specified equivalent record length) to create the random "bootstrap" sample to generate the realization-specific frequency curve used for sampling events.

Randomize Skew – this option is only enabled when the selected distribution type is **Log Pearson type III**, and is enabled by default to be consistent with the uncertainty description

in *Bulletin 17C*. When **Randomize Skew** is enabled (select the ☒ checkbox), the computation will use the skew coefficient computed from the "bootstrap" sample. *Bulletin 17B* uncertainty does not recognize the uncertainty in the skew coefficient, and if the user prefers to maintain consistency with *Bulletin 17B*, the user should not select the **Randomize Skew** option. In this case, the skew is not re-computed from the bootstrap sample, and instead the original user-entered skew coefficient is used.

User Defined Uncertainty

This option is only available when the selected distribution type is **Empirical (graphical)**. Select **User Defined Uncertainty**, this enables the table, which displays default values (Figure 2-22). If necessary, edit the default values in the table to override the computed standard deviation of uncertainty for each frequency quantile, which is based on the order statistics method. Right-click inside the table to access the same shortcut menu options (e.g., cut, copy, paste, etc.) discussed Section 1.2.4.

The screenshot shows the 'Uncertainty' dialog box. It has three radio buttons: 'No Uncertainty.', 'Equiv. years of record:' (with a value of 78), and 'User Defined Uncertainty' (which is selected). To the right of the 'Equiv. years of record:' is a checked 'Randomize Skew' checkbox. Below the radio buttons is a table with two columns: 'Exceedance Probability' and 'Standard Deviation (of log)'. The table has three rows, with the first two containing data.

Exceedance Probability	Standard Deviation (of log)
0.9	10.0
0.1	100.0

Figure 2-23 Hydrologic Sampling Editor – Uncertainty Box – User Defined Uncertainty

Click **Apply** to save changes made to the **Primary Locations** tab. Alternatively, if a user is finished adding information or editing, click the **OK** to close the **Hydrologic Sampling Editor**. Users can click **Data Check** (Section 1.2.6) to determine if any primary locations were missed before proceeding to the **Secondary Locations** tab (Section 2.4), if desired. Note, the **Data Check** is generally used after all required inputs have been defined to avoid generating a long list of as-yet undefined inputs (e.g., undefined **Cross Correlation Matrix** and **Shape Sets** data).

2.4 Secondary Locations Tab

From the **Hydrologic Sampling Editor**, the **Secondary Locations** tab (Figure 2-24) allows the user to define secondary flow locations for the less significant inflow sites, chosen from common computation points in the watershed. As opposed to primary locations, which generate flow uniquely, flow for each secondary location is instead generated as a ratio of the flow magnitude from the associated primary location. This method for generating flows for secondary locations results in a perfect correlation of flows between each secondary location and its associated primary location.

The **Secondary Locations** tab (Figure 2-24) has two options based on the selected **Location**. The **Link to Primary** list, consists of primary locations, while the **Maximum Ratio** box contains the **Ratio with Maximum at Primary Location (Multiplier)**. Users create a list of secondary locations, then enter information specific for each secondary location.

The screenshot shows the 'Hydrologic Sampling Editor' window with the 'Secondary Locations' tab selected. The 'Name' field is set to 'FullSampling'. The 'Data to be Sampled' is 'Flow Sampling' and the 'Sampling Method' is 'Correlated Flow Frequency Curves'. The 'Locations with perfect correlation to a Primary location and no random number' section contains a 'Location' dropdown, a 'Link to Primary' dropdown, and a 'Select Secondary Locations' button. Below this is a 'Maximum Ratio' section with a text input field labeled 'Ratio with Maximum at Primary Location (Multiplier)'. At the bottom are 'Data Check', 'OK', 'Cancel', and 'Apply' buttons.

Figure 2-24 Hydrologic Sampling Editor - Correlated Flow Frequency – Secondary Locations Tab

2.4.1 Location List

The first step is to define the secondary flow location(s):

1. From the **Secondary Locations** tab (Figure 2-24), click **Select Secondary Locations**, the **Selection Editor** will open (Figure 2-25).

The screenshot shows the 'Selection Editor' window. It has two main panes: 'Available Locations' on the left and 'Selected Locations' on the right. The 'Available Locations' list includes 'Queen Shoals', 'Radford', 'Replete', 'Summersville Outflow', 'Sutton', 'Walker Creek conf', 'Webster Springs', 'Wolf Creek conf', and several locations starting with '~Prim:'. The 'Selected Locations' list currently contains 'Charleston Lock 6' and 'Kanawha Falls'. Between the panes are buttons for 'Add', 'Remove', 'Add All', and 'Remove All'. At the bottom are 'OK' and 'Cancel' buttons.

Figure 2-25 Selection Editor

2. Select a secondary flow location(s) from the **Available Locations** list individually, or select multiple while holding the **Ctrl** key, and click **Add** to move the selected location(s) to the **Selected Locations** list. **Add All** moves all **Available Locations** to the **Selected Locations** list. Alternatively, double-clicking a desired location (e.g., *Queen Shoals*) moves the location to the **Selected Locations** list.

Note: All common computation points added as primary locations in the **Primary Locations** tab (Section 2.3) are displayed with "**~Prim:**" in front of the location name at the bottom of the **Available Locations** list, as displayed in Figure 2-25. The "**~Prim:**" indicates that those locations were already selected as primary locations, and should therefore not be selected again. If one or more of the primary locations are re-selected as secondary locations, and the **OK** is clicked, then a **Location Selection Warning** window (Figure 2-26) will open. Warning the user that the selected location will be deleted as a primary location and added as a secondary location. If the user clicks **Yes**, those locations will change from primary to secondary, and any previously specified frequency curve inputs will be lost.

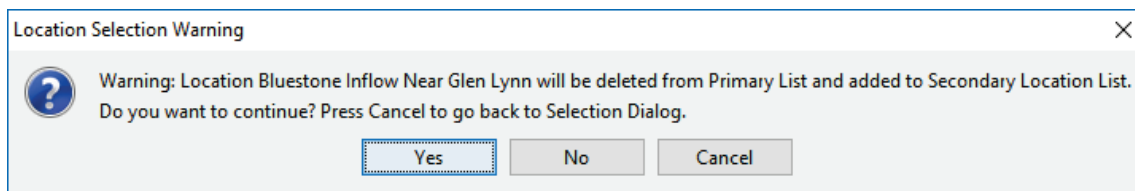


Figure 2-26 Location Selection Warning Window

3. Following the successful selection of the secondary locations, click **OK**, the **Selection Editor** dialog will close (Figure 2-25). Users can modify the secondary locations list at any time. However, if a user attempts to remove secondary locations, then a **Location Selection Warning** message will open (Figure 2-26), which requires the user to confirm the deletion of the secondary location and all related information.
4. The **Location** list automatically populates with all locations set in the **Selection Editor** as secondary locations.
5. Next, for each secondary location listed in the **Location** list, the user must specify the primary location that the secondary location will be linked with (**Link to Primary** list) and the maximum ratio for the primary location (**Maximum Ratio** box).

2.4.2 Link to Primary List and Maximum Ratio Box

The **Link to Primary** list (Figure 2-24) contains the primary flow locations specified in the **Primary Locations** tab (Section 2.3). Each secondary location must be linked to a primary location. The hydrologic sampling algorithm of HEC-WAT generates the flow magnitude at the secondary location by multiplying the randomly sampled primary flow magnitude by the entered maximum ratio. A perfect correlation results between sampled events for the linked pair of locations.

1. From the **Location** list (Figure 2-27), select a secondary location.

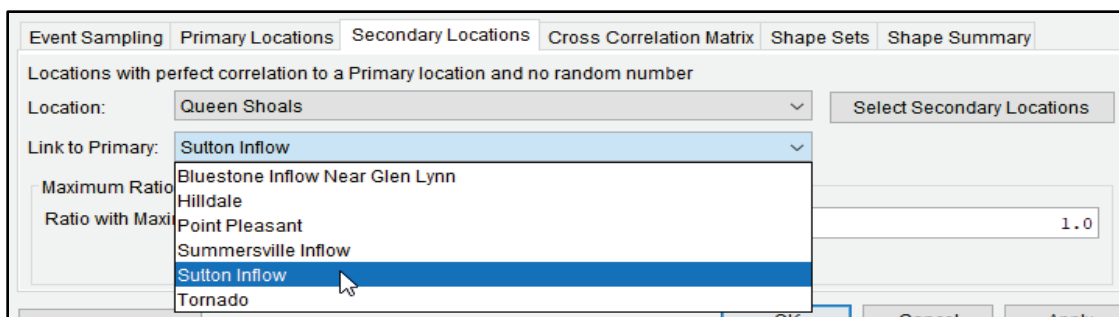


Figure 2-27 Link to Primary List

- From the **Link to Primary** list (Figure 2-27); select the primary location to link to the selected secondary location. Note, if the list does not contain the required primary location for the selected secondary location, refer to Section 2.3 to add the missing primary location.
- Next, set the maximum ratio value if the default value of **1.0** (Figure 2-27) is not appropriate. In the **Ratio with Maximum at Primary Location (Multiplier)** box, enter the ratio value for the selected secondary and linked primary locations (Figure 2-27). The maximum ratio (1.0 equals 100%) is required, and the entered ratio is multiplied by the primary location's sampled maximum flow to define the flow magnitude of the secondary location.
- Repeat Steps 1 through 3 for all defined secondary locations in the **Location** list (Figure 2-27), to define each secondary location to a primary location and define the appropriate maximum ratio value.
- Click **Apply** to save changes made to the **Secondary Locations** tab before continuing to the next tab. Alternatively, click **OK** to save the hydrologic sampling alternative and close the **Hydrologic Sampling Editor**. Users can click **Data Check** (Section 1.2.6) to determine if any secondary locations were missed before proceeding to the **Cross Correlation Matrix** tab (Section 2.5), if desired. Note, the **Data Check** is generally used after all required inputs have been defined to avoid generating a long list of as-yet undefined inputs (e.g., undefined **Cross Correlation Matrix** and **Shape Sets** data).

2.5 Cross Correlation Matrix Tab

Correlation coefficient values may vary between negative one and positive one. A correlation value of zero suggests that the maximum flows at two sites are independent (or do not have a linear relationship). A correlation of positive one suggests a perfect linear relationship between flow magnitudes at two sites. A correlation of negative one means the two sites have a perfect but opposite linear relationship, where a large value at one site would occur with a small value at the other site. Other correlation values imply some amount of linear relationship.

The correlation matrix requires a cross-correlation between each pair of primary locations, estimated from a basin-wide correlation analysis. These correlation values drive the correlated random sampling process generating the random numbers used to sample the maximum flow magnitudes at the primary flow locations. Because two locations that are both correlated with a

third location must have some level of correlation with each other, the specified correlations must be consistent as a set. If the matrix of correlations is not consistent and therefore not usable, the data check will identify the problem and report that the matrix is "not positive definite."

From the **Hydrologic Sampling Editor**, the cross correlation matrix is entered on the **Cross Correlation Matrix** tab (Figure 2-28), which requires the user to enter a linear correlation coefficient for each pair of primary locations in the lower triangle of the matrix (editable area). Entered correlation values must be between negative one and positive one, and cells cannot be blank.

1. Enter the cross correlation values for each pair of inflow locations in the lower triangle of the matrix. To enter a value in an empty cell, click once to highlight the cell and manually enter the value.

Note, users can copy (**C**opy shortcut command or Ctrl+C) and paste values (**P**aste shortcut command or Ctrl+V) from an outside source (e.g., Microsoft® Excel, text editor), as long as the copied data is tab delimited or a spreadsheet. Several shortcut commands are available for editing tables (refer to Section 1.2.4 for more information).

2. Double-click to change a value already entered into the editable cells. The upper triangle of the cross correlation matrix (light-gray area) is non-editable. The values displayed in the upper triangle populate automatically as the cross correlation values are entered into the lower triangle of the matrix (Figure 2-29).

Inflow Locations	Bluestone Inflow Near Glen Lynn	Hilldale	Point Pleasant	Summersville Inflow	Sutton Inflow	Tornado
Bluestone Inflow Near Glen Lynn	1.0					
Hilldale		1.0				
Point Pleasant			1.0			
Summersville Inflow				1.0		
Sutton Inflow					1.0	
Tornado						1.0

Figure 2-28 Hydrologic Sampling Editor - Correlated Flow Frequency – Cross Correlation Matrix Tab – Default Values

Inflow Locations	Bluestone Inflow Near Glen Lynn	Hilldale	Point Pleasant	Summersville Inflow	Sutton Inflow	Tornado
Bluestone Inflow Near Glen Lynn	1.0	0.4899	0.0	0.292	0.2978	0.4811
Hilldale	0.4899	1.0	0.0	0.774	0.8688	0.7528
Point Pleasant	0.0	0.0	1.0	0.0	0.0	0.0
Summersville Inflow	0.292	0.774	0.0	1.0	0.8622	0.6582
Sutton Inflow	0.2978	0.8688	0.0	0.8622	1.0	0.6779
Tornado	0.4811	0.7528	0.0	0.6582	0.6779	1.0

Figure 2-29 Cross Correlation Matrix

3. All cells in the matrix must contain values between negative one and positive one, and all cells must have a value. The user can expand individual columns to view the complete header text.
4. Click **Apply** to save the selected hydrologic sampling alternative when navigating between alternatives. Alternatively, click **OK** which saves the hydrologic sampling alternative and closes the **Hydrologic Sampling Editor** (Figure 2-28). Use **Data Check** (refer to Section 1.2.6) to check whether the correlation values entered in the matrix are internally consistent. If the values are not internally consistent, the data check will report an error saying the matrix is not positive definite.

2.6 Shape Sets Tab

A shape hydrograph must be provided for every primary and secondary flow location (refer to Sections 2.3 and 2.4, respectively). Typically, actual flood events (historical floods) are used to define shape sets in the watershed, with the shape hydrograph for each location being used. However, artificial shape sets, or hydrographs from some other watershed, may be used to supplement historical floods if the historical events do not provide all reasonable examples of flood event timing. The goal is for the collection of shape sets to capture many possible hydrograph shapes and timing of peaks at all locations.

Section 2.6.3 provides more information regarding DSS time series, and includes examples of shape set hydrographs. It is important to note that the DSS time-window (start and end dates and times) of each hydrograph shape *within* a shape set must be the same for *all* locations. However, both the DSS time-window and event duration of the shape hydrographs may vary *between* different shape sets. The time interval (e.g., 15 minutes, 1 hour, 1 day, etc.) for *all* hydrographs in *all* shape sets must be the same. Note, if an HEC-ResSim model requires a significantly long lookback period, each shape set should be defined with adequate time-steps (compute interval) for the lookback window before the start of the event (refer to Section 2.6.3 for examples). Refer to the HEC-WAT User's Manual or the HEC-ResSim User's Manual for more information on lookback periods and time-steps.

The hydrologic sampling algorithm in HEC-WAT generates flood events of all sizes reflected in the flood frequency curves, based on randomly sampled exceedance probabilities. Some shape sets are suitable for only the very largest generated events (produced by very small exceedance probabilities), and some are appropriate for a wider range of event magnitudes. To ensure the pairing of each shape set with the appropriate event magnitudes, the user specifies an exceedance probability filter for each shape set that defines the range of exceedance probabilities for which that shape set is available.

The user must also specify a prominent location in the basin as the key location for filtering. For each sampled event, the exceedance probability at the key location is compared to the filter range of each shape set, and those sets with filters spanning that exceedance probability are available to be sampled.

The user-specified shape set weight defines the relative likelihood of each set (weight of set divided by the sum of the available sets weights), which is used in randomly selecting a shape set for each event. The **Shape Set Summary** tab (refer to Section 2.7) shows the resulting relative likelihood of each set for each range of exceedance probability, because likelihoods will differ in ranges for which some sets are not available.

From the **Hydrologic Sampling Editor**, the **Shape Sets** tab (Figure 2-30) allows the user to specify shape sets with DSS records (which are contained in a DSS file, *.dss) for each primary and secondary location. Each shape set must also have a weight for defining its relative likelihood among all shape sets, and a probability range within which it may be used. A shape set is a collection of flood event shape hydrographs used to convert randomly sampled flow magnitudes into flood event hydrographs (time series). The shape hydrographs have no magnitude, and are each scaled such that the maximum average value of the hydrograph (across the specified duration) matches the maximum average flow magnitude randomly sampled at each location.

Hydrologic Sampling Editor

Name: FullSampling

Description:

Data to be Sampled: Flow Sampling

Sampling Method: Correlated Flow Frequency Curves

Event Sampling Primary Locations Secondary Locations Cross Correlation Matrix Shape Sets Shape Summary

Shape Set: 1987

Description:

New Set... Rename Set... Save Set As ... Delete Set...

Location for Exc. Probability filter (same for all shape sets): Bluestone Inflow Near Glen Lynn

Exceedance probability filter: Exceedance Probability Max: 1 Exceedance Probability Min: 0

Weight: 1 Total Weight: 3 Probability (full range): 0.333

Location	Type	DSS File	Part A	Part B	Part C	Part E	Part F
Bluestone Inflow Near Glen Lynn	Primary						
Hilldale	Primary						
Point Pleasant	Primary						
Summersville Inflow	Primary						
Sutton Inflow	Primary						
Tornado	Primary						
Charleston Lock 6	Secondary						
Claytor Lake	Secondary						
Kanawha Falls	Secondary						
Queen Shoals	Secondary						

Plot... Tabulate... Select DSS Path...

Data Check OK Cancel Apply

Figure 2-30 Hydrologic Sampling Editor - Correlated Flow Frequency – Shape Sets Tab – Default Values

From the **Shape Sets** tab (Figure 2-30) users can create, rename, save as, and delete shape set(s); set the exceedance probability filter maximum and minimum; set the weight of the shape set and view the resulting total weight and probability; and, from the DSS time series panel, for set the DSS record pathname for all primary and secondary locations.

2.6.1 Create Shape Sets

For each new shape set, the user will specify the shape set's **Weight**, **Exceedance probability filter** and a **DSS record** for each primary and secondary location.

1. From the **Shape Set** tab (Figure 2-30), click **New Set**, the **Create New Shape Set** dialog box will open (Figure 2-31).

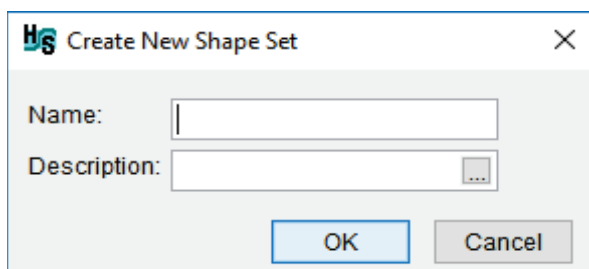



Figure 2-31 Create New Shape Set Dialog Box

2. Enter a name for the new shape set in the **Name** box. Enter a description of the shape set in the **Description** box (optional, but recommended). Click , which opens the **Enter Description** window, which allows the user enter or view a length description. **Note:** the **Name** (and description) can be used to match the correct DSS file (*.dss) with the correct **Shape Set**.
3. Click **OK**, the **Create New Shape Set** dialog box will close (Figure 2-31). The **Hydrologic Sampling Editor** updates with the created shape set (Figure 2-30).

2.6.2 Assign Shape Set Filters and Weights

From the **Shape Sets** tab (Figure 2-30); users can continue to define a created shape set by entering exceedance probability filters and a weight for the selected shape set, as follows:

1. From the **Location for Exc. Probability filter (same for all shape sets)** list (Figure 2-32) by selecting a primary location from the dropdown list. The sampled exceedance probability at the selected location is the reference value for filtering which shape sets are available to be sampled for a given event, based on their exceedance probability ranges.

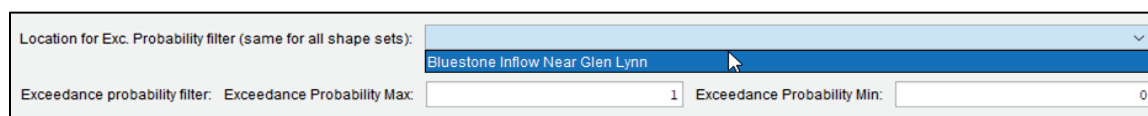


Figure 2-32 Shape Set - Exceedance Probability Filter

Note: The **Location for Exc. Probability filter (same for all shape sets)** list (Figure 2-32) is modifiable at any time, and is applied to all shape sets contained in the **Shape Set** list (Figure 2-30).

2. For each shape set, enter an **exceedance probability filter** (maximum and/or minimum). The exceedance probability maximum and minimum values allow the user to define the

appropriate probability range for each shape set, with the exceedance probability corresponding to the sampled flow. For example, some historical flood event shapes are appropriate to very large flood events (with small exceedance probabilities), and some are only appropriate to smaller flood events (with large exceedance probabilities).

- By default, the **Exceedance Probability Max** is *1* (Figure 2-32), and the **Exceedance Probability Min** is *0* (Figure 2-32). Use the default maximum and minimum to allow the selected shape set to be randomly chosen for any flood event.
 - To limit a shape set to only *large* events (that correspond to small exceedance probabilities), assign the **Exceedance Probability Max** value (Figure 2-32) a probability smaller than 1.0.
 - To limit a shape set to only *small* events (that correspond to large exceedance probabilities), assign the **Exceedance Probability Min** value (Figure 2-32) a probability larger than 0.0.
3. For individual shape sets, the purpose of the weight (Figure 2-33) is to define the relative likelihood of sampling individual shape sets. One shape set may be unusual for the watershed, and another might be quite common. Therefore, users can assign each shape set a weight; based on that weight the probability is automatically generated. The probability is computed, as the shape set's weight divided by the sum of the weights of all relevant shape sets. Equal weights will result in individual shape sets having equal likelihood of being sampled, while shape sets with higher weights have a greater likelihood of being sampled.

Weight:	<input type="text" value="1"/>	Total Weight:	<input type="text" value="1"/>	Probability (full range):	<input type="text" value="1"/>
---------	--------------------------------	---------------	--------------------------------	---------------------------	--------------------------------

Figure 2-33 Shape Set - Weight

- By default, the **Weight** for a new shape set is a value of *1* (Figure 2-33), which results in the shape set having equal likelihood of being sampled. For example, if a hydrologic sampling alternative contains three shape sets and each shape set has a **Weight** value of one, then each will have a one-third chance of being selected for each flood event (weight 1.0 divided by total weight 3.0).
- If one of the three shape sets has a **Weight** of 2, it will then have a probability of one-half of being chosen (weight 2.0 divided by total weight 4.0), and the other two shape sets will have a probability of one-quarter (weight 1.0 divided by total weight 4.0).

For convenience, users can view a list of all created and defined shape sets, with the exceedance probability bounds, the weight and resultant probability (full range) displayed for each shape set, from the **Shape Set Summary** tab (refer to Section 2.7).

2.6.3 Select Shape Set Time Series

A shape set is a collection of hydrograph time series used in conjunction with sampled event flow magnitudes to create flood event hydrographs. The duration of flooding and relative timing of the peak at various locations in the watershed are important aspects to capture, and are often affected by the storm's characteristics (type, speed, and direction of travel across the watershed).

Generally, several historical flood events should be chosen that collectively capture an array of possible flood patterns. For example, Figure 2-34, displays two different shape sets, each with four hydrographs from an historical flood event. The four hydrographs for each historical flood event together form a shape set for a study with four primary and secondary locations.

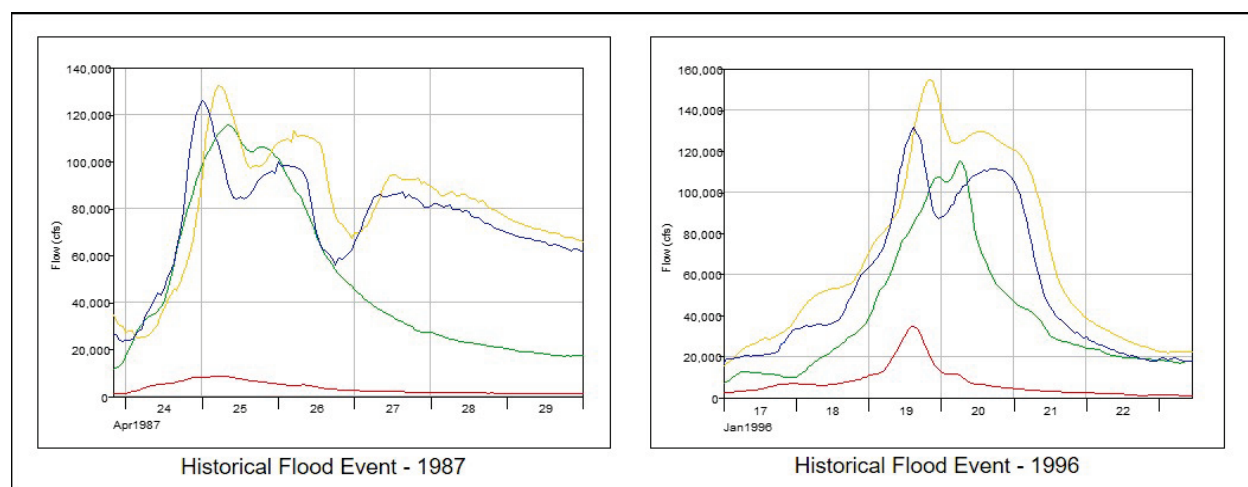


Figure 2-34 Correlated Flow Frequency – Hydrograph Shape Sets – Historical Flood Events

The DSS time-window (start and end dates and times) of each hydrograph shape *within* a shape set must be the same for all locations. However, both the DSS time-window and event duration of the shape hydrographs may vary *between* different shape sets (Figure 2-34). The time interval (e.g., 15 minutes, 1 hour, 1 day, etc.) for *all* hydrographs in *all* shape sets must be the same.

Each hydrograph must be stored as a DSS record, most conveniently in the same HEC-DSS file (*.dss). Refer to the HEC-DSSVue User's Manual for more information regarding HEC-DSS files. Users select the stored DSS records referenced in the Hydrologic Sampler through the **Hydrologic Sampling Editor** (Figure 2-30).

Note: If an HEC-ResSim model requires a significantly long lookback period, each shape set should be defined with adequate time-steps (compute interval) for the lookback window before the start of the event. In other words, all hydrographs in the shape set must have a time-window appropriate for an HEC-ResSim model's lookback window. Figure 2-35 provides an example of five hydrographs in a shape set with added time-steps to extend the start of the time-window. Refer to the HEC-WAT User's Manual or the HEC-ResSim User's Manual for more information on lookback periods and time-steps.

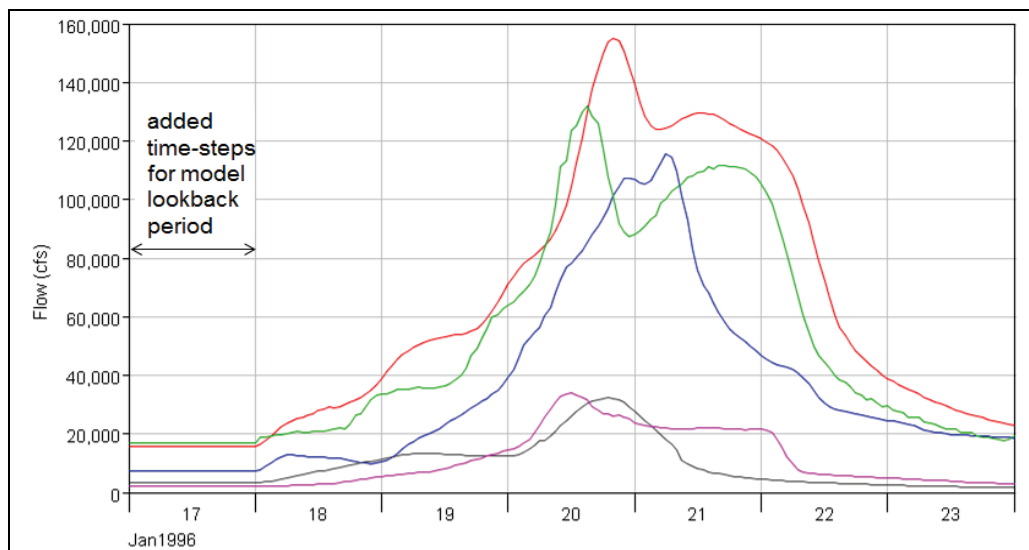


Figure 2-35 Example – Correlated Flow Frequency – Time-Steps Added to Extend Hydrographs in a Shape Set for HEC-ResSim

The next step is to define a hydrograph for each location, including both primary locations (Section 2.3.1) and when appropriate secondary locations listed (Section 2.4.1) in the DSS input table. DSS records must be specified for all created shape sets.

1. From the **Shape Set** list (Figure 2-30), select a shape set. The DSS input table will display the locations for the selected shape set, and the type (Primary, Secondary) of each location (Figure 2-30). A DSS record must be identified for each location.

Important: Note that the time-step (or time interval) for the time series DSS records must be the same for all locations in all shape sets within a Hydrologic Sampling alternative. In other words, **Part E** (e.g., 1HOUR) must be the same for all locations in all shape sets contained in the **Shape Sets** dropdown list. Similarly, the DSS record length (start and end dates, and times) must be the same for every record in a shape set. However, different shape sets (contained in the **Shape Sets** list) can have different DSS record lengths as long as they are consistent within a shape set for every primary and secondary location.

For example, the Hydrologic Sampler allows for the following situation: all DSS records in *Shape Set 1996* contain 156 ordinates with a time-window of 16Jan1996, 24:00 through 23Jan1996, 11:00; and all DSS records in *Shape Set 1987* contain 149 ordinates with a time-window of 23Apr1987, 20:00 through 29Apr1987, 24:00.

2. To select a DSS path for a location, click any cell in the row of a location; click **Select DSS Path** (Figure 2-30). An **HEC-DSSVue** dialog box will open (Figure 2-36). Refer to the HEC-DSSVue User's Manual for more information regarding DSS pathnames and HEC-DSSVue.

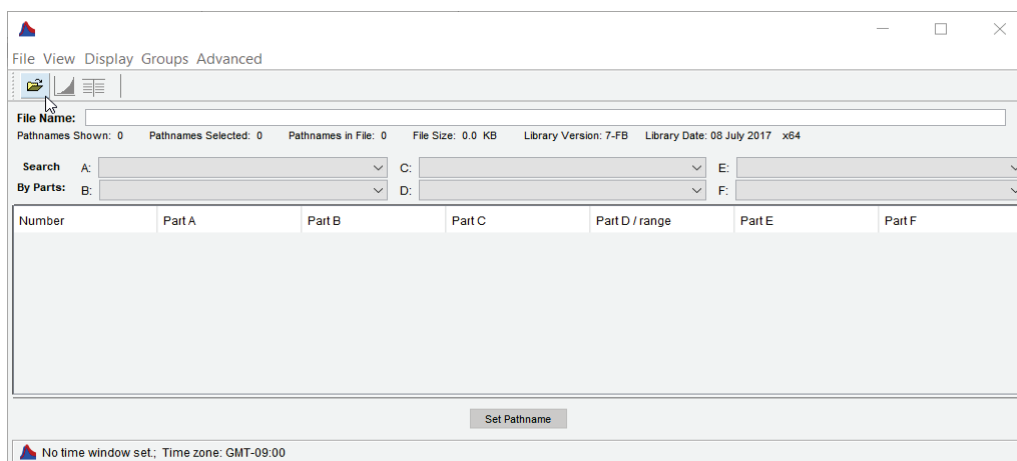



Figure 2-36 HEC-DSSVue Dialog Box

- From the **HEC-DSSVue** dialog box, click  (Figure 2-36); the **Open HEC-DSS File** browser will open (Figure 2-37). Browse to the location of a DSS file (*.dss) that contains the time series of interest (e.g., shape set hydrographs). Click on the appropriate *.dss file, the **File name** box now contains the name of the selected file (e.g., *shapes_20150615.dss*).
- Click **Open**, the **Open HEC-DSS File** browser will close (Figure 2-37). The **HEC-DSSVue** dialog box (Figure 2-36) now displays the DSS records for the selected DSS file.
- For the location (e.g., *Bluestone Inflow Near Glen Lynn*) that was selected in the DSS input table in the **Hydrologic Sampling Editor** (Figure 2-30), find and select the proper pathname (record) from the list of DSS records in the **HEC-DSSVue** dialog box (Figure 2-36), click **Set Pathname**. From the **Hydrologic Sampling Editor** (Figure 2-30), the DSS input table now contains the **DSS File** pathname (Parts A – F) for the selected **Location** (e.g., *Bluestone Inflow Near...*).

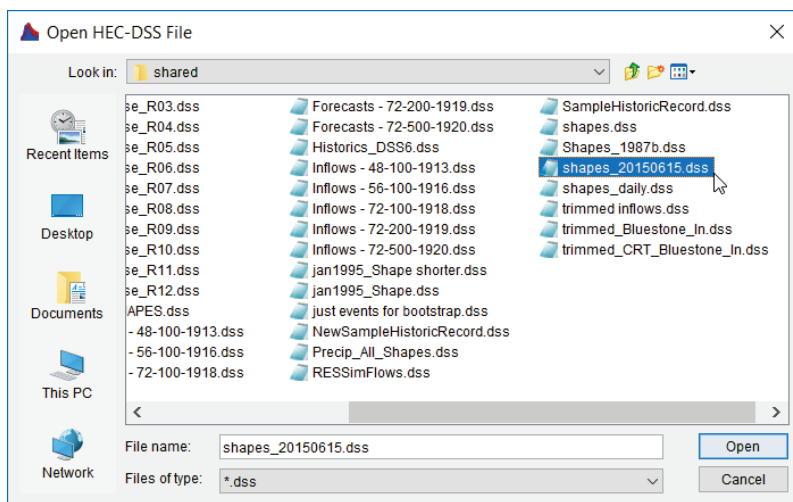


Figure 2-37 Open HEC-DSS File Browser

6. Select the next location, from the **HEC-DSSVue** dialog box (Figure 2-36), find and select the proper pathname (record) from the list of DSS records in the **HEC-DSSVue** dialog box (Figure 2-36), click **Set Pathname**. Repeat this step until all locations in the DSS input table (Figure 2-38) contain the correct DSS filename and the DSS pathnames.

Shape Set: 1987

Description: [Text Box]

New Set... Rename Set... Save Set As ... Delete Set...

Location for Exc. Probability filter (same for all shape sets): Bluestone Inflow Near Glen Lynn

Exceedance probability filter: Exceedance Probability Max: 1 Exceedance Probability Min: 0.02

Weight: 2 Total Weight: 4 Probability (full range): 0.5

Location	Type	DSS File	Part A	Part B	Part C	Part E	Part F
Bluestone Inflow Near Gle...	Primary	shared/shapes_20150615.dss	KANAWHA	BLNO7	FLOW	1HOUR	SHAPE1987
Hilldale	Primary	shared/shapes_20150615.dss	KANAWHA	HDGO7	FLOW	1HOUR	SHAPE1987
Point Pleasant	Primary	shared/shapes_20150615.dss	KANAWHA	PT-PLS	STAGE	1HOUR	SHAPE1987
Summersville Inflow	Primary	shared/shapes_20150615.dss	KANAWHA	SUGM7	FLOW	1HOUR	SHAPE1987
Sutton Inflow	Primary	shared/shapes_20150615.dss	KANAWHA	SUEK7	FLOW	1HOUR	SHAPE1987
Tornado	Primary	shared/shapes_20150615.dss	KANAWHA	TORM5	FLOW	1HOUR	SHAPE1987
Charleston Lock 6	Secondary	shared/shapes_20150615.dss	KANAWHA	CLKL5-LOCAL	FLOW	1HOUR	SHAPE1987
Kanawha Falls	Secondary	shared/shapes_20150615.dss	KANAWHA	KFKM6-LOCAL	FLOW	1HOUR	SHAPE1987
Queen Shoals	Secondary	shared/shapes_20150615.dss	KANAWHA	QSEL6-LOCAL	FLOW	1HOUR	SHAPE1987

Plot... Tabulate... Select DSS Path...

Figure 2-38 Shape Set – Completed DSS Record Definition for a Shape Set

7. Click **Apply** (Figure 2-30), from this point the user can choose to define the DSS records for the other shape sets selected from the **Shape Set** list (and repeating Steps 1 through 6), move onto reviewing the shape sets and making adjustments (Section 2.7), or click **OK** (Figure 2-30) to save the selected hydrologic sampling alternative and close the **Hydrologic Sampling Editor**. Recall that **Data Check** (Section 1.2.6) can be used to search for data consistency error(s) prior to closing the editor.

2.6.4 Rename a Shape Set

To rename a completed shape set, from the **Shape Set** list (Figure 2-30), select a shape set, click **Rename Set** (Figure 2-30). The **Rename Shape Set** dialog box will open (Figure 2-39). Enter the new name for the shape set in the **Name** box and a description in the **Description** box (optional, but recommended). Click **OK**, the **Rename Shape Set** dialog box will close (Figure 2-39) and the newly named shape set will display in the **Shape Set** list (Figure 2-30).

Rename Shape Set

Name: Set_A_1987

Description: Example Shape Set Rename

OK Cancel

Figure 2-39 Rename Shape Set Dialog Box

2.6.5 Copy a Shape Set

To make a copy of a selected shape set, from the **Shape Set** list (Figure 2-30) select a shape set, click **Save Set As** (Figure 2-30). The **Save Shape Set As** dialog box will open (Figure 2-40). Either use the default name or manually enter the copied shape set name in the **Name** box and a description in the **Description** box (optional, but recommended). Click **OK**, the **Save Shape Set As** will close (Figure 2-40) and the newly named shape set will display in the **Shape Set** list (Figure 2-30).

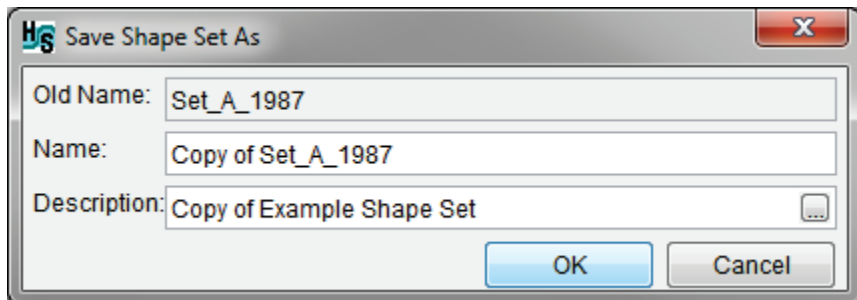


Figure 2-40 Save Shape Set As Dialog Box

2.6.6 Delete a Shape Set

To delete a shape set, from the **Shape Set** list (Figure 2-30), select the shape set that will be deleted, click **Delete Set**. A **Confirm delete** window will open (Figure 2-41). To delete the shape set, click **Yes**. The **Confirm delete** window will close (Figure 2-41) and the shape set will have been deleted from the **Shape Set** list (Figure 2-30).

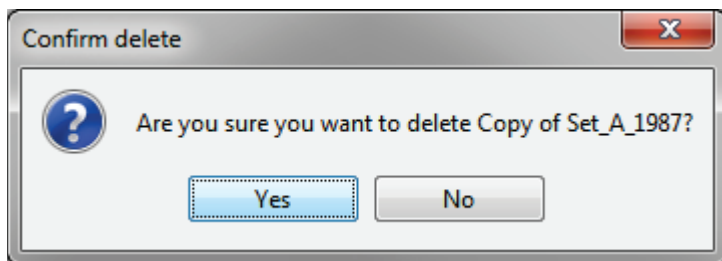


Figure 2-41 Confirm delete Window

2.7 Shape Summary Tab

From the **Hydrologic Sampling Editor**, the **Shape Summary** tab (Figure 2-42) displays all the defined shape sets at the same time. The **Shape Summary** tab consists of two main sections: the shape set summary table and the **Exceedance Probability Filter Plot** (Figure 2-42). The summary table lists the defined shape sets, with the weight and resultant probability displayed for each shape set. The shape set summary table is editable, and edits that occur on the **Shape Summary** tab, automatically update the **Shape Sets** tab and the **Exceedance Probability Filter Plot** (Figure 2-42). To edit a cell, click once and type in the new number. Select a cell (or multiple cells, columns or rows) and right-click to access the shortcut menu options to copy, paste, fill, etc. (refer to Section 1.2.4 for shortcut options).

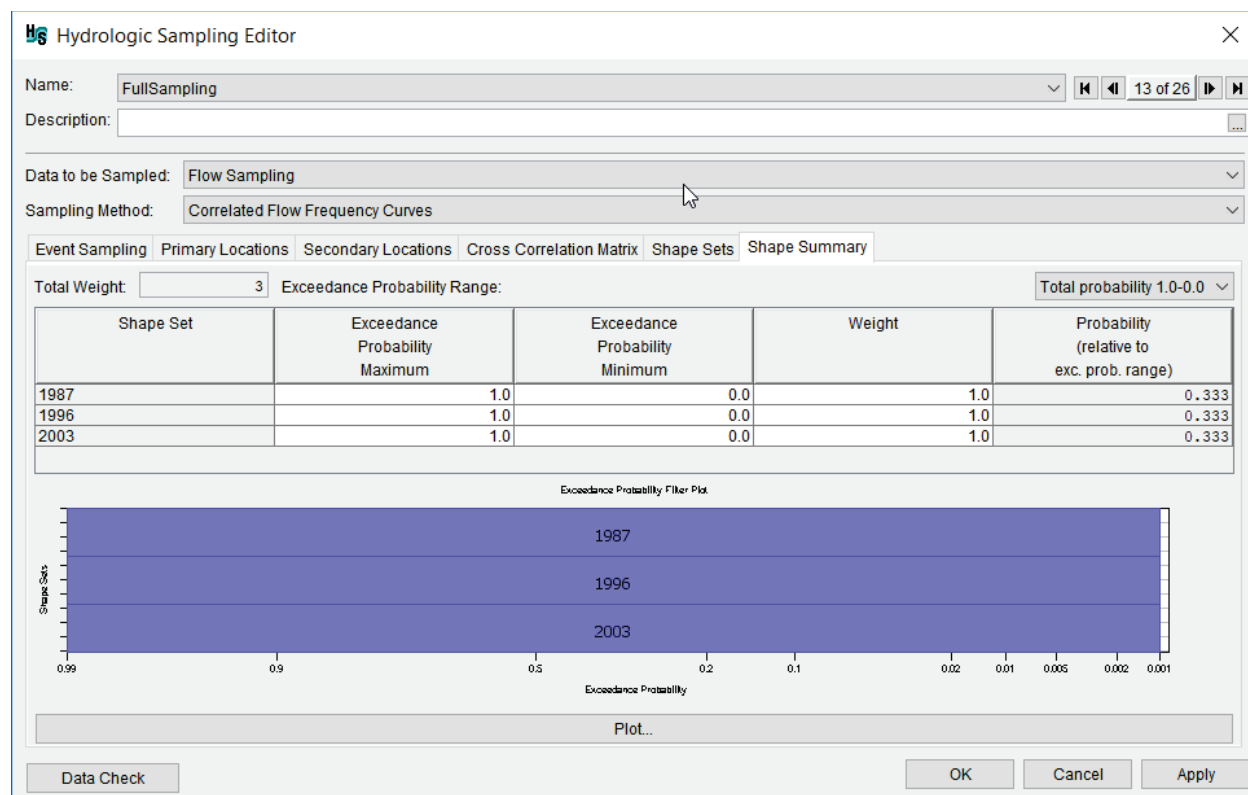


Figure 2-42 Hydrologic Sampling Editor - Correlated Flow Frequency – Shape Summary Tab

The **Exceedance Probability Filter Plot** is displayed at the bottom of the tab (Figure 2-42). To view the **Exceedance Probability Filter Plot** in a new window, click **Plot** (Figure 2-42). The plot illustrates the relative selection probability of each shape set, as well as the exceedance probability range in which each shape set can be selected. Each shape set's vertical thickness reflects the shape set's relative probability of being randomly selected (as defined by the weights). Each shape set's horizontal span depicts the range (between 0.0 and 1.0) of the exceedance probability range that applies to each shape set, on a normal probability axis. The vertical order of the shape sets corresponds to the order in which they were created (top to bottom, first to last).

As can be seen in the **Exceedance Probability Filter Plot** (Figure 2-42), the result of limiting the exceedance probability ranges of shape sets is that the complete 0.0 to 1.0 range is divided at all bounding values, creating sub-ranges in which some shape sets are excluded. Therefore, the relative probability of a given shape set (defined as the shape set's weight divided by the total weight of all available shape sets) may be different in each sub-range. Users can view modified probabilities for different preset sub-ranges in the shape set table by selecting a sub-range from the **Exceedance Probability Range** list (Figure 2-43). Note, selecting a different exceedance probability ranges does not change the **Exceedance Probability Filter Plot** (Figure 2-42); instead, the selection only updates the last column in the summary table (Figure 2-42).

With a sub-range selected (e.g., 0.2-0.05), the **Probability (relative to exc. prob. range)** column of the table (Figure 2-44) of resultant relative probability displays the values for the selected sub-range, with excluded shape sets having a probability of zero, and others having probability based

Event Sampling	Primary Locations	Secondary Locations	Cross Correlation Matrix	Shape Sets	Shape Summary
Total Weight: 7		Exceedance Probability Range:			Total probability 1.0-0.0
Shape Set	Exceedance Probability Maximum	Exceedance Probability Minimum	Weight	Total probability 1.0-0.0	
1878 at Bluestone	1.0	0.0	2	1.0-0.8	
1901 at Bluestone	0.05	0.0	1	0.8-0.2	
1936 at Bluestone	0.8	0.0	2	0.2-0.05	
				0.05-0.0	
				No-interval probability	

Figure 2-43 Shape Summary Tab – Exceedance Probability Range List

on the total weight of active shape sets. Figure 2-44 displays an example of a probability sub-range resulting from the collection of ranges, and the subsequent probability of each shape set. The **No-interval probability** option available from the **Exceedance Probability Range** list (Figure 2-43) provides the relative probabilities of the shape set(s) if not modified by the probability filters.

Data to be Sampled:	Flow Sampling				
Sampling Method:	Correlated Flow Frequency Curves				
Event Sampling	Primary Locations	Secondary Locations	Cross Correlation Matrix	Shape Sets	Shape Summary
Total Weight: 7		Exceedance Probability Range:			0.2-0.05
Shape Set	Exceedance Probability Maximum	Exceedance Probability Minimum	Weight	Probability (relative to exc. prob. range)	
1878 at Bluestone	1.0	0.0	2.0	0.400	
1901 at Bluestone	0.05	0.0	1.0	0.000	
1936 at Bluestone	0.8	0.0	2.0	0.400	
1987	1.0	0.2	1.0	0.000	
1996	1.0	0.0	1.0	0.200	

Figure 2-44 Shape Summary Tab –Exceedance Probability Range Selection – 0.2-0.05

When only one shape set exists, that shape set's exceedance probability must span from 0.0 to 1.0. When two or more shape sets exist, the exceedance probability range for all shape sets must together span the full range from 0.0 to 1.0. If the full range for the exceedance probability is not spanned, the missing probability range will be marked in red in the summary table and with an "ERROR" label in the **Exceedance Probability Filter Plot** (Figure 2-45). In this case, at least one shape set must be redefined to span the missing range, or another shape set added for the missing exceedance probability range.

Click **Apply** to save changes made in the **Shape Summary** tab when navigating between Hydrologic Sampling alternatives. Alternatively, click **OK** to save the Hydrologic Sampling alternative and close the **Hydrologic Sampling Editor**. Recall the **Data Check** button (refer to Section 1.2.6) can be used to search for data consistency error(s) prior to closing the editor.

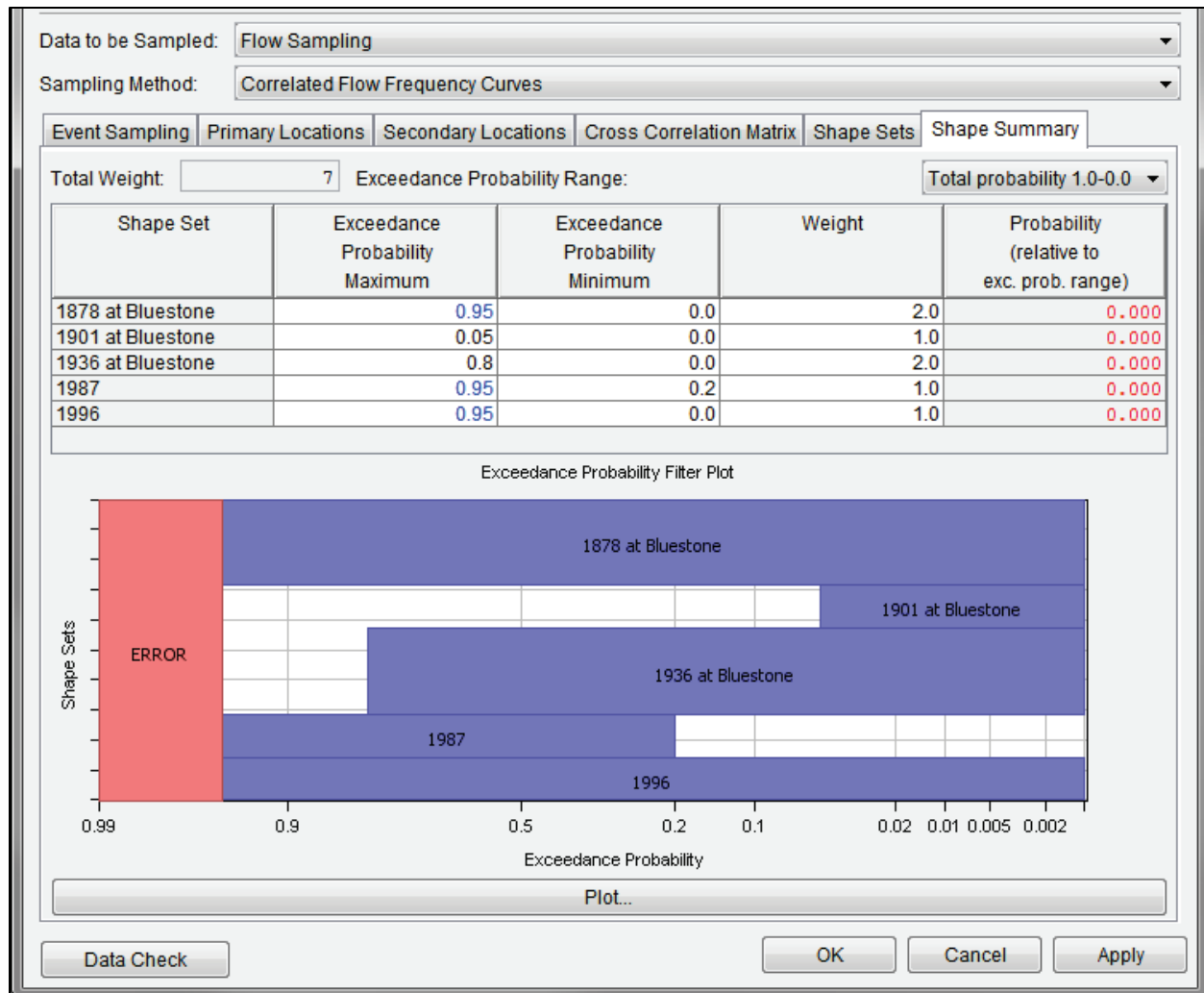


Figure 2-45 Shape Summary Tab – Exceedance Probability Filter Plot with Example Error

CHAPTER 3

Bootstrapping Historical/Synthetic Basin-wide Events

This chapter describes how to set up the Hydrologic Sampler with a flow-sampling alternative using the **Bootstrapping Historical/Synthetic Basin-wide Events** sampling method. This sampling method randomly samples from a "bucket" of user-defined historical and optional synthetic basin-wide flood events to provide flood hydrographs for all basin inflow locations within the modeled watershed.

To use the Bootstrapping Historical/Synthetic Basin-wide Events method for hydrologic sampling, concurrent historical time series of flood events are needed at all required watershed inflow locations. Events are randomly sampled from the historical time series (hydrographs) and additional synthetic events (if applicable), such that all defined inflow locations use the hydrographs associated with the sampled event/year. This sampling approach is meant to ensure that flood event hydrographs across the watershed can feasibly occur together, and mimic how the flood hydrographs were measured during historic floods, by choosing from events the user has provided. Historical flood events receive a likelihood of $1/N$, where N is the number of historical years in the time series. Synthetic events can be developed outside of the Hydrologic Sampler and added to the sampling "bucket". Synthetic events are typically either larger than events in the historical record or defined to represent a different origination of flow throughout the watershed, and are generated to have a specified exceedance probability. Synthetic events are assigned a likelihood related to their exceedance probability. When synthetic events are included, the sampling probability of the largest historical events is reduced, as described in Section 3.4, to bring the total probability of all events to 1.0.

The Bootstrapping Historical/Synthetic Basin-wide Events sampling method has the option to generate random hydrologic forecasts (e.g., an April-August snowmelt runoff volume) for each event, for cases in which management of projects in the watershed requires those forecasts. Forecast error statistics and starting forecast volumes are required user inputs. The user-defined forecast errors are then randomly sampled and added to the starting volume of the sampled event, producing the random hydrologic forecast. The purpose for including the optional ability to generate random forecasts within the Bootstrapping Historical/Synthetic Basin-wide Events method is provided in Section 3.1.1.

With the Bootstrapping Historical/Synthetic Basin-wide Events sampling method selected (Figure 3-1), the **Hydrologic Sampling Editor** contains the following five method-specific tabs:

Settings	The Settings tab (Section 3.2) is for specifying information about the locations for sampling and some method-specific choices. Two tabs are available from the Settings tab - the Hydrographs and Forecasts tabs (Sections 3.2.1 and 3.2.2, respectively).
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The **Hydrographs** tab (Section 3.2.1) allows the user to **Select Hydrograph Locations** for inflow hydrographs, choose the location and duration for **Ranking of Historical Record Events** to determine the largest event, select the **Uncertainty Method** and specify the **Exceedance Probabilities of Synthetic Events** as needed.

The **Forecasts** tab (Section 3.2.2) is only enabled when **Include Forecasts** has been selected (Section 3.1.1). From the **Forecasts** tab, the user can **Select Forecast Locations** at which to generate random forecasts. **Forecast Statistics** are defined for each selected location: forecast date(s), forecast error statistics and serial correlation between forecasts.

Historical Record

The **Historical Record** tab (Section 3.3) is for providing the time series that represents the record of flows that occurred in the watershed. Two tabs are available from the **Historical Record** tab - the **Hydrographs** and **Forecasts** tabs (Sections 3.3.1 and 3.3.2, respectively).

The **Hydrographs** tab (Section 3.3.1) contains the DSS input table for specifying the historical time series DSS records for all of the locations selected in the **Settings** tab. The **Forecasts** tab (Section 3.3.2) is enabled when **Include Forecasts** has been selected. The DSS input table allows the user to specify time series DSS records of the starting forecast values (before random error is added) for each location and forecast date defined on the **Settings** tab (Section 3.2).

Synthetic Events

The **Synthetic Events** tab (Section 3.4) is used for adding synthetic flood events that are either larger than those in the historical record, or reflect some other feasible and relevant origination of flow throughout the watershed. Any number of synthetic events may be added for a given exceedance probability, and synthetic events may be added for many exceedance probabilities as well. In the **Synthetic Events** tab, users can add new, rename, copy, or delete existing synthetic events. Two tabs are available from the **Synthetic Events** tab - the **Hydrographs** and **Forecasts** tabs (Sections 3.4.2 and 3.4.6, respectively)

The **Hydrographs** tab (Section 3.4.2) contains the DSS input table for specifying input flow time series data for synthetic events for all locations selected in the **Settings** tab using the **Select DSS Path** button.

The second tab, **Forecasts** (Section 3.4.6), is enabled when the **Include Forecasts** checkbox is selected. The DSS input table allows the user to specify time series of starting forecast values (before random error is added) for each location and forecast date defined on the **Settings** tab, using the **Select DSS Path** button.

Synthetic Summary

The **Synthetic Summary** tab (Section 3.5) provides two summary tables of the user-defined synthetic events. The summary tables are for viewing

purposes only, and the information displayed in the tables cannot be modified from this tab.

The first table has a row for each exceedance probability for which synthetic events have been created. This table contains four columns: exceedance probability, return period, total incremental probability, and adjusted probability assigned to that exceedance probability/return period. The adjusted probability column lists the multiplier used to adjust the probabilities.

The second table references the single exceedance probability selected in the first table, and contains the same four columns. This table displays the list of synthetic events created for the exceedance probability, and the weight, subsequent incremental and adjusted probabilities assigned to each event.

Hydrologic Sampling Editor

Name: Ex_Bootstrap

Description:

Data to be Sampled: Flow Sampling

Sampling Method: Bootstrapping Historical/Synthetic Basin-wide Events

Start of Water Year: 01Jan

☐ Include Forecasts ☐ Incremental Probability Override

Settings | Historical Record | Synthetic Events | Synthetic Summary | **Probability Override**

Hydrographs | Forecasts

Select Hydrograph Locations...

Ranking of Historical Record Events

Location for event ranking:

Flow duration for event ranking (days): 3

Uncertainty Method

☐ No uncertainty

☒ Equivalent Years of Record

Exceedance Probabilities of Synthetic Events

Exceedance Probability	Return Period
0.0200	50
0.0100	100
0.0050	200
0.0040	250
0.0020	500
0.0010	1000

New Delete


Data Check OK Cancel Apply

Figure 3-1 Hydrologic Sampling Editor – Bootstrapping Historical/Synthetic Basin-wide Events

Probability Override (optional)	When the Incremental Probability Override option is selected, the Probability Override tab (Section 3.1.2) is enabled. This tab allows users to modify the incremental probabilities for each of the historical and synthetic events used in the Bootstrapping Historical/Synthetic Basin-wide Events sampling method, and provides a check to ensure the total incremental probability is equal to 1.0.
--	--

3.1 Data and Method Selection

First, either create a new Hydrologic Sampling alternative (Section 1.3) or edit an existing alternative (Section 1.4.1) using the **Hydrologic Sampling Editor**. Next, select the desired Hydrologic Sampling method (and any desired options), from the editor, as follows:

1. From the **Data to be Sampled** list (Figure 3-1), select **Flow Sampling**. By default, **Flow Sampling** is selected.
2. From the **Sampling Method** list (Figure 3-1), select **Bootstrapping Historical/Synthetic Basin-wide Events**. The **Hydrologic Sampling Editor** dialog updates for the Bootstrapping Historical/Synthetic Basin-wide Events sampling method, as displayed in Figure 3-1.
3. Set the **Start of Water Year** used for parsing flood events, by either manually entering the date (DDMMM), or clicking  which opens the **Select Date** dialog box (Figure 3-2) from which the user can select the month and day.

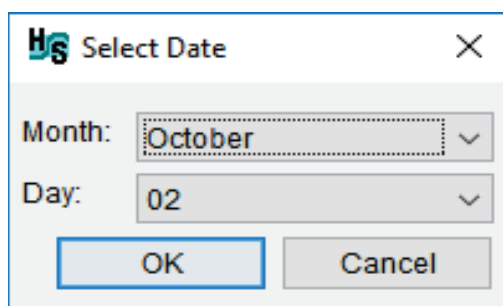


Figure 3-2 Select Date Dialog Box

3.1.1 Including Forecasts (Optional)

Depending on the purpose of the Flood Risk Analysis (FRA) study, the user may wish to include the option to generate random hydrologic forecasts (e.g., an April through August volume) within the Bootstrapping Historical/Synthetic Basin-wide Events sampling method. For instance, some watersheds might include reservoir operations that require hydrologic forecast modeling (produced by National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS), or USACE) to determine the depth of flood pools needed to store forecast runoff (e.g., from snowmelt). Consequently, in HEC-WAT, an imported HEC-ResSim model (refer to the HEC-WAT User's Manual) would require these forecasts as input in simulating a flood event, in addition to the inflow time series.

Furthermore, the Bootstrapping Historical/Synthetic Basin-wide Events sampling method supports generation of random hydrologic forecasts. Evaluating forecast uncertainty consists of randomly generating new event forecasts that share the error characteristics of a location's forecast method, but represent different instances of forecasts that could have been produced. For example, for a snowmelt runoff forecast of April through August volume, the user provides an initial April through August volume and a generated random error is added by the Hydrologic Sampler to the volume; this produces a random (incorrect) forecast of that volume. Note, the user-specified forecast volume can be the correct streamflow volume, which the forecast attempts to predict, or some other volume such as the historical forecast.

For specified forecast locations, in addition to the initial forecast volume time series, the user also supplies forecast dates and error statistics, which are used by the Hydrologic Sampler to generate random forecast errors using an autoregressive lag 1, AR(1) process. The user-supplied forecast error statistics for each location and date are standard error, serial correlation with the previous forecast date, minimum possible forecast, and the slope and intercept of a forecast bias line. The bias line incorporates the fact that large events tend to be under-forecasted, and small events tend to be over-forecasted (Faber, 2016).

To include forecasts in the Bootstrapping Historical/Synthetic Basin-wide Events sampling method, from the **Hydrologic Sampling Editor** (Figure 3-1), select the **Include Forecasts** option. A **Forecasts** tab is then enabled on the **Settings**, **Historical Record** and **Synthetic Events** tabs.

3.1.2 Incremental Probability Override (Optional)

The **Incremental Probability Override** is optional (Figure 3-1) and enables the **Probability Override** tab. This provides an additional setup for including incremental probability overrides in the Bootstrapping Historical/Synthetic Basin-wide Events sampling method. Prior to completing the probability override setup, the historical record hydrographs must first be completed (Section 3.3).

Probability Override Tab

The incremental probabilities assigned to each historical event and each synthetic event are computed within the Hydrologic Sampler. The **Probability Override** tab (Figure 3-3) is useful when the user wants more control over the allocation of probability among all of the events included in the sampling "bucket". Furthermore, this option exposes the computed incremental probabilities within the **Hydrologic Sampling Editor**, which is informative even when the user does not change them.

The most basic incremental probability computation is that for N historical years, each year is given an equal incremental probability of $1/N$. When synthetic events are included, the assigned incremental probabilities for the events is based on their defined exceedance probability, the number of events of that exceedance probability, and the next smallest exceedance probability included, as described in Section 3.4.

The Hydrologic Sampler includes further computations that affect the computed (or default) incremental probability of synthetic events. When synthetic events are included, probability equal to the largest specified exceedance probability (e.g., 1%) must be allocated to the synthetic events. That allocated probability must be taken from what had been allocated to the historical events (before the synthetic event was included), which otherwise span the entire 0.00 to 1.00 probability range, with $1/N * N = 1$. Because the largest events in the historical record are the most similar to the synthetic events in magnitude, an algorithm based on the binomial distribution (and the likelihood of actually seeing a 100-year event in an N -year historical record) takes more probability away from the largest historical events. The results of this algorithm could make the largest historical event less likely to be sampled than the user prefers, and the **Probability Override** tab (Figure 3-3) allows the user to adjust those probability results.

Hydrologic Sampling Editor

Name: Ex_Bootstrap 9 of 26

Description:

Data to be Sampled: Flow Sampling

Sampling Method: Bootstrapping Historical/Synthetic Basin-wide Events

Start of Water Year: 02Oct ☐ Include Forecasts ☒ Incremental Probability Override

Settings Historical Record Synthetic Events Synthetic Summary **Probability Override**

Incremental Probability Override

Water Year or Synthetic Name	Year Type	Duration Maximum Flow (cfs)	Computed Incremental Probability	Override Incremental Probability
1995	Historic	257,957.67	0.014286	0.014286
1998	Historic	261,515.15	0.014286	0.014286
1942	Historic	262,970.72	0.014286	0.014286
1986	Historic	267,639.93	0.014286	0.014286
1970	Historic	268,108.33	0.014286	0.014286
1949	Historic	269,545.95	0.014286	0.014286
1966	Historic	270,365.55	0.014286	0.014286
1962	Historic	271,078.63	0.014286	0.014286
1984	Historic	272,037.93	0.014286	0.014286
1978	Historic	274,874.40	0.014286	0.014286
1983	Historic	275,038.93	0.014286	0.014286

Incremental Probability Total 1.000000 1.000000

Data Check OK Cancel Apply

Figure 3-3 Hydrologic Sampling Editor – Bootstrapping Historical/Synthetic Basin-wide Events – Probability Override Tab

The second computation involved in defining the default incremental probabilities for historical and synthetic events is the synthetic probability multiplier. Because the bootstrap sampling used in this method cannot choose from a continuous range of flood event magnitudes, but instead only from defined events and so a discrete set of magnitudes, the resulting inflow frequency

curves from the Monte Carlo simulation will have a stair-step pattern that has segments falling below the original frequency relationship. To reduce this effect, and to more accurately span the probability of each synthetic event, the default algorithm uses a multiplier to increase the probability assigned to the synthetic events, causing the stair-step pattern to have segments falling both above and below the original frequency relationship. Currently, the multiplier of 1.25 is set internally in the Hydrologic Sampler, meaning that when the smallest synthetic event has an exceedance probability of 1% (0.01), the total probability assigned to the synthetic events is not 0.01 but rather 0.0125. Thus, the total probability taken from the historical events is 0.0125.

To include probability overrides in the Bootstrapping Historical/Synthetic Basin-wide Events sampling method, from the **Hydrologic Sampling Editor** (Figure 3-3), select the **Incremental Probability Override** option. The **Probability Override** tab will be enabled (Figure 3-3). The **Incremental Probability Override** table (Figure 3-3) provides the synthetic event name (or water year), year type, maximum duration flow, and computed incremental probability. The last column, **Override Incremental Probability** (Figure 3-3) is where the user-defined incremental probabilities for the all listed water years and synthetic events.

When values are copied into the **Override Incremental Probability** column (Figure 3-4), click any cell in the table to update the **Incremental Probability Total** value. Cells in the **Override Incremental Probability** column are color-coded (Figure 3-4):

Water Year or Synthetic Name	Year Type	Duration Maximum Flow (cfs)	Computed Incremental Probability	Override Incremental Probability
1953	Historic	478,762.17	0.014085	0.014085
1953	Historic	482,762.17	0.014085	0.014085
1946	Historic	484,467.27	0.014085	
1951	Historic	486,515.90	0.014085	0.014085
1991	Historic	487,563.58	0.014085	0.02
1984	Historic	493,343.27	0.014085	0.014085
1952	Historic	494,838.00	0.014085	-0.01
1999	Historic	497,267.35	0.014085	0.014085
1976	Historic	497,736.02	0.014085	0.014085
1958	Historic	498,178.13	0.014085	0.014085
Incremental Probability Total			1.000000	.967777

Figure 3-4 Probability Override Tab – Color Codes

- Yellow: empty cell, which must be filled, or zero.
- White: the entered value equals the original value produced by the Hydrologic Sampler computation.
- Blue: the entered value is different from the original value produced by the Hydrologic Sampler computation.
- Red: the entered value is negative, which is not an allowable probability.

The **Incremental Probability Total** boxes are also color-coded (Figure 3-4):

- Red: override incremental probabilities sum to a value that is either greater than or less than 1.00, within a tolerance.
- Green: override incremental probabilities sum near 1.00, within a tolerance.

Once the required values have been entered, if the **Incremental Probability Total** sums to 1.00 the box turns green. Figure 3-3 displays an example of a completed **Incremental Probability Override** table.

Click **Apply** to save the selected hydrologic sampling alternative when navigating between alternatives. Alternatively, click **OK** to save the hydrologic sampling alternative and close the **Hydrologic Sampling Editor**. **Data Check** (Section 1.2.6) can be used to search for data consistency error(s) prior to closing the editor.

3.2 Settings Tab

From the **Settings** tab hydrograph locations are selected; ranking of the historical record events, uncertainty method, and define the exceedance probability of the synthetic events are available from the **Hydrographs** tab. If the **Include Forecasts** option (Section 3.1.1) has been selected, forecast information about the defined hydrograph locations will be entered on the **Forecasts** tab.

3.2.1 Hydrographs Tab

Select the required hydrograph locations:

1. From the **Hydrographs** tab (Figure 3-1), click **Select Hydrograph Locations**, the **Selection Editor** will open (Figure 3-5).

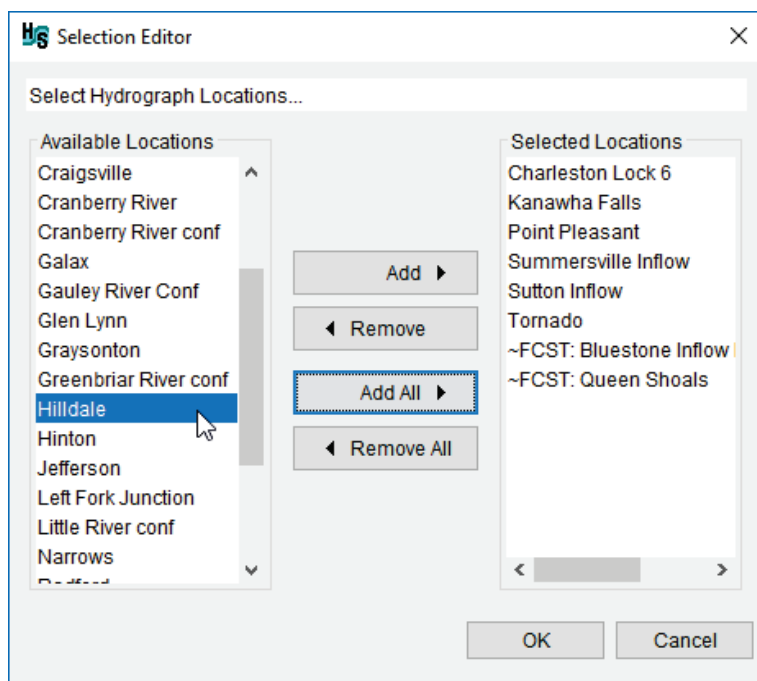


Figure 3-5 Selection Editor

2. Select hydrograph location(s) from the **Available Locations** list (Figure 3-5) individually (e.g., *Hilldale*), or select multiple locations while holding down the **Ctrl** key, click **Add**, this will move the selected location(s) to the **Selected Locations** list. **Add All** moves all locations from the **Available Locations** list to the **Selected Locations** list. Alternatively, double-clicking on a desired location (e.g., *Hilldale*) will move the location from the **Available Locations** list to the **Selected Locations** list.
3. To remove locations from the **Selected Locations** list (Figure 3-5), select a location, either click **Remove** for individually selected locations, or click **Remove All** to remove all selected locations from the **Selected Locations** list, and move the locations back to the **Available Locations** list.

Note, users can add or remove hydrograph locations at any time. However, if users attempt to remove hydrograph locations, a **Location Selection Warning** message window will open (Figure 3-6), which requires users to confirm the deletion of the selected hydrograph location(s) and all related information. Furthermore, for users editing an existing hydrologic sampling alternative when forecast locations have been selected (Section 3.2.2), these locations are displayed with "~FCST:" in front of the location name at the bottom of the **Selected Locations** list (Figure 3-5). The "~FCST:" indicates that those locations were already selected as hydrograph locations as well as forecast locations.

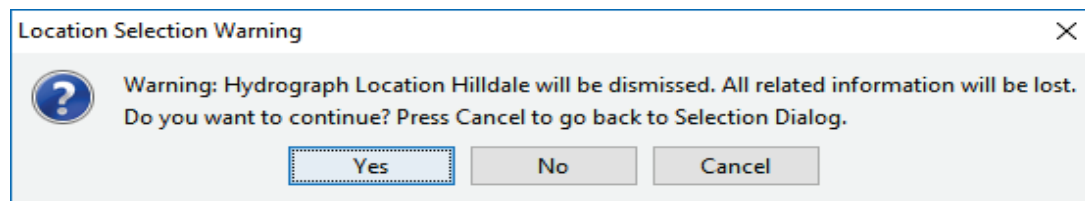


Figure 3-6 Location Selection Warning Message Window

4. Following the successful selection of the hydrograph location(s), click **OK**, and the **Selection Editor** will close (Figure 3-5).
5. The **Location for event ranking** list (Figure 3-1) will now contain the selected hydrograph locations. For each hydrograph location, the user will need to define the flow location and uncertainty method.

Location for Event Ranking and Flow Duration

The next step is to select the location used to rank the events/years in the historical record by maximum volume, and set the duration of that volume. The historical record is ranked to identify the largest events, and those events contribute a portion of their allotted incremental probability to the set of synthetic events. Generally, the selected location should be significant, since it is used by the Hydrologic Sampler to represent the watershed as a whole. Note, while the time series provided for the Bootstrapping Historical/Synthetic Basin-wide Events sampling method generally consists of system inflows needed in the watershed models, the user can include an additional location with a time series for the ranking that is not needed as model input (e.g., total channel flow).

1. From the **Hydrologic Sampling Editor** (Figure 3-1), from the **Ranking of Historical Record Events** box, from the **Location for event ranking** list select a hydrograph location (choose the location that best represents the watershed as a whole).
2. From the **Flow duration for event ranking (days)** list (Figure 3-1) select the appropriate flow duration for the selected hydrograph location. Available options are 1, 2, 3, 5, 7, 15, 30, 45, 60, and 90 days. The Hydrologic Sampler computes the maximum average flow across the selected duration to rank the historical events (**Historical Record** tab, Section 3.3) from largest to smallest. For all hydrograph locations, repeat Steps 1 and 2.

Uncertainty

Next, define the uncertainty in frequency to use in the Bootstrapping Historical/Synthetic Basin-wide Events sampling method. From the **Hydrologic Sampling Editor** (Figure 3-1), from the **Uncertainty Method** panel (Figure 3-7), set the uncertainty options and the corresponding user inputs required are:



Figure 3-7 Hydrographs Tab – Uncertainty Method

- **No uncertainty** – In this case, the sub-sample that captures uncertainty in each realization is not created. All historical record and synthetic events are included in the event "bucket" for all realizations, using their computed or overridden incremental probabilities.
- **Equivalent Years of Record** – With this choice, uncertainty in the frequency description is defined by the sampling error due to limited record length. At the beginning of each realization, a sub-sample of size N that equals **Equivalent Years of Record** (Figure 3-7) is generated, and then used as the event "bucket" for that realization. All events in the sub-sample are given equal incremental probability, because the sub-sample is a possible realization of an historical record.

Exceedance Probabilities of Synthetic Events

The **Exceedance Probabilities of Synthetic Events** panel (Figure 3-8) contains a table where the user defines the exceedance probabilities (and corresponding return periods) available for synthetic events (Section 3.4). The user does not need to make use of all of the available probabilities when creating synthetic events. Conversely, if a required exceedance probability is not present in the default table, the user may add the desired exceedance probability to the table.

Exceedance Probability	Return Period
0.0500	20
0.0200	50
0.0100	100
0.0040	250
0.0020	500
0.0010	1000

New Delete

Figure 3-8 Hydrographs Tab – Exceedance Probabilities of Synthetic Events Table

Modifying the **Exceedance Probabilities of Synthetic Events** table:

1. From the **Hydrologic Sampling Editor** (Figure 3-1), from the **Hydrographs** tab, from the **Exceedance Probabilities of Synthetic Events** panel (Figure 3-8), click **New**, and the **New Exceedance Probability** dialog box opens (Figure 3-9).

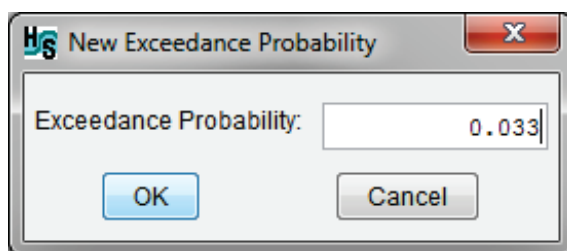


Figure 3-9 New Exceedance Probability Dialog Box

2. Enter the desired exceedance probability, between 0.00 – 1.00, in the **Exceedance Probability** box, click **OK**. The **New Exceedance Probability** dialog box will close (Figure 3-9) and the **Exceedance Probabilities of Synthetic Events** table updates automatically with the new exceedance probability value and associated return period.
3. Repeat Steps 1 and 2 until the **Exceedance Probabilities of Synthetic Events** table (Figure 3-8) contains the desired exceedance probabilities.

To delete exceedance probabilities from the **Exceedance Probabilities of Synthetic Events** table (Figure 3-8):

4. From the **Hydrologic Sampling Editor** (Figure 3-1), from the **Hydrographs** tab, from the **Exceedance Probabilities of Synthetic Events** panel (Figure 3-8), select the exceedance probability to delete, click **Delete**. The **Exceedance Probabilities Message** window will open (Figure 3-10). Click **Yes** to confirm the deletion, the **Exceedance Probabilities Message** window will close. The table updates with the selected exceedance probability deleted from the table. Repeat this step as necessary to remove individual exceedance probabilities from the table.

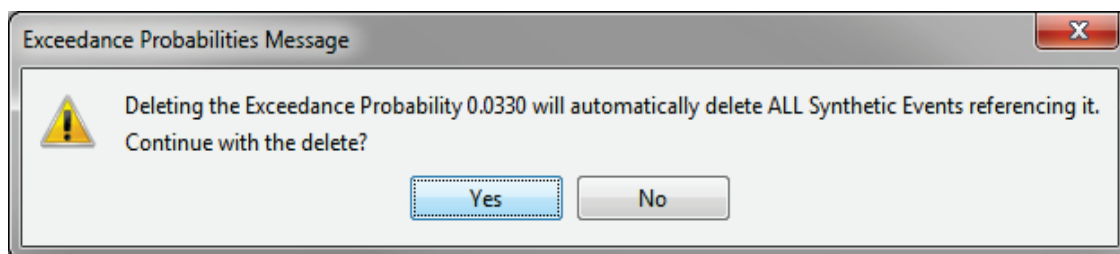


Figure 3-10 Exceedance Probabilities Message Window

3.2.2 Forecasts Tab

From the **Forecasts** tab, (Figure 3-11) users will define forecast locations based on hydrograph locations that have already been defined. From the **Forecast Statistics** panel, a table for entering the forecast statistics for each defined forecast location is available.

The screenshot shows the "Hydrologic Sampling Editor" window with the "Forecasts" tab selected. The "Name" field is "Ex_Bootstrap". The "Data to be Sampled" is "Flow Sampling" and the "Sampling Method" is "Bootstrapping Historical/Synthetic Basin-wide Events". The "Start of Water Year" is "01Jan". There are checkboxes for "Include Forecasts" (checked) and "Incremental Probability Override" (unchecked). Below these are tabs for "Settings", "Historical Record", "Synthetic Events", "Synthetic Summary", and "Probability Override". The "Forecasts" sub-tab is active, showing a "Location" dropdown and a "Select Forecast Locations..." button. Below this is a "Forecast Statistics" table with columns: Date, Min Forecast Override (KAF), Relationship of Error to Magnitude (subdivided into Mean Error Intercept (KAF) and Mean Error Slope), Standard Error (KAF), and Serial Correlation. The table has 6 rows. At the bottom are "Data Check", "OK", "Cancel", and "Apply" buttons.

Figure 3-11 Hydrologic Sampling Editor – Bootstrapping Historical/Synthetic Basin-wide Events – Settings Tab – Forecasts Tab

It is important to note that users can only generate random hydrologic forecasts at locations in the watershed, which also include the inflow hydrograph time series for that location. In other words, forecast locations can only be selected from the list of available hydrograph locations (Section 3.2.1). For this reason, the **Hydrographs** tab must have at least one hydrograph location selected before the **Forecasts** tab can be completed. If a hydrograph location has not been

selected and users attempt to add forecast locations, then a **No Available Locations** message window will open, reminding the user to first define hydrograph locations (primary locations) before trying to select forecast locations. Therefore, the hydrograph location setup must be completed (Section 3.2.1) prior to including forecast locations in a hydrologic sampling alternative.

Select Forecast Locations

The first step is to select forecast locations from the defined hydrograph locations of the watershed:

1. From the **Forecasts** tab (Figure 3-11), click **Select Forecast Locations**, a **Selection Editor** will open (similar to Figure 3-5). The editor allows users to identify forecast location(s) from the list of hydrograph locations that have been defined for the watershed (e.g., *Bluestone Inflow Near Glen Lynn*).
2. Select forecast location(s) from the **Available Locations** list (Figure 3-5) individually (e.g., *Hilldale*), or select multiple locations while holding down the **Ctrl** key, click **Add**, this will move the selected location(s) to the **Selected Locations** list. **Add All** moves all locations from the **Available Locations** list to the **Selected Locations** list. Alternatively, double-clicking on a desired location (e.g., *Hilldale*) will move the location from the **Available Locations** list to the **Selected Locations** list.
3. To remove locations from the **Selected Locations** list (Figure 3-5), select a location, either click **Remove** for individually selected locations, or click **Remove All** to remove all selected locations from the **Selected Locations** list, and move the locations back to the **Available Locations** list.

Note, users can add or remove forecast locations at any time. However, if users attempt to remove forecast locations, a **Location Selection Warning** message window will open (similar to Figure 3-6), which requires users to confirm the deletion of the selected forecast location(s) and all related information.

4. Following the successful selection of the forecast location(s), click **OK**, and the **Selection Editor** will close (Figure 3-5).
5. The **Location** list (Figure 3-11) will now contain the selected forecast locations. For each forecast location, the user will need to define forecast statistics.

Forecast Statistics

Now that forecast location(s) have been defined, users need to complete the forecast statistics table (Figure 3-12). Information required for the table includes forecast dates and error statistics for each identified forecast location. The error statistics of mean, standard error and serial correlation are used in the AR(1) forecast generation process. At least one forecast date (e.g., *01Jan*) needs to be defined for a forecast location.

Hydrographs Forecasts

Location: Bluestone Inflow Near Glen Lynn

Select Forecast Locations...

Forecast Statistics

Date	Min Forecast Override (KAF)	Relationship of Error to Magnitude		Standard Error (KAF)	Serial Correlation
		Mean Error Intercept (KAF)	Mean Error Slope		
01Mar	44.89488	278.54	-0.1094	8.0	
01Apr	42.26052	-885.28	0.4781	2.735763148	0.6675
01May	38.88903	-1140.2	0.6058	1.470238076	0.62
01Jun	35.92225	-1261.6	0.6678	0.56	0.48

Figure 3-12 Settings Tab – Forecasts Tab – Forecast Statistics Table

Define the forecast date(s), forecast statistics, and serial correlation for each forecast location:

1. From the **Location** list (Figure 3-12), select a forecast location of interest (e.g., *Bluestone Inflow Near Glen Lynn*).
2. In the **Forecast Statistics** table (Figure 3-12), from the **Date** column, click the dropdown list to select a forecast date (e.g., *01Mar*).
3. The **Min Forecast Override** value (Figure 3-12), is a pseudo-random value that can be very small, producing a very small forecast that is outside the range of the true real-time forecast method. The user should enter the smallest forecast value (kilo-acre-feet, KAF) that can be produced by the real-time forecast method (e.g., *44.89488*) that would be used in decision-making.
4. Forecasts tend to be biased toward the average of possible outcomes of the value being forecasted. Thus, large volumes tend to be under-forecasted, and small volumes tend to be over-forecasted. The Hydrologic Sampler random forecast generation method uses a bias line that defines a mean forecast error as a function of the starting forecast value. This mean is used in the autoregressive lag 1, AR(1), forecast generation.

The **Relationship of Error to Magnitude** (Figure 3-12) data provides the necessary data for the forecast generation method:

- i. From the **Mean Error Intercept** column (Figure 3-12), the user will enter the intercept of the error bias line (e.g., *278.54*) in KAF. Enter *0.0* if no bias line is desired.
 - ii. From the **Mean Error Slope** column (Figure 3-12), the user will enter the intercept of the slope of the error bias line (e.g., *-0.1094*). Enter *0.0* if no bias line is desired.
5. From the **Standard Error** column (Figure 3-12), the user will enter the standard error that will be used in the AR(1) forecast generation (e.g., *8.0*).

6. When more than one forecast date has been entered in the forecast statistics table, a serial correlation of forecast must be defined between each date and the previous date in the **Serial Correlation** column (Figure 3-12). For example, in Figure 3-12, a second forecast date has been defined, with a serial correlation of 0.6675 being entered.
7. For each row in the **Forecast Statistics** table (Figure 3-12), the user can enter data by repeating Steps 1 through 6.

Alternatively, users can copy and paste values from an outside source (e.g., Microsoft® Excel or a text editor), as long as the copied data is tab delimited. Several shortcut menus are available that provide commands for editing tables (Section 1.2.4).

8. The **Forecast Statistics** table defaults to six rows, but if more than six forecast dates are required then additional row(s) can be added. To insert extra row(s), right-click in a cell in the last row, from the shortcut menu (Section 1.2.4); click **Insert Row(s)**. The **Insert Row(s)** dialog box will open, which allows the user to set the number of rows to add to the **Forecast Statistics** table.
9. Click **Apply** (Figure 3-11) to save changes made to the **Forecasts** tab. Alternatively, if a user is finished adding information or editing, click **OK** to close the **Hydrologic Sampling Editor** (Figure 3-11). Users can click **Data Check** (Section 1.2.6) to determine if any forecast locations were missed before proceeding to the **Historical Record** tab (Section 3.3), if desired. Note, **Data Check** is generally used after all required inputs have been defined to avoid generating a long list of as-yet undefined inputs.

3.3 Historical Record Tab

From the **Hydrologic Sampling Editor**, click the **Historical Record** tab (Figure 3-13); this tab is where for the Bootstrapping Historical/Synthetic Basin-wide Events sampling method the user must at least one historical hydrograph DSS record for each hydrograph location (Section 3.2.1) must be defined.

All historical records (for all locations) must span exactly the same time-window, meaning that the hydrographs have the same start and end dates and times. Within each year of the historical period of record, the relevant hydrograph time series for a study can have time-windows that extend from a single day to a full year. The benefit of defining shorter time-windows (less than a full year) is a reduction in the FRA compute time, but this should be balanced with ensuring that time-windows are long enough to capture full routing of the storm events of interest. If the **Include Forecasts** option (Section 3.1.1) has been selected, forecast information about the selected historical locations will be entered on the **Forecasts** tab (see Section 3.3.2).

Hydrologic Sampling Editor

Name: Ex_Bootstrap_Defaults

Description: Copy of Copy of Ex_Bootstrap

Data to be Sampled: Flow Sampling

Sampling Method: Bootstrapping Historical/Synthetic Basin-wide Events

Start of Water Year: 02Oct

☐ Include Forecasts ☐ Incremental Probability Override

Settings | **Historical Record** | Synthetic Events | Synthetic Summary | Probability Override

Hydrographs | Forecasts

Location	DSS File	Part A	Part B	Part C	Part E	Part F
Bluestone Inflow Near Glen Lynn						
Charleston Lock 6						
Hilldale						
Kanawha Falls						
Point Pleasant						
Queen Shoals						
Summersville Inflow						
Sutton Inflow						
Tornado						

Plot... Tabulate... Select DSS Path...

Data Check OK Cancel Apply

Figure 3-13 Hydrologic Sampling Editor – Bootstrapping Historical/Synthetic Basin-wide Events – Historical Record Tab

3.3.1 Hydrographs Tab

The **Hydrographs** tab (Figure 3-13) contains a DSS time series panel, where a user will select the DSS records for the flow time series spanning the historical period of record, providing the events to be sampled. The selected DSS time series records need to span the historical period of record and contain data only for the relevant time periods within each year (e.g., the flood event(s) time-window(s)), with blanks for all other time periods. The length of an event within each year can vary. Furthermore, the flood event time-windows (start and end dates and times) must also be the same for all locations.

For example, Figure 3-14, displays a historical flow time series for an entire period of record for the watershed. Figure 3-15 displays an example annual rain event and an example annual snowmelt runoff for three different locations in the watershed.

However, if the FRA compute in the watershed model is actually intended to simulate a full year, rather than shorter events within each year, the time series records can be continuous. In this case, data would be present in all time periods within the entire period of record without blanks. The **Start of Water Year** (Section 3.1) defines the beginning of each year to divide the historical record into annual events for sampling, and it is important to specify this correctly when using continuous data.

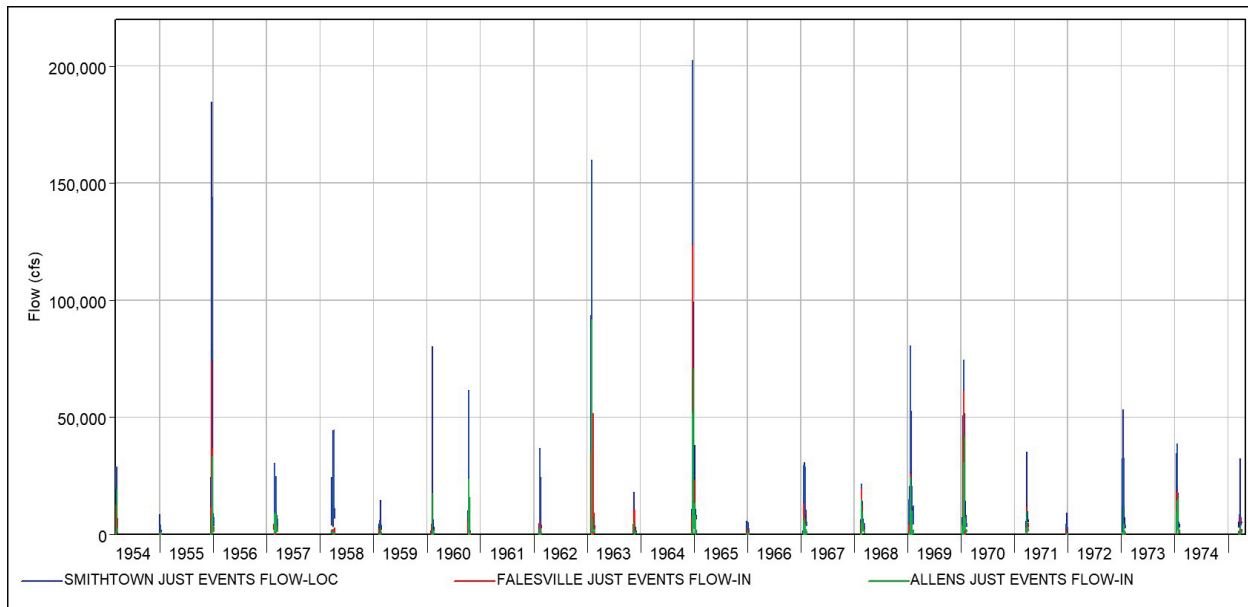


Figure 3-14 Historical Hydrographs – Example DSS Time Series for a Period of Record

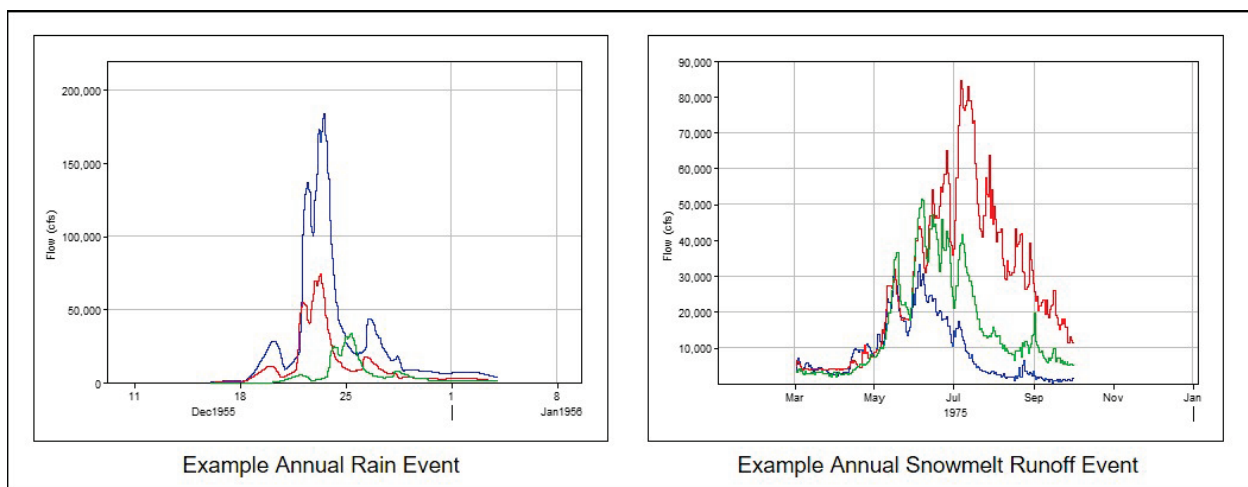


Figure 3-15 Example Annual Rain Event and Example Annual Snowmelt Runoff Event

To specify the DSS time series that defines the historical inflow hydrographs throughout the watershed, from the **Hydrologic Sampling Editor**, click the **Historical Record** tab (Figure 3-13). From the **Hydrographs** tab, from the DSS time series panel:

1. For each **Location** (hydrograph) listed, a DSS path must be identified (**DSS File** and pathname **Parts A – F**). To define the DSS record for a location of interest, click on a cell of the row of the hydrograph location (Figure 3-13).
2. Click **Select DSS Path** (Figure 3-13), the **HEC-DSSVue** dialog box will open (Figure 3-16). Refer to the HEC-DSSVue User's Manual for more information regarding DSS pathnames and HEC-DSSVue.

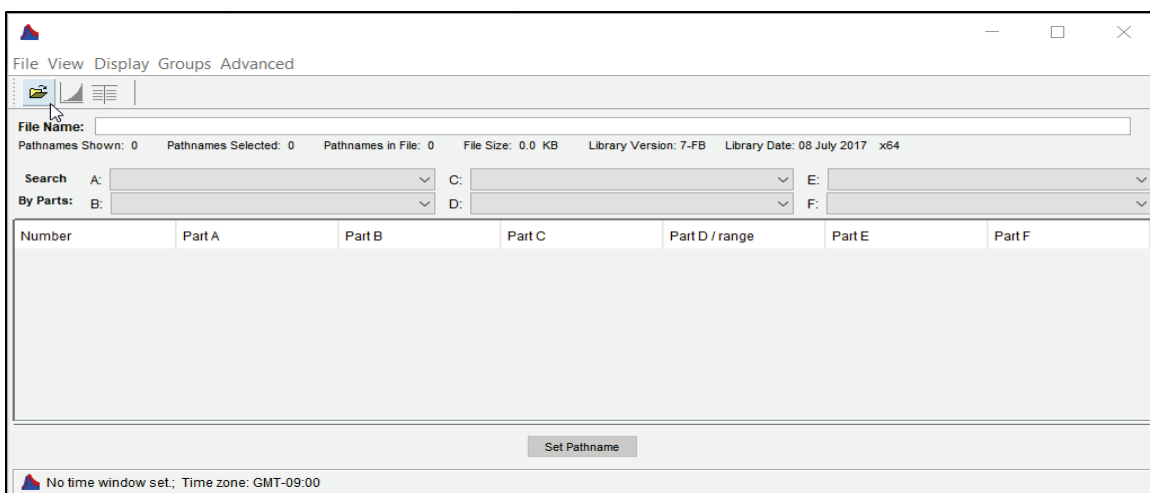



Figure 3-16 HEC-DSSVue Dialog Box

- From the **HEC-DSSVue** dialog box, click  (Figure 3-16); the **Open HEC-DSS File** browser will open (Figure 3-17). Browse to the location of a DSS file (*.dss) that contains the time series of interest (e.g., hydrographs). Click on the appropriate *.dss file, the **File name** box now contains the name of the selected file (e.g., *trimmed_Bluestone_In.dss*).

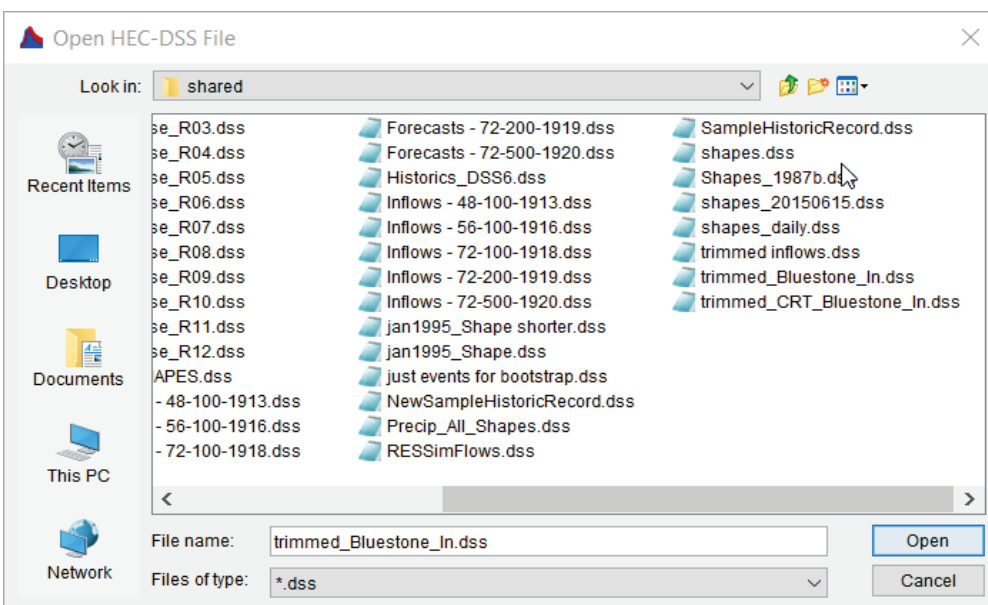


Figure 3-17 Open HEC-DSS File Browser

- Click **Open**, the **Open HEC-DSS File** browser will close (Figure 3-17). The **HEC-DSSVue** dialog box (Figure 3-16) now displays the DSS records for the selected DSS file.
- For the location (e.g., *Bluestone Inflow Near Glen Lynn*) that was selected in the DSS input table in the **Hydrologic Sampling Editor** (Figure 3-13), find and select the proper pathname (record) from the list of DSS records in the **HEC-DSSVue** dialog box (Figure 3-16), click **Set Pathname**. From the **Hydrologic Sampling Editor** (Figure 3-18), the

DSS input table now contains the **DSS File** pathname (Parts A – F) for the selected **Location** (e.g., *Bluestone Inflow Near Glenn Lynn*).

Hydrographs Forecasts						
Location	DSS File	Part A	Part B	Part C	Part E	Part F
Bluestone Inflow Near Glen Lynn	shared/trimmed_Bluestone_In.dss		BLUESTONE_IN	FLOW-UNREG	1Day	COMPUTED
Charleston Lock 6	shared/trimmed_Bluestone_In.dss		CHARLESTON_LOCK_6_IN	FLOW-UNREG	1Day	COMPUTED
Hilldale	shared/trimmed_Bluestone_In.dss		HILLDALE_IN	FLOW-UNREG	1Day	COMPUTED
Kanawha Falls	shared/trimmed_Bluestone_In.dss		KANAWHA_FALLS_IN	FLOW-UNREG	1Day	COMPUTED
Point Pleasant	shared/trimmed_Bluestone_In.dss		POINT_PLEASANT_IN	FLOW-UNREG	1Day	COMPUTED
Queen Shoals	shared/trimmed_Bluestone_In.dss		QUEEN_SHOALS_IN	FLOW-UNREG	1Day	COMPUTED
Summersville Inflow	shared/trimmed_Bluestone_In.dss		SUMMERSVILLE_IN	FLOW-UNREG	1Day	COMPUTED
Sutton Inflow	shared/trimmed_Bluestone_In.dss		SUTTON_IN	FLOW-UNREG	1Day	COMPUTED
Tornado	shared/trimmed_Bluestone_In.dss		TORNADO_IN	FLOW-UNREG	1Day	COMPUTED

Figure 3-18 Hydrographs Tab – Completed DSS Record Definition for Hydrograph Locations

6. Select the next location, from the **HEC-DSSVue** dialog box (Figure 3-17), find and select the proper pathname (record) from the list of DSS records in the **HEC-DSSVue** dialog box (Figure 3-16), click **Set Pathname**. Repeat this step until all locations in the DSS input table (Figure 3-18) contain the correct DSS filename and the DSS pathnames.
7. Click **Apply** (Figure 3-13), this saves data and keeps the **Hydrologic Sampling Editor** open for further modifications. When finished, click **OK** (Figure 3-13) to save the selected hydrologic sampling alternative and close the **Hydrologic Sampling Editor**. **Data Check** (Section 1.2.6) can be used to search for data consistency error(s) prior to closing the editor.

3.3.2 Forecasts Tab

From the **Forecasts** tab (Figure 3-19), of the **Historical Record** tab, a user will select the DSS records for the forecast locations that were defined in the **Settings** tab (Section 3.2.2).

Hydrologic Sampling Editor

Name: Ex_Bootstrap_Defaults

Description: Copy of Copy of Ex_Bootstrap

Data to be Sampled: Flow Sampling

Sampling Method: Bootstrapping Historical/Synthetic Basin-wide Events

Start of Water Year: 02Oct

☒ Include Forecasts ☐ Incremental Probability Override

Settings | Historical Record | Synthetic Events | Synthetic Summary | Probability Override

Hydrographs | Forecasts

Location	DSS File	Part A	Part B	Part C	Part E	Part F
Bluestone Inflow Near Glen Lynn						
Sutton Inflow						

Plot... Tabulate... Select DSS Path...

Data Check OK Cancel Apply

Figure 3-19 Hydrologic Sampling Editor – Bootstrapping Historical/Synthetic Basin-wide Events – Historical Record Tab – Forecasts Tab

Select Historical Forecast Time Series

Forecast DSS time series data is required for the forecast sampling option and is used as the starting volume to which randomly sampled forecast error is added. Most commonly, these values will be the actual or "true" volumes that a forecast is targeting. For example, the actual April through August volume of a year is typically used as the starting value for a randomly generated snowmelt forecast of April through August volume. A generated error deflects the forecast from the actual value by an amount randomly sampled from the forecast error statistics and an Autoregressive lag 1, AR(1), sampling process. Each specified forecast DSS time series must have a volume value in KAF for every forecast date of every year.

The DSS time series of initial forecast volumes for the historical record (**Forecasts** tab, Figure 3-19) must match the historical flow record (**Hydrographs** tab, Figure 3-13). To illustrate this period of record relationship, Figure 3-20 displays an example of a flow record (for snowmelt runoff hydrology, displayed in blue) at a location with forecasts, and the corresponding time series of forecast volumes (displayed in red) for the same period of record.

When including forecasts in the Bootstrapping Historical/Synthetic Basin-wide Events sampling method, the forecast time series must be specified in a particular manner so that models following a hydrologic sampling alternative in an HEC-WAT compute, do not interpolate a forecast volume between forecast dates incorrectly. To ensure a correct interpolated value, the time series data must contain a value for both the beginning and the end of each forecast period. For example, Figure 3-20 and 3-21 illustrate the forecast time series requirements for two types of forecasts.

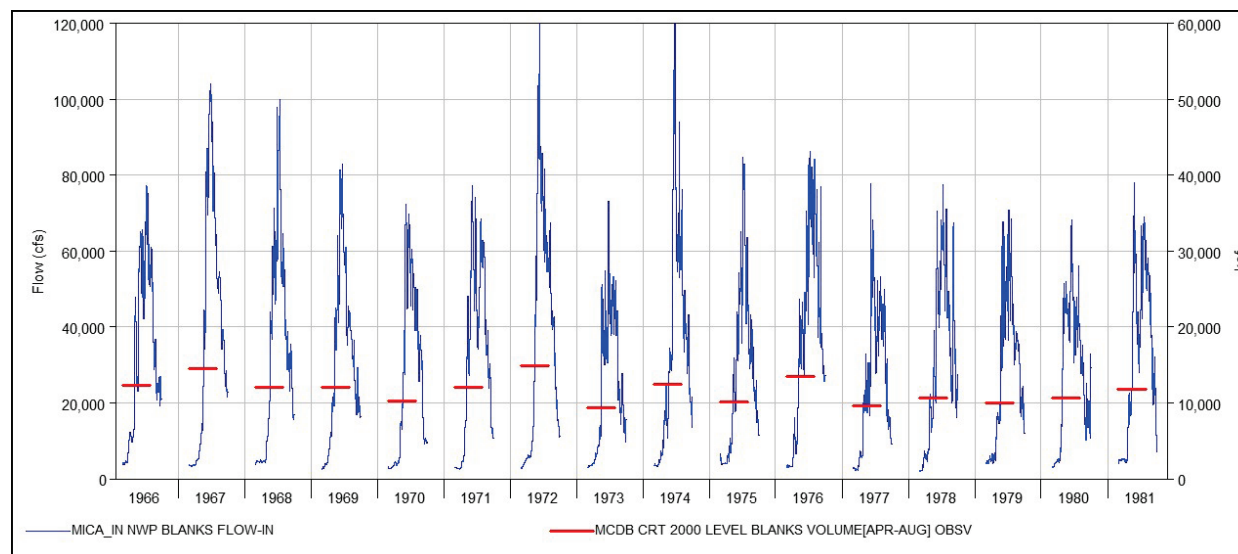


Figure 3-20 Example Historical Hydrographs from Continuous Snowmelt Runoff (*blue lines*), and Forecast (*red lines*) Time Series for a Period of Record

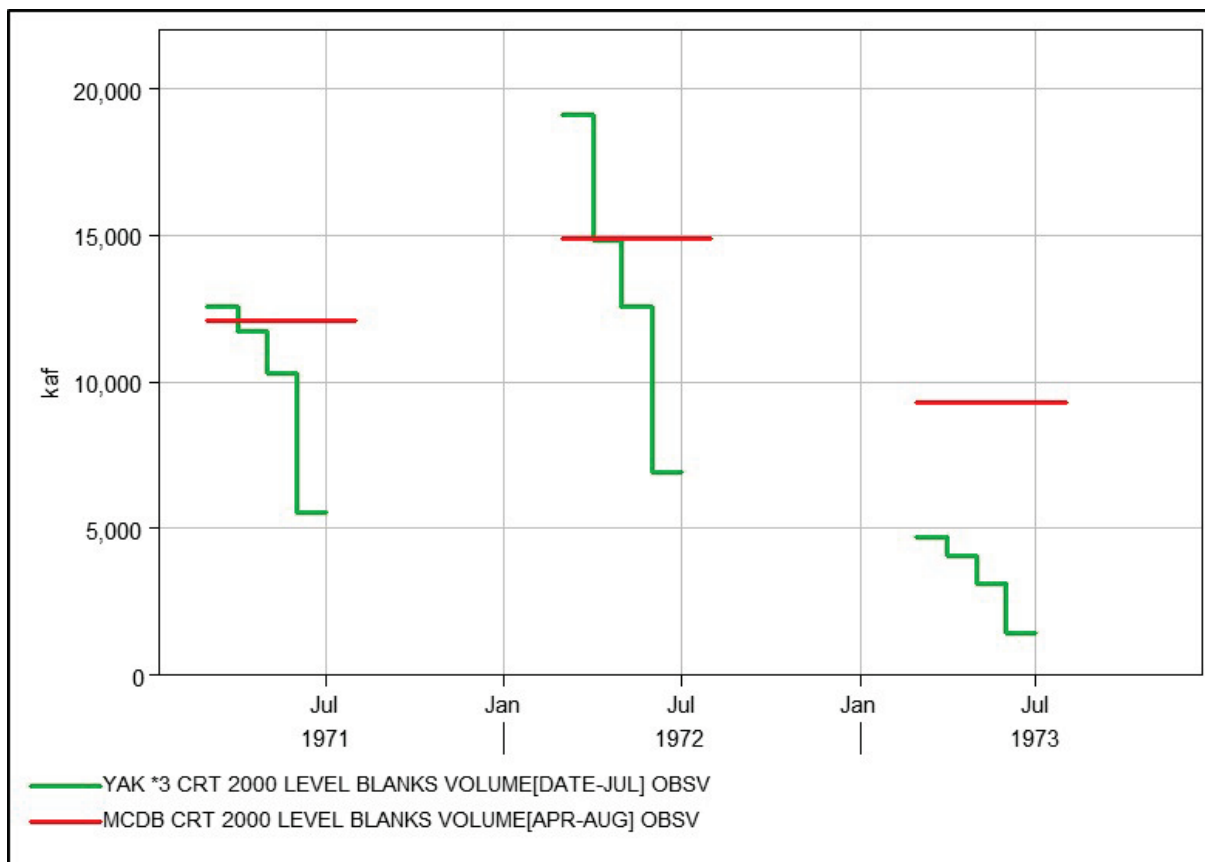
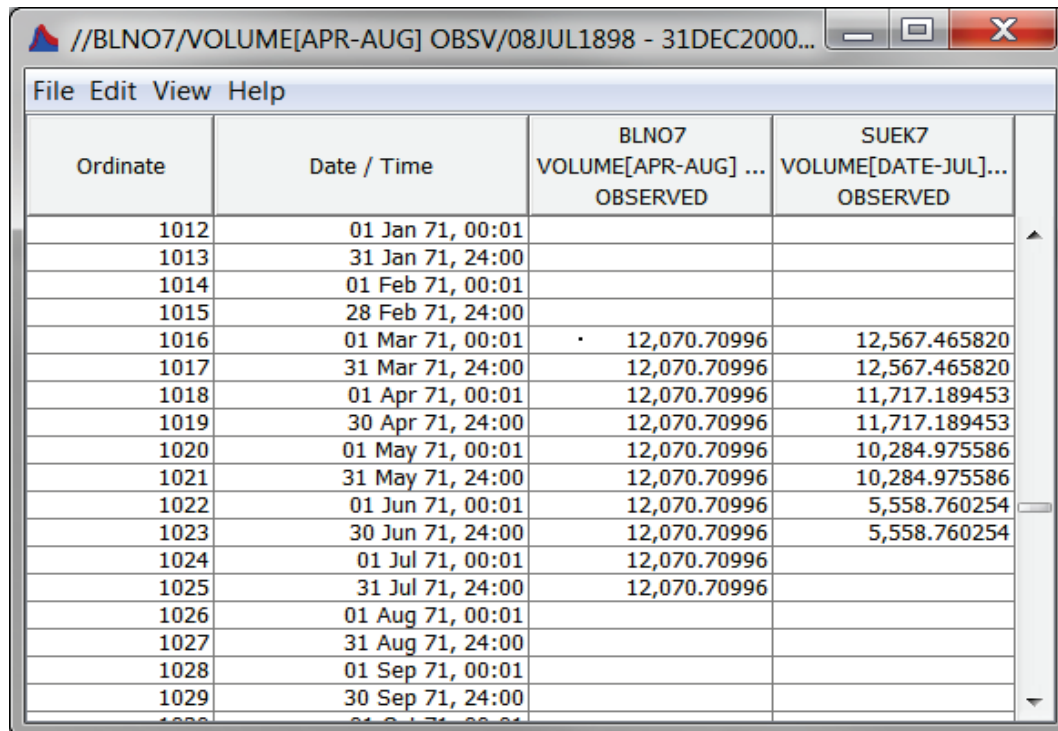


Figure 3-21 Historical Forecasts (Abbreviated) – Two Examples for Annual Snowmelt Runoff Volume

Figure 3-21 includes both a close-up view of a representative three years of the forecast time series displayed in Figure 3-20 (red time series), and an example of a different type of forecast (green time series). In Figure 3-21, the red time series shows monthly forecasts for March 1 through June 1 for which each forecast targets the April through July streamflow volume. Within the forecast period, the true value of every forecast is thus constant. Conversely, the green time series displayed in Figure 3-21 contains monthly forecasts for March 1 through July 1 for which each forecast targets the streamflow volume from the date of the forecast through the end of July (called "date – July"). Specifically, for the green time series (Figure 3-21), the true value of each forecast thus decreases by the volume of the previous month, within the forecast period.

To illustrate the forecast time series requirements, Figure 3-22 provides an example of a tabulated forecast time series, that is displayed graphically in Figure 3-20. Specifically, the tabulated time series for location *BLNO7*, which corresponds to the red time series displayed in Figure 3-20, lists a constant forecast volume (*12,070.7 KAF*) for March 1 through July 31. In comparison, the tabulated times series for location *SUEK7*, which corresponds to the green time series displayed in Figure 3-20, lists the March forecast volume (e.g., *12,567.5 KAF*) for March 1 through March 31, then changes to a lower value on April 1. Specification of both the beginning and ending date is necessary for forecasts so that the forecast value is accurate for any day within the forecast period of interest (e.g., March through July).




Ordinate	Date / Time	BLNO7 VOLUME[APR-AUG] ... OBSERVED	SUEK7 VOLUME[DATE-JUL]... OBSERVED
1012	01 Jan 71, 00:01		
1013	31 Jan 71, 24:00		
1014	01 Feb 71, 00:01		
1015	28 Feb 71, 24:00		
1016	01 Mar 71, 00:01	12,070.70996	12,567.465820
1017	31 Mar 71, 24:00	12,070.70996	12,567.465820
1018	01 Apr 71, 00:01	12,070.70996	11,717.189453
1019	30 Apr 71, 24:00	12,070.70996	11,717.189453
1020	01 May 71, 00:01	12,070.70996	10,284.975586
1021	31 May 71, 24:00	12,070.70996	10,284.975586
1022	01 Jun 71, 00:01	12,070.70996	5,558.760254
1023	30 Jun 71, 24:00	12,070.70996	5,558.760254
1024	01 Jul 71, 00:01	12,070.70996	
1025	31 Jul 71, 24:00	12,070.70996	
1026	01 Aug 71, 00:01		
1027	31 Aug 71, 24:00		
1028	01 Sep 71, 00:01		
1029	30 Sep 71, 24:00		

Figure 3-22 Historical Forecasts (Abbreviated) – Tabulated Example Continuous Annual Snowmelt Runoff Volume – Tabulated

To specify the DSS time series that defines the forecast volume for specific locations, from the **Hydrologic Sampling Editor**, click the **Historical Record** tab. From the **Historical Record** tab click the **Forecasts** tab (Figure 3-19), from the DSS input table, users must specify the DSS time series that defines the historical forecast volume for each selected forecast location (Section 3.2.2) listed in the DSS input table. Note that each specified forecast time series must have a volume value for every forecast date (e.g., *01Jan*, Figure 3-22) of every year in the period of record.

To complete the **Forecasts** tab (Figure 3-19) of the **Historical Record** tab:

1. For each **Location** (forecast) listed, a DSS path must be identified (**DSS File** and pathname **Parts A – F**). To define the DSS record for a location of interest, click on a cell of the row of the forecast location (Figure 3-19).
2. Click **Select DSS Path** (Figure 3-19), the **HEC-DSSVue** dialog box will open (Figure 3-16). Refer to the HEC-DSSVue User's Manual for more information regarding DSS pathnames and HEC-DSSVue.
3. From the **HEC-DSSVue** dialog box, click  (Figure 3-16); the **Open HEC-DSS File** browser will open (Figure 3-17). Browse to the location of a DSS file (*.dss) that contains the time series of interest (e.g., hydrographs). Click on the appropriate *.dss file, the **File name** box now contains the name of the selected file (e.g., *Bluestone_Forecasts-Historical.dss*).

- Click **Open**, the **Open HEC-DSS File** browser will close (Figure 3-17). The **HEC-DSSVue** dialog box (Figure 3-16) now displays the DSS records for the selected DSS file.
- For the location (e.g., *Bluestone Inflow Near Glen Lynn*) that was selected in the DSS input table in the **Hydrologic Sampling Editor** (Figure 3-19), find and select the proper pathname (record) from the list of DSS records in the **HEC-DSSVue** dialog box (Figure 3-16), click **Set Pathname**. From the **Hydrologic Sampling Editor** (Figure 3-23), the DSS input table now contains the **DSS File** pathname (Parts A – F) for the selected **Location** (e.g., *Bluestone Inflow Near Glenn Lynn*).

Hydrographs		Forecasts				
Location	DSS File	Part A	Part B	Part C	Part E	Part F
Bluestone Inflow Near Glen Lynn	shared/Bluestone_Forecasts-Historical.dss		ROU	VOLUME[DATE-JUL] FCST	IR-Century	CRT 2000 LEVEL
Sutton Inflow	shared/Bluestone_Forecasts-Historical.dss		CHL	VOLUME[DATE-JUL] FCST	IR-Century	CRT 2000 LEVEL

Figure 3-23 Forecasts Tab – Completed DSS Record Definition for Forecast Locations

- Select the next location, from the **HEC-DSSVue** dialog box (Figure 3-17), find and select the proper pathname (record) from the list of DSS records in the **HEC-DSSVue** dialog box (Figure 3-16), click **Set Pathname**. Repeat this step until all locations in the DSS input table (Figure 3-23) contain the correct DSS filename and the DSS pathnames.
- Click **Apply** (Figure 3-19), this saves data and keeps the **Hydrologic Sampling Editor** open for further modifications. When finished, click **OK** (Figure 3-19) to save the selected hydrologic sampling alternative and close the **Hydrologic Sampling Editor**. **Data Check** (Section 1.2.6) can be used to search for data consistency error(s) prior to closing the editor.

3.4 Synthetic Events Tab

From the **Hydrologic Sampling Editor**, the **Synthetic Events** tab (Figure 3-24) allows users to include synthetic, probability-based flood events in the sampling "flood bucket". Users may add events that are larger than historical events, or have different event timing or spatial origin of flow throughout the watershed. For example, users can include 100-, 200-, and 500-year events (1.0%, 0.5%, and 0.2% chance events) in the Bootstrapping Historical/Synthetic Basin-wide Events sampling method, with any number of events defined for each return period/exceedance probability. Creating synthetic events involves selecting an exceedance probability, creating the event, and then providing the inflow time series DSS (*.dss) records that define the event.

From the **Synthetic Events** tab (Figure 3-24) the user will select an exceedance probability, for that exceedance probability the user can create, rename, create a copy, and delete synthetic events; set a weight for the selected synthetic event; and, view the total weight of events for the selected exceedance probability (**Synthetic Events for selected Exceedance Probability** panel). In addition, a table is provided for the user to define the DSS records for all synthetic hydrograph locations. If the **Include Forecasts** option (Section 3.1.1) has been selected, forecast information about the selected historical locations will be entered on the **Forecasts** tab.

Hydrologic Sampling Editor

Name: Ex_Bootstrap_Defaults 11 of 26

Description: Copy of Copy of Ex_Bootstrap

Data to be Sampled: Flow Sampling

Sampling Method: Bootstrapping Historical/Synthetic Basin-wide Events

Start of Water Year: 02Oct ☐ Include Forecasts ☐ Incremental Probability Override

Settings Historical Record Synthetic Events Synthetic Summary Probability Override

Exceedance Probability: 0.0100 Return Period: 100 years

Synthetic Events for selected Exceedance Probability

Synthetic Event: 1948 100 1912

Description:

New synthetic... Rename synthetic... Save synthetic as ... Delete synthetic...

Weight: 1.00 Total Weight: 6.00

Hydrographs Forecasts

Location	DSS File	Part A	Part B	Part C	Part E	Part F
Bluestone Inflow Near Glen Lynn						
Charleston Lock 6						
Hilldale						
Kanawha Falls						
Point Pleasant						
Queen Shoals						
Summersville Inflow						
Sutton Inflow						
Tornado						

Plot... Tabulate... Select DSS Path...

Data Check OK Cancel Apply

Figure 3-24 Hydrologic Sampling Editor – Bootstrapping Historical/Synthetic Basin-wide Events – Synthetic Events Tab

The following sections describe steps for creating and defining synthetic events for a selected exceedance probability (Section 3.2.1). Any desired number of synthetic events can be created for specified exceedance probabilities. For example, if the user wanted to have three 100-year synthetic events, one 200-year synthetic event, and one 500-year synthetic event, then three corresponding synthetic events would need to be created and defined for exceedance probability 0.0100, and one event each would need to be created and defined for exceedance probability 0.0050 and exceedance probability 0.0020.

3.4.1 Create Synthetic Events and Assign Weights

Synthetic events are created individually for a selected exceedance probability, and any number of synthetic events are allowed. Create new synthetic events and assign weights for the events:

1. From the **Synthetic Events** tab, from the **Exceedance Probability** list (Figure 3-24), select an exceedance probability. The associated **Return Period** box (Figure 3-24) automatically updates (e.g., for the default exceedance probability 0.0200, the return period is 50 years). Note, if the desired exceedance probability is not in the list, return to the **Settings** tab (Section 3.2.1) to add that value to the exceedance probability table.

2. Click **New synthetic**, the **Create New Synthetic Event** dialog box will open (Figure 3-25).

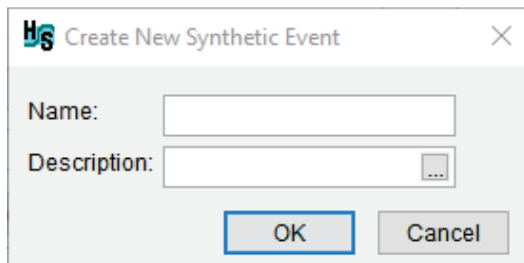



Figure 3-25 Create New Synthetic Event Dialog Box

Enter the name of the synthetic event in the **Name** box (e.g., *1948 100 1912*). Enter a description in the **Description** box (optional, but recommended). To view the entire description for long descriptions, click , the **Enter Description** dialog box will open. Note, the **Name** (and description) can be used to match the correct DSS file (*.dss) with the correct **Synthetic Event**.

3. Click **OK**; the **Create New Synthetic Event** dialog box will close (Figure 3-25). The created synthetic event appears in the **Synthetic Event** list (Figure 3-24).
4. Each synthetic event(s) must be assigned a weight. The weight, when combined with the weights of other synthetic events of the same exceedance probability, defines the relative likelihood of each event within that group. The default weight is **1.00**, and users can manually overwrite the default weight for a selected synthetic event. From the **Weight** box (Figure 3-24), highlight the default value (**1.00**) and manually enter the desired weight for the selected synthetic event.
5. Click **Apply** (Figure 3-24), this will save the synthetic event for the selected exceedance probability. Continue creating synthetic events for the appropriate exceedance probabilities, click **Apply** when finished.

3.4.2 Assigning Synthetic Hydrograph DSS Records

Once synthetic events have been created for each exceedance probability, users must define the synthetic hydrograph records. From the **Hydrographs** tab (Figure 3-14), the DSS input table contains the hydrograph locations that were selected from the **Settings** tab (Section 3.2).

In contrast to the historical hydrographs which span the historical period of record (with blanks for all other time periods), the DSS time series for a synthetic event should contain only the time period for the event of interest (e.g., the 100-year flood event time-window), without blanks for all other time periods. Furthermore, the synthetic hydrograph event time-window (start and end dates and times) must be the same for all locations. For example, Figure 3-26, displays a flow DSS dataset (time series) for a synthetic event for three locations.

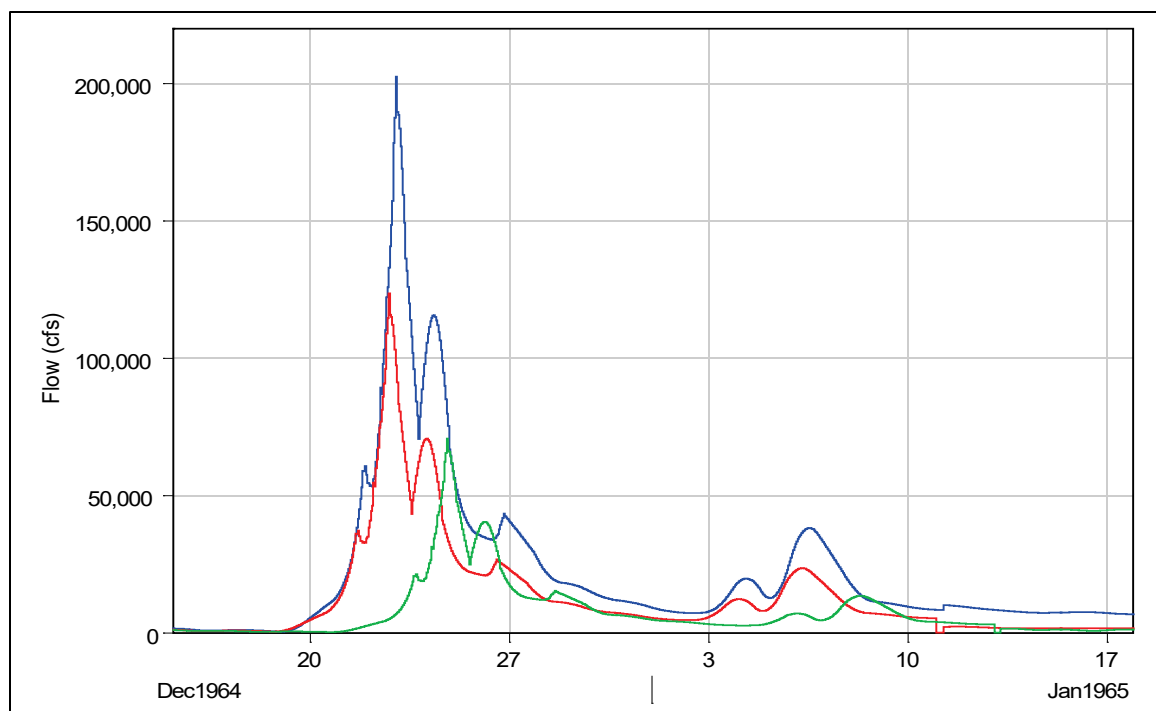



Figure 3-26 Synthetic Hydrographs

From the DSS input table (Figure 3-24); users need to specify the DSS records that defined the inflow hydrographs throughout the watershed for selected synthetic event(s). A hydrograph, must be defined for each inflow location (Section 3.2.1) listed in the DSS input table, for the selected synthetic event (**Synthetic Event** list, Figure 3-24).

1. For each **Location** (hydrograph) listed, a DSS path must be identified (**DSS File** and pathname **Parts A – F**). To define the DSS record for a location of interest, click on a cell of the row of the location (Figure 3-24).
2. Click **Select DSS Path** (Figure 3-24), the **HEC-DSSVue** dialog box will open (Figure 3-16). Refer to the HEC-DSSVue User's Manual for more information regarding DSS pathnames and HEC-DSSVue.
3. From the **HEC-DSSVue** dialog box, click  (Figure 3-16); the **Open HEC-DSS File** browser will open (Figure 3-17). Browse to the location of a DSS file (*.dss) that contains the time series of interest (e.g., hydrographs). Click on the appropriate *.dss file, the **File name** box now contains the name of the selected file (e.g., *Inflow – 48-100-1913.dss*).
4. Click **Open**, the **Open HEC-DSS File** browser will close (Figure 3-17). The **HEC-DSSVue** dialog box (Figure 3-16) displays the DSS records for the selected DSS file.
5. For the location (e.g., *Bluestone Inflow Near Glen Lynn*) that was selected in the DSS input table in the **Hydrologic Sampling Editor** (Figure 3-24), find and select the proper pathname (record) from the list of DSS records in the **HEC-DSSVue** dialog box (Figure 3-16), click **Set Pathname**. From the **Hydrologic Sampling Editor** (Figure 3-27), the

DSS input table now contains the **DSS File** pathname (Parts A – F) for the selected **Location** (e.g., *Bluestone Inflow Near Glenn Lynn*).

Location	DSS File	Part A	Part B	Part C	Part E	Part F
Bluestone Inflow Near Glen Lynn	shared/Inflows - 48-100-1913.dss		BLUESTONE_IN	FLOW-UNREG	1DAY	COMPUTED
Charleston Lock 6	shared/Inflows - 48-100-1913.dss		CHARLESTON_LOCK_6_IN	FLOW-UNREG	1DAY	COMPUTED
Hilldale	shared/Inflows - 48-100-1913.dss		HILLDALE_IN	FLOW-UNREG	1DAY	COMPUTED
Kanawha Falls	shared/Inflows - 48-100-1913.dss		KANAWHA_FALLS_IN	FLOW-UNREG	1DAY	COMPUTED
Point Pleasant	shared/Inflows - 48-100-1913.dss		POINT_PLEASANT_IN	FLOW-UNREG	1DAY	COMPUTED
Queen Shoals	shared/Inflows - 48-100-1913.dss		QUEEN_SHOALS_IN	FLOW-UNREG	1DAY	COMPUTED
Summersville Inflow	shared/Inflows - 48-100-1913.dss		SUMMERSVILLE_IN	FLOW-UNREG	1DAY	COMPUTED
Sutton Inflow	shared/Inflows - 48-100-1913.dss		SUTTON_IN	FLOW-UNREG	1DAY	COMPUTED
Tornado	shared/Inflows - 48-100-1913.dss		TORNADO_IN	FLOW-UNREG	1DAY	COMPUTED

Buttons at the bottom: Plot..., Tabulate..., Select DSS Path...

Figure 3-27 Synthetic Events Tab – Hydrographs Tab – DSS Table

6. Select the next location, from the **HEC-DSSVue** dialog box (Figure 3-16), find and select the proper pathname (record) from the list of DSS records in the **HEC-DSSVue** dialog box (Figure 3-16), click **Set Pathname**. Repeat this step until all locations in the DSS input table (Figure 3-27) contain the correct DSS filename and the DSS pathnames.
7. Click **Apply** (Figure 3-24), this saves data and keeps the **Hydrologic Sampling Editor** open for further modifications. When finished, click **OK** (Figure 3-24) to save the selected hydrologic sampling alternative and close the **Hydrologic Sampling Editor**. **Data Check** (Section 1.2.6) can be used to search for data consistency error(s) prior to closing the editor.

3.4.3 Rename a Synthetic Event

To rename a synthetic event, from the **Synthetic Event** list (Figure 3-24) select a synthetic event. Click **Rename synthetic**, the **Rename Synthetic Event** dialog box will open (Figure 3-28). Enter the new name for the synthetic event in the **Name** box and a description in the **Description** box (optional, but recommended). Click **OK**, the **Rename Synthetic Event** dialog box will close (Figure 3-28), and the new name will display in the **Synthetic Event** list (Figure 3-24).

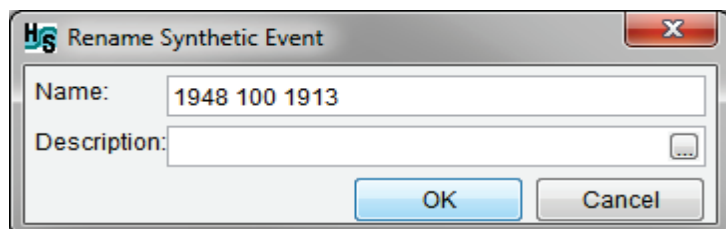


Figure 3-28 Rename Synthetic Event Dialog Box

3.4.4 Copy a Synthetic Event

To copy a synthetic event, from the **Synthetic Event** list (Figure 3-24) select a synthetic event. Click **Save synthetic as**, the **Save Synthetic Event As** dialog box will open (Figure 3-29).

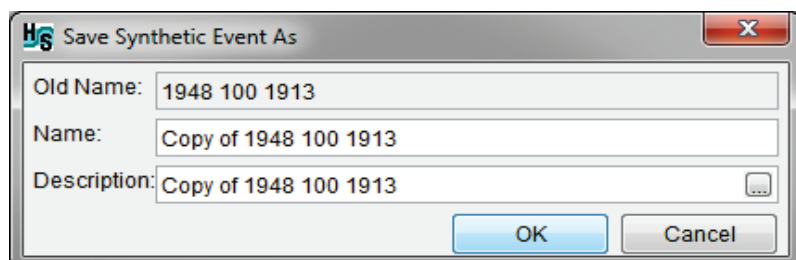


Figure 3-29 Save Synthetic Event As Dialog Box

Either use the default name or manually enter the name for the copied synthetic event in the **Name** box and a description in the **Description** box (optional, but recommended). Click **OK**, the **Save Synthetic Event As** dialog box will close (Figure 3-29), and the new name will display in the **Synthetic Event** list (Figure 3-24).

3.4.5 Delete a Synthetic Event

To delete a synthetic event, from the **Synthetic Event** list (Figure 3-24) select a synthetic event. Click **Delete synthetic**, a **Confirm delete** window will open (Figure 3-30). Click **Yes** to delete the selected synthetic event, the **Confirm delete** window will close (Figure 3-30) and the name will no longer display in the **Synthetic Event** list (Figure 3-24).

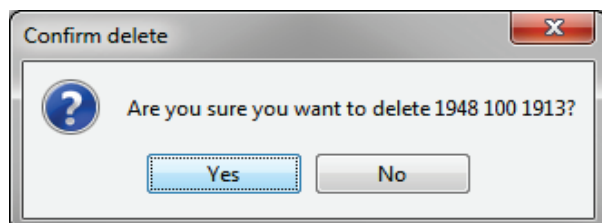


Figure 3-30 Confirm delete Window

3.4.6 Forecasts Tab

From the **Forecasts** tab (Figure 3-21), of the **Synthetic Events** tab, a user will select the DSS records containing the time series data that defines the starting forecast volumes of the synthetic events that were defined in the **Settings** tab (Section 3.2.2).

1. From the **Exceedance Probability** list (Figure 3-31), select an exceedance probability.
2. From the **Synthetic Events for selected Exceedance Probability** box (Figure 3-31), either select a synthetic event from the **Synthetic Event** list or create a new synthetic event (Section 3.4.1).
3. For each **Location** listed, a DSS path must be identified (**DSS File** and pathname **Parts A – F**). To define the DSS record for a location of interest, click on a cell of the row of the location (Figure 3-31).

Hydrologic Sampling Editor

Name: 9 of 26

Description:

Data to be Sampled:

Sampling Method:

Start of Water Year: ☒ Include Forecasts ☐ Incremental Probability Override

Settings | Historical Record | Synthetic Events | Synthetic Summary | Probability Override

Exceedance Probability: Return Period: years

Synthetic Events for selected Exceedance Probability

Synthetic Event:


Description:

Weight: Total Weight:

Hydrographs | Forecasts

Location	DSS File	Part A	Part B	Part C	Part E	Part F
Bluestone Inflow Near Glen Lynn						
Queen Shoals						

Figure 3-31 Hydrologic Sampling Editor – Bootstrapping Historical/Synthetic Basin-wide Events – Synthetic Events Tab – Forecasts Tab

- Click **Select DSS Path** (Figure 3-31), the **HEC-DSSVue** dialog box will open (Figure 3-16). Refer to the HEC-DSSVue User's Manual for more information regarding DSS pathnames and HEC-DSSVue.
- From the **HEC-DSSVue** dialog box, click  (Figure 3-16); the **Open HEC-DSS File** browser will open (Figure 3-17). Browse to the location of a DSS file (*.dss) that contains the time series of interest (e.g., hydrographs). Click on the appropriate *.dss file, the **File name** box now contains the name of the selected file (e.g., *Forecasts – 48-100-1913.dss*).
- Click **Open**, the **Open HEC-DSS File** browser will close (Figure 3-17). The **HEC-DSSVue** dialog box (Figure 3-16) now displays the DSS records for the selected DSS file.
- For the location (e.g., *Bluestone Inflow Near Glen Lynn*) that was selected in the DSS input table in the **Hydrologic Sampling Editor** (Figure 3-24), find and select the proper pathname (record) from the list of DSS records in the **HEC-DSSVue** dialog box (Figure

3-16), click **Set Pathname**. From the **Hydrologic Sampling Editor** (Figure 3-32), the DSS input table now contains the **DSS File** pathname (Parts A – F) for the selected **Location** (e.g., *Bluestone Inflow Near Glenn Lynn*).

Location	DSS File	Part A	Part B	Part C	Part E	Part F
Bluestone Inflow Near Glen Lynn	shared\Forecasts - 48-100-1913.dss		ROU	VOLUME[DATE-JUL] FCST	IR-CENTURY	CRT 2000 LEVEL
Sutton Inflow	shared\Forecasts - 48-100-1913.dss		CHL	VOLUME[DATE-JUL] FCST	IR-CENTURY	CRT 2000 LEVEL

Figure 3-32 Synthetic Events Tab – Forecasts Tab – DSS Table

8. Select the next location, from the **HEC-DSSVue** dialog box (Figure 3-16), find and select the proper pathname (record) from the list of DSS records in the **HEC-DSSVue** dialog box (Figure 3-16), click **Set Pathname**. Repeat this step until all locations in the DSS input table (Figure 3-32) contain the correct DSS filename and the DSS pathnames.
9. Click **Apply** (Figure 3-31), this saves data and keeps the **Hydrologic Sampling Editor** open for further modifications. When finished, click **OK** (Figure 3-31) to save the selected hydrologic sampling alternative and close the **Hydrologic Sampling Editor**. **Data Check** (Section 1.2.6) can be used to search for data consistency error(s) prior to closing the editor.

3.5 Synthetic Summary Tab

From the **Hydrologic Sampling Editor**, the **Synthetic Summary** tab (Figure 3-33) displays all exceedance probabilities and synthetic events at the same time for viewing purposes only and information about individual synthetic events. Information on the **Synthetic Summary** tab (Figure 3-33) is displayed in two tables. The upper table describes the **Total Incremental Probability of Synthetics**. This probability is defined by the largest exceedance probability that has a synthetic event (i.e., the smallest and most frequent synthetic events). For example, if the largest exceedance probability is a 1% chance exceedance (100 year) event, then the incremental probabilities of all synthetic events will total 0.01 or 1%.

The upper table displays each exceedance probability assigned to a synthetic event. Information includes the exceedance probability and return period. The total incremental probability (of all synthetic events of that return period) is the difference between the exceedance probability and the next largest exceedance probability (in the next row). Using the values in Figure 3-33 as an example, the chance of seeing an event that equals or exceeds a 100-year or 1% ACE magnitude is 1% or 0.01, and the chance of seeing an event that equals or exceeds the 200-year or 0.5% ACE magnitude is 0.5% or 0.005. In other words, for the example in Figure 3-33, the chance of seeing an event equaling or exceeding the 1% event, but *not* exceeding the 0.5% event, is: $0.01 - 0.005 = 0.005$. Therefore, the incremental probability assigned for all 1% or 100-year events is 0.005, divided among them based on their specified weight. The same process applies to each exceedance probability group, based on the next largest exceedance probability. For the smallest exceedance probability used, the subtraction uses 0.0 as the second value.

The last column of the upper table (Figure 3-33) is the incremental probability adjusted by a multiplier currently set to 1.25; the user will be able to modify this value in future versions of the software. This technique of assigning incremental probability to synthetic events will slightly underestimate the likelihoods of large events (can be historic events as well as large synthetic events) in repeated sampling, and the multiplier helps account for this outcome by slightly increasing them. Refer to Section 3.1.2 for further explanation of this multiplier.

The lower table, **Synthetic Events for Selected Exceedance Probability** (Figure 3-33), will be blank upon first accessing the **Synthetic Summary** tab (Figure 3-33). This table populates when the user selects a row in the upper table (Figure 3-33). The lower table has a row for each synthetic event for the selected exceedance probability; information includes weight, incremental probability, and the probability adjusted by 1.25 multiplier.

Hydrologic Sampling Editor

Name: 9 of 26

Description:

Data to be Sampled:

Sampling Method:

Start of Water Year: ☐ Include Forecasts ☐ Incremental Probability Override

Settings | Historical Record | Synthetic Events | **Synthetic Summary** | Probability Override

Total Incremental Probability of Synthetics (equals Largest Exceedance Probability):

Exceedance Probability	Return Period	Total Incremental Probability	Probability adjusted by 1.25 Multiplier
0.0100	100	0.0050	0.006250
0.0050	200	0.0030	0.003750
0.0020	500	0.0020	0.002500

Synthetic Events for Exceedance Probability Selected in Table Above

Exceedance Probability: Total Weight: Total Incremental Probability:

Synthetic Event	Weight	Incremental Probability	Probability adjusted by 1.25 Multiplier

Data Check OK Cancel Apply

Figure 3-33 Hydrologic Sampling Editor – Bootstrapping Historical/Synthetic Basin-wide Events – Synthetic Summary Tab

The incremental probability for each event listed in the lower table is equal to the **Total Incremental Probability** from the table above times the fraction of total weight. Using the values in Figure 3-33 as an example, when the 0.01 exceedance probability is selected in the upper table, three synthetic events corresponding to that exceedance probability are displayed in the lower table. In this example, the first two synthetic events have a weight of 1.0 and the last event has a weight of 3.0; as a result, the first two events each receive 1/5 of the total incremental probability, and the last event receives 3/5.

To edit the information displayed in the **Synthetic Summary** tab (Figure 3-33), the user needs to return to the **Synthetic Events** tab (Section 3.4) and individually edit specific synthetic events. Click **Apply** to save the selected hydrologic sampling alternative when navigating between

alternatives. Alternatively, click **OK** to save the alternative and close the **Hydrologic Sampling Editor** (Figure 3-33).

CHAPTER 4

Precipitation Sampling – Basin Average Frequency Curve

This chapter describes how to set up the Hydrologic Sampler with a precipitation-sampling alternative using the **Basin Average Frequency Curve** sampling method. This sampling method generates a hyetograph for every specified location within the modeled watershed for each sampled event based on a basin average precipitation depth-frequency curve, user-defined hyetograph shape sets and a flood season distribution. The Basin Average Frequency Curve sampling method in the Hydrologic Sampler is described below and the user input steps are described starting in Section 4.1.

The Basin Average Frequency Curve sampling method (refer to Chapter 2) is similar to the Correlated Flow Frequency Curves sampling method (for sampling flows) in that event magnitudes are generated from a user-defined frequency curve. Specifically, the annual maximum basin average precipitation depths are randomly sampled from a precipitation frequency curve to generate the total storm depth for each precipitation event. However, a primary difference between the two methods is whether the frequency curves are aggregated or site-specific. Flow sampling is done separately at various sites from site-specific flow frequency curves, while precipitation sampling uses an aggregated basin average precipitation frequency curve. Furthermore, the randomly sampled precipitation depth is disaggregated (as described below) into precipitation hyetographs for user-specified subbasin locations.

The aggregated user-defined basin average precipitation frequency curve is the annual maximum precipitation depth over some duration of time. Moreover, the duration must be chosen carefully when the frequency curve is generated. In particular, analysts should strive to capture the "critical" duration for the watershed, which reflects the duration of extreme precipitation events that have the greatest effect on the resulting peak streamflow, and/or reservoir stage. Currently, the Hydrologic Sampler requires that the duration of the frequency curve must also match the duration of effective (non-zero) precipitation in the user-defined shape sets (described below).

The set of precipitation time series generated by the Hydrologic Sampler for subsequent models in the HEC-WAT model sequence (one for every subbasin location) is created by scaling a randomly chosen user-defined shape set (which is another similarity to the Correlated Flow Frequency Curves sampling method). In this method, a shape set contains scalable hyetographs for every subbasin location that together capture the relative spatial and temporal distribution of rainfall throughout the watershed for a given event, which is usually defined by a large event from the historical record. In other words, each shape set is a unique combination of how precipitation occurred in both space and time. For example, one shape set might contain an event centered over the upper part of a watershed while another shape set is an event centered in the lower half of the watershed.

The scaling of a user-defined shape set, such that the shape set's area-weighted average precipitation depth matches the randomly sampled value, is how the randomly sampled basin average precipitation depth is disaggregated to the subbasins. Specifically, the basin average precipitation depth is computed for each shape set by weighting the total precipitation depth for each subbasin, using the user-defined subbasin area divided by the total of all subbasin areas, and then summing the weighted subbasin depths. Furthermore, once an event depth is sampled from the basin average precipitation frequency curve and a shape set randomly chosen, then that sampled depth is divided by the selected shape set's total basin average depth to compute a ratio. This computed ratio is then used for scaling every hyetograph in the shape set for reproducing the sampled basin average depth among the set of scaled hyetographs. Finally, the scaled hyetograph shape sets are then placed on a date that is randomly sampled from the flood season distribution.

When the **Basin Average Frequency Curve** option is selected, the **Hydrologic Sampling Editor** interface will change based on the selected method (Figure 4-1).

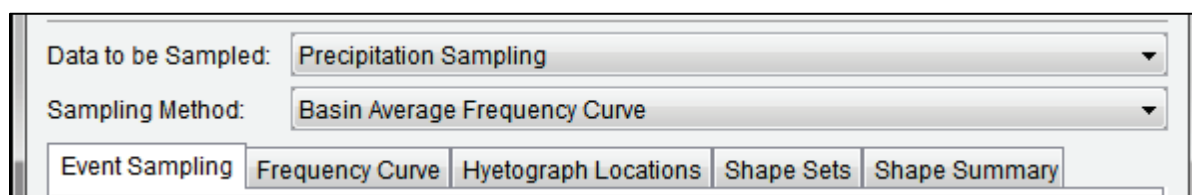


Figure 4-1 Hydrologic Sampling Editor – Precipitation Sampling – Basin Average Frequency Curve – Tabs Overview

The **Hydrologic Sampling Editor** set to apply the **Basin Average Frequency Curve** sampling method contains the following five tabs:

- | | |
|-----------------------------|---|
| Event Sampling | This tab allows the user to define the Flood Season from which the date of each year's maximum precipitation (flood) event is randomly sampled. One of five available probability distributions, including their corresponding user inputs and seasonal bounds, are used to define the flood season. |
| Frequency Curve | This tab allows the user to define the Precipitation Frequency Curve and its Uncertainty . The user chooses the frequency curve distribution type, specifies its corresponding user inputs, and defines the associated uncertainty. |
| Hyetograph Locations | This tab allows the user to define the Hyetograph Locations (and the optional hyetograph location Description) at which flood event hyetographs are produced. Each hyetograph location must include an Override Area in square miles. |
| Shape Sets | In this tab, the user defines one or more hyetograph shape sets. A shape set is a group of hyetographs specified for all subbasin locations that are scaled to the precipitation magnitudes for each randomly sampled event. Each shape set has a specified Exceedance |

probability filter (minimum and maximum) that defines the range of exceedance probabilities to which each shape set applies, a **Weight**, which defines the relative likelihood for the shape set, and the **DSS Pathnames** for all subbasin hyetograph time series.

Shape Summary

The **Shape Summary** tab displays all defined shape sets together in a summary table and plot. The table allows the user to modify the **Exceedance Probability Maximum** and **Minimum**, and **Weight** for the shape sets created in the **Shape Sets** tab.

4.1 Sampled Data Type and Sampling Method Selection

First, either create a new hydrologic sampling alternative (refer to Section 1.3), or edit an existing alternative (Section 1.4.1). From the **Hydrologic Sampling Editor**, from the **Data to be Sampled** list, select **Precipitation Sampling**. From the **Sampling Method** list, select **Basin Average Frequency Curve**. From the **Sampling Method** list, select **Basin Average Frequency Curve** (Figure 4-2).

Figure 4-2 Precipitation Sampling – Event Sampling Tab – Flood Season Definition – Default

4.2 Event Sampling Tab

From the **Hydrologic Sampling Editor**, from the **Event Sampling** tab, the user can set the flood season (Figure 4-2). The flood season defines when precipitation events might occur within a year, and is described as a probability distribution of possible flood dates (day-month). Users can describe the probability distribution for the flood season using one of five distribution types (**Uniform**, **Triangular**, **Normal**, **Gamma** and **Empirical**).

The flood season can be as simple as a Uniform distribution between a minimum to maximum date, allowing the selection of any date in the range with equal likelihood. The flood season can also be a more complex distribution with some dates more likely than other dates. When an

analytical distribution type is chosen (Uniform, Triangular, Normal or Gamma), the corresponding user inputs needed for that distribution must be entered.

The default values for minimum (start) and maximum (end) dates are 1 January (01Jan) and 31 December (31Dec), respectively, though the user may enter their own values to define the flood season bounds. For Normal and Gamma distributions, which do not have explicit upper and lower bounds, user-specified start and end dates may truncate the tails of the distribution. **Note:** When the defined flood season distribution spans January 1, minimum and maximum dates must be re-defined from the defaults. Another distribution option is to create a user-defined non-parametric empirical (graphical) distribution, which requires a table of cumulative probability versus date entered by the user.


As explained in the introduction to this chapter, the sampled date is used to place the peak of the flood event hyetograph in time, as defined by the sampled and scaled shape set (refer to Section 4.5). Because different locations within a watershed might have different relative peak dates within a shape set's time-window, the location with the largest total hyetograph depth is used to match the peak to the sampled date.

4.2.1 Flood Season Definition

The **Flood Season Definition** panel of the **Hydrologic Sampling Editor** (Figure 4-2) allows the user to select a probability distribution type from five options (**Uniform** (default), **Triangular**, **Normal**, **Gamma** and **Empirical**), specify the distribution's corresponding user inputs, as well as set the season start, and end dates. The **Start** and **End** dates are user inputs, which function differently for different distribution types. For the first two distributions, **Uniform** and **Triangular**, the start and end dates are explicit distribution inputs. However, for the second two distributions, **Normal** and **Gamma**, the start and end dates can be used to truncate the season distribution.

Default dates are *01Jan* and *31Dec*, and these must be re-defined if the flood season spans January 1 (e.g., when using a standard water year, from 1 October to 30 September). As the last step in the event generation algorithm, the hydrologic sampling algorithm randomly samples this user-defined flood season distribution to set the date (as day and month) of each flood event. The user must select the most representative distribution and define its corresponding user inputs accordingly.

Uniform Distribution

Uniform distribution is the default uncertainty distribution for the Correlated Flow Frequency Curves sampling method. The Uniform distribution includes two inputs – **Min (Start)** and **Max (End)** (Figure 4-3). Defaults are 01Jan (**Min**) and 31Dec (**Max**). If necessary, update the **Min (Start)** and **Max (End)** dates in DDMMM format either manually or by selecting the  buttons to open the **Select Date** dialog box (Figure 4-3), which provides dropdown lists to select the **Month** and/or **Day**. When the defined flood season distribution spans January 1, minimum and maximum dates must be re-defined from the defaults. Changes made to the inputs immediately updates the **Season Distribution Plot** panel of the **Hydrologic Sampling Editor**.

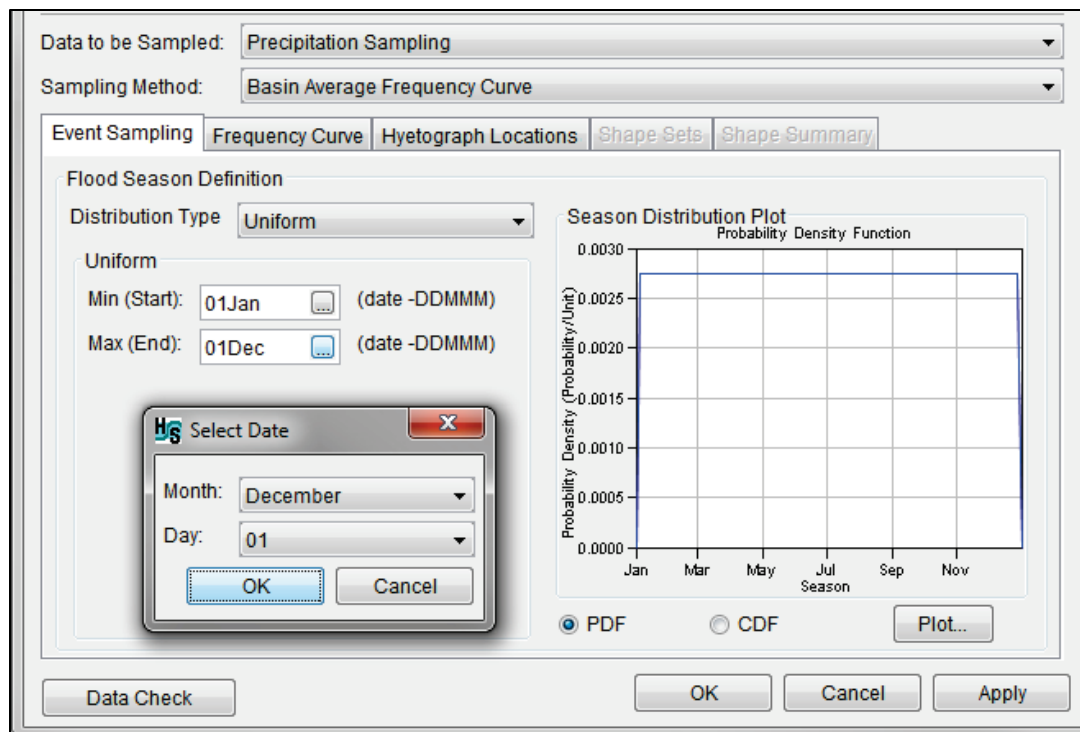



Figure 4-3 Precipitation Sampling – Event Sampling Tab – Flood Season Definition – Uniform Distribution Type – Select Date Dialog

Triangular Distribution

The Triangular distribution includes three inputs – **Min (Start)**, **Mode**, and **Max (End)** dates (Figure 2-4). Defaults are 01Jan (**Min**), 01Jul (Mode), and 31Dec (**Max**). If necessary, update the **Min (Start)**, **Mode**, and **Max (End)** dates in DDMMM format (e.g., Figure 4-4) either manually or by selecting the  buttons to open the **Select Date** dialog box (Figure 4-3). When

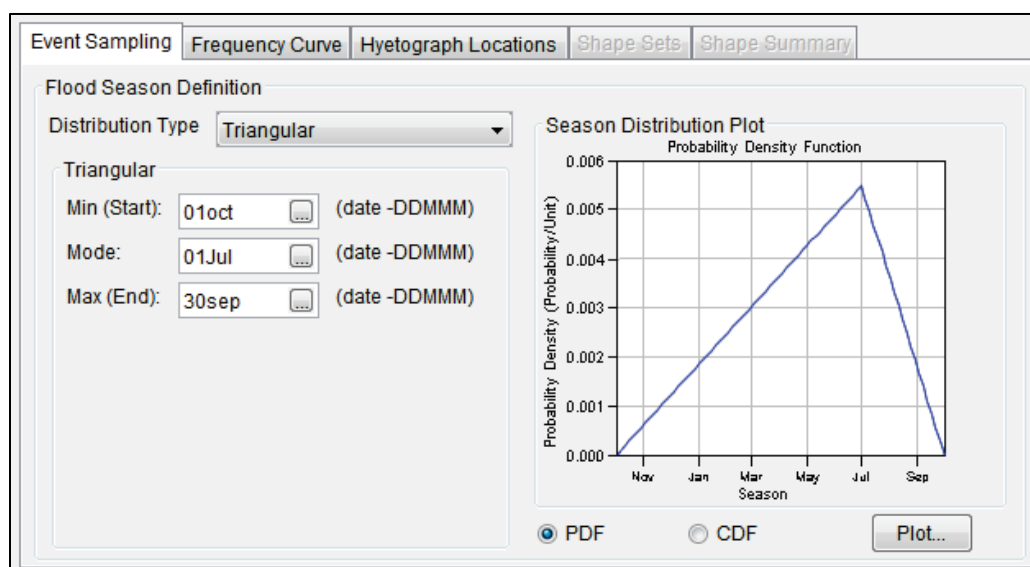



Figure 4-4 Precipitation Sampling – Event Sampling Tab – Flood Season Definition – Triangular Distribution – Example Settings

the defined flood season distribution spans January 1, minimum and maximum dates must be re-defined from the defaults. Changes made to the user inputs immediately update the **Season Distribution Plot**.

Normal Distribution

The Normal distribution includes four inputs – **Mean**, standard deviation (**Std Dev.**), **Min (Start)**, and **Max (End)** (Figure 2-5). Defaults are 01 Jul (**Mean**), 20 (**Std Dev.**), 01Jan (**Min**), and 31Dec (**Max**). Set the **Mean** and the standard deviation (**Std Dev**) in days. If necessary, update the default **Min (Start)**, and **Max (End)** date, in DDMMM format, to define the boundaries of the flood season (e.g., Figure 4-5). Edits can be made either manually or by selecting the  button to open the **Select Date** dialog box (Figure 4-3). The start and end dates must be redefined when the flood season spans January 1 (e.g., when using a standard water year, October 1 to September 30). Changes made to the inputs immediately update the **Season Distribution Plot**.

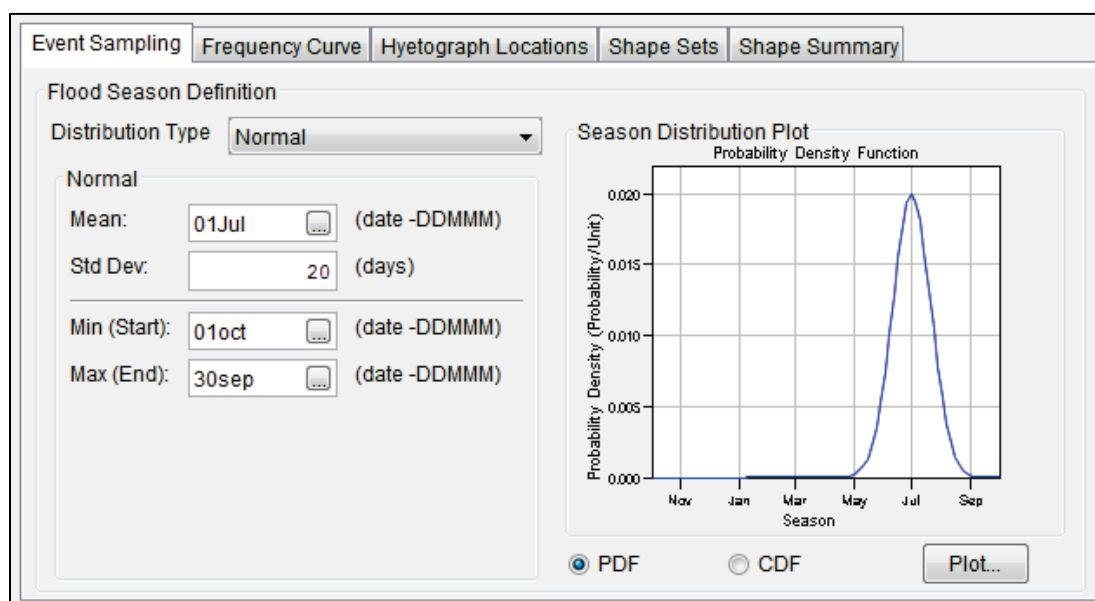



Figure 4-5 Precipitation Sampling – Event Sampling Tab – Flood Season Definition – Normal Distribution – Example Settings

The Normal distribution does not have explicit upper and lower bounds; therefore, the user-specified start and end dates can optionally be used to truncate the tails of the distribution resulting from the user-defined mean and standard deviation (e.g., Figure 2-8). However, the start and end dates must be redefined when the season spans 1 January.

Gamma Distribution

The Gamma distribution includes five inputs – **Shape**, **Scale**, **Shift**, **Min (Start)**, and **Max (End)** (Figure 4-6). Defaults are 2 (**Shape**), 20 (**Scale**), 0 (**Shift**), 01Jan (**Min**), and 31Dec (**Max**). Manually enter the **Shape**, and the **Scale** and **Shift** in days. If necessary, update the default **Min (Start)**, and **Max (End)** date in DDMMM format to define the boundaries of the flood season

(e.g., Figure 4-3), either manually or by selecting the  button to open the **Select Date** dialog box. For Gamma distributions, the **Min (Start)** date becomes the zero point of the distribution, which can also be adjusted with **Shift**. Changes made to the inputs immediately updates the **Season Distribution Plot** panel of the **Hydrologic Sampling Editor**.

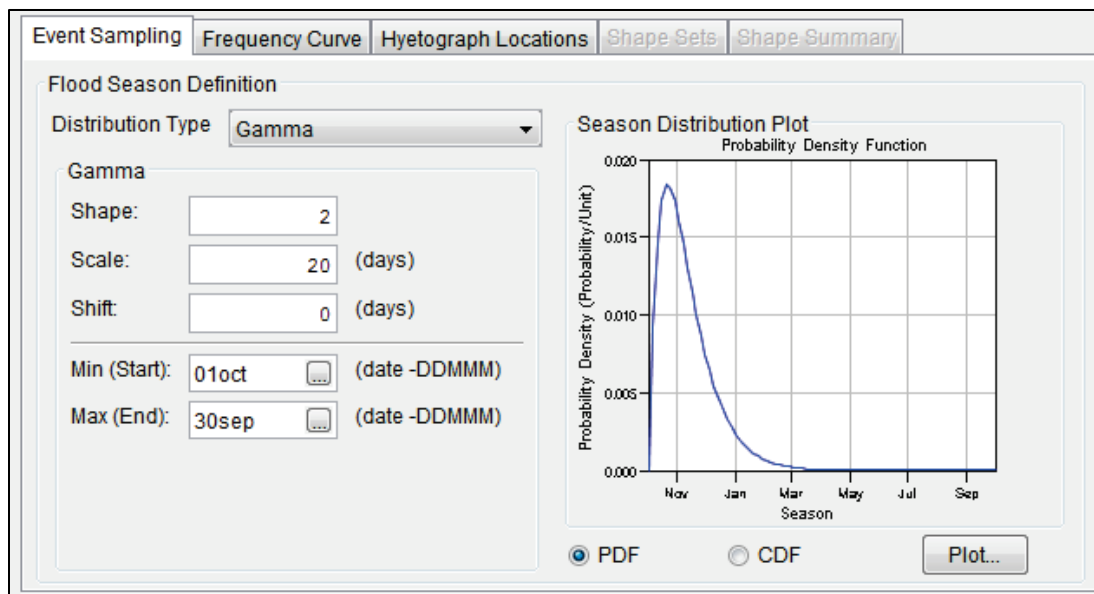



Figure 4-6 Precipitation Sampling – Event Sampling Tab – Flood Season Definition – Gamma Distribution – Example Settings

The Gamma distribution does not have explicit upper and lower bounds; therefore, the user-specified start and end dates can optionally be used to truncate the tails of the distribution resulting from the user-defined shape, scale and shift parameters. However, the start and/or end date must be redefined when the flood season spans January 1 (e.g., when using a standard water year, October 1 to September 30).

Empirical (graphical) Distribution

For an Empirical, distribution a default Cumulative Probability function is provided (e.g., Figure 2-8). If necessary, the user can update the Cumulative Probability function, from the **Cumulative Probability** and **Date** (in DDMMM format, chronologically) columns in the table provided (e.g., Figure 4-7). The entered cumulative probability range must span from 0.0 to 1.0. Either set the dates manually, or use the  buttons to open the **Select Date** dialog box (Figure 4-3). Changes made to the inputs immediately updates the **Season Distribution Plot** panel of the **Hydrologic Sampling Editor**.

The **Cumulative Probability** function can be copied (**Copy** shortcut command or Ctrl+C) from an outside source (e.g., Microsoft® Excel or a text editor) and pasted (**Paste** shortcut command or Ctrl+V) into the table, or copied from the table to an outside destination, as long as the copied data is tab delimited or from/to a spreadsheet. Several shortcut commands are available for editing tables (refer to Section 1.2.4 for more information).

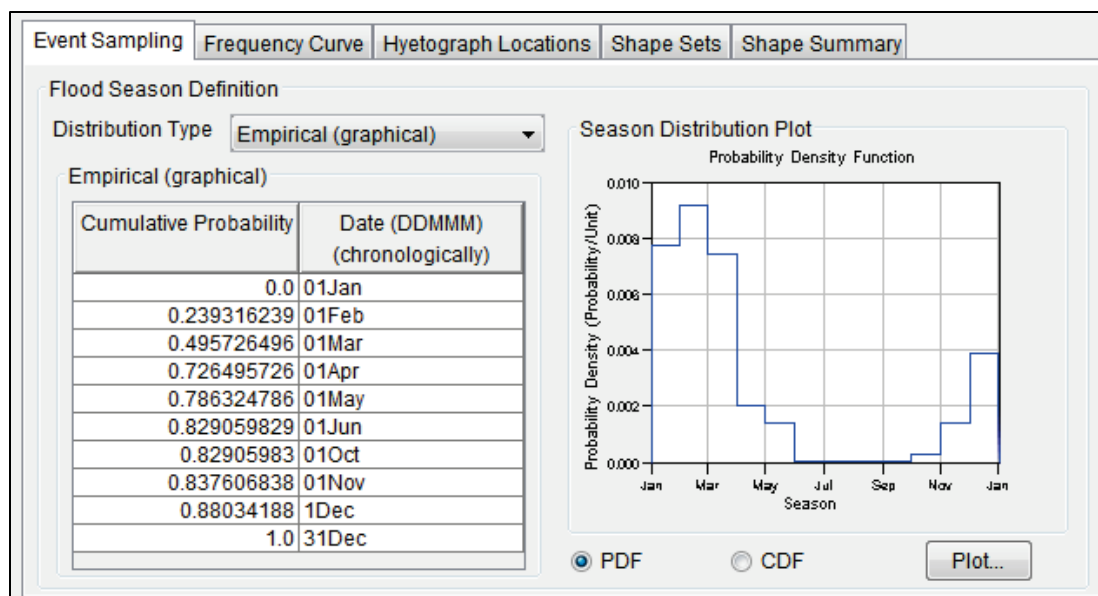


Figure 4-7 Precipitation Sampling – Event Sampling Tab – Flood Season Definition – Empirical Distribution – Example Settings

4.2.2 Season Distribution Plot

A **Season Distribution Plot** (Figure 4-2) displays the defined season distribution. The plot has two viewing options: **PDF** (probability density function) or **CDF** (cumulative distribution function). Toggling between **PDF** and **CDF**, changes the plot in the **Season Distribution Plot** panel (Figure 4-8). In addition, to view the season distribution plot in a new window, the user can click **Plot**, or double-click on the plot displayed in the **Season Distribution Plot** panel, to open the plot in a new window. Figure 4-8 displays an example of a PDF (Figure 4-8a) and a CDF (Figure 4-8b) plots, respectively.

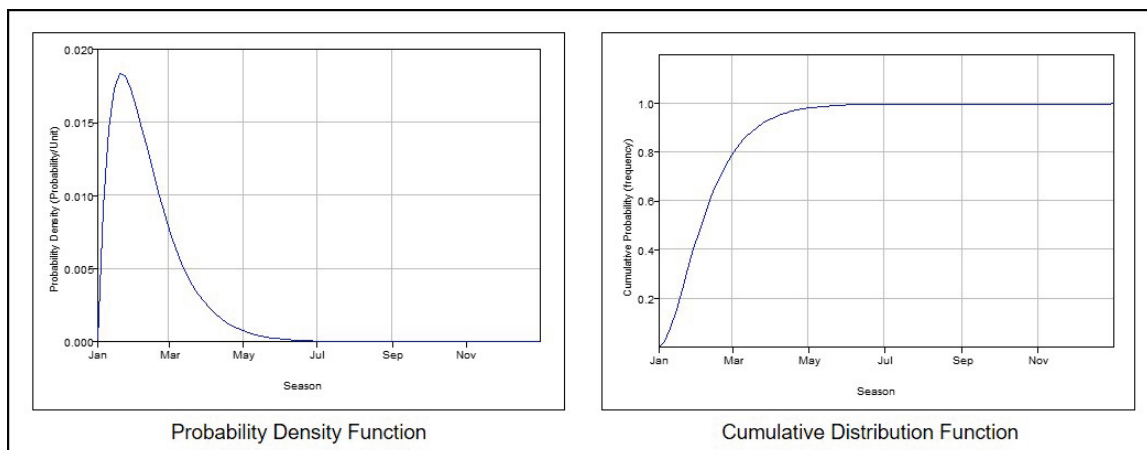


Figure 4-8 Probability Density and Cumulative Distribution Functions

4.3 Frequency Curve Tab

From the **Hydrologic Sampling Editor**, the **Frequency Curve** tab (Figure 4-9) is where the annual maximum basin average **Precipitation Frequency Curve** is defined. The **Frequency**

Curve tab allows users to select the probability **Distribution Type** and define its corresponding user inputs. This tab also includes the ability for users to specify the **Uncertainty** for the selected precipitation frequency curve.

Data to be Sampled: **Precipitation Sampling**

Sampling Method: **Basin Average Frequency Curve**

Event Sampling | **Frequency Curve** | Hyetograph Locations | Shape Sets | Shape Summary

Precipitation Frequency Curve

Distribution Type: **Pearson type III**

Pearson type III

Mean:

St. dev.:

Skew:

☐ Clip Min Value:

Prob < Min:

☐ Clip Max Value:

Prob > Max:

Precipitation Frequency Curve

Return Period

1.1 2 5 10 50 200

10 8 6 4 2

0.99 0.9 0.5 0.2 0.1 0.02 0.002

Exceedance Probability

Define Ordinates and Tabulate... Plot...

Uncertainty

☐ No Uncertainty.

☒ Equiv. years of record:

☐ User Defined Uncertainty:

Exceedance Probability	Standard Deviation
0.9	1.0
0.1	10.0

Data Check OK Cancel Apply

Figure 4-9 Precipitation Sampling – Frequency Curve Tab – Default View

As described in the introduction to this chapter, the Hydrologic Sampler generates a basin average precipitation depth for every event by randomly sampling an event depth from the precipitation frequency curve. A unique curve is generated for each realization, fit to a parametric bootstrap sample of N equals EYR values, to capture the knowledge uncertainty about the user-entered curve. The sampled basin average precipitation value is then disaggregated to each subbasin hyetograph location based on both subbasin areas and a randomly chosen shape set, in a process that disaggregates the area-weighted average. This process will reproduce the temporal and spatial distribution of rainfall in the watershed as represented by the user-defined shape set, with a range of event depths from the user-defined basin average precipitation frequency curve.

The **Frequency Curve** tab has two panels: the **Precipitation Frequency Curve** panel for defining the **Distribution Type** and its corresponding user inputs, which is graphically displayed in the **Precipitation Frequency Curve** plot (refer to Section 4.3.1), and the **Uncertainty** panel (refer to Section 4.3.2).

4.3.1 Precipitation Frequency Curve – Distribution Type

The first step to completing the **Frequency Curve** tab is to select the distribution type of the precipitation frequency curve from the **Precipitation Frequency Curve** panel. The distribution type has four options available: **Log Pearson Type III** (selected by default), **Normal**, **GEV (Generalized Extreme Value)**, and **Empirical (graphical)**. When completing the **Precipitation Frequency Curve** panel, users must select a distribution type and define its corresponding user inputs. Note, for the empirical distribution, a table of exceedance probability versus precipitation (total in inches) must be entered. To the right of the inputs or the input table is the **Precipitation Frequency Curve** plot, which displays the selected distribution based on the entered user inputs.

The Hydrologic Sampler automatically updates the plot for precipitation (in) calculated based on the user inputs for the entered distribution for a default list of exceedance probability ordinates. Users can open the **Precipitation Frequency Curve** plot for closer examination by clicking the **Plot** button, or by double-clicking inside the plot to open the graph in another window. Refer to Section 1.2.5 for more details regarding plots in the **Hydrologic Sampling Editor**. Additional frequency ordinates can be computed and added to the plot. Those ordinates, and a tabulation of the precipitation depth at each ordinate, are displayed in a table opened by the **Define Ordinates and Tabulate** button (Figure 4-9). Users can insert and delete rows to change which ordinates are plotted.

For distributions other than **Empirical (graphical)**, the user may choose to “clip,” or exclude, the entered distribution beyond a defined minimum or maximum value, to limit the range of values sampled. Clipping limits are defined using the optional **Clip Min Value** and **Clip Max Value** checkboxes located below the user inputs. User-defined clipping thresholds automatically update the **Precipitation Frequency Curve** plot, as well as the table opened by the **Define Ordinates and Tabulate** button.

Viewing the Maximum Flow Frequency Curve

Whatever method the user chooses to generate a maximum flow frequency curve, a plot of the curve is displayed on the **Hydrologic Sampling Editor** (Figure 4-16). This plot automatically updates when user inputs are changed. In addition, by clicking **Plot**, the **Precipitation Frequency Curve** dialog box will open (Figure 4-10) displaying a plot of the current precipitation frequency curve. The plot allows the user to examine the resultant graph of the defined curve in more detail. Refer to Section 1.2.5 for more details regarding plots in the **Hydrologic Sampling Editor**.

In addition, users can view a tabulated report that displays the calculated precipitation values for default exceedance probability ordinates of the precipitation frequency curve. To view the table, click **Define Ordinates and Tabulate** (Figure 4-16), the **Define Ordinates and Tabulate Distribution** dialog box will open (Figure 4-11). Furthermore, the table displayed in this dialog allows the user to extend the distribution graph to more extreme ordinates.

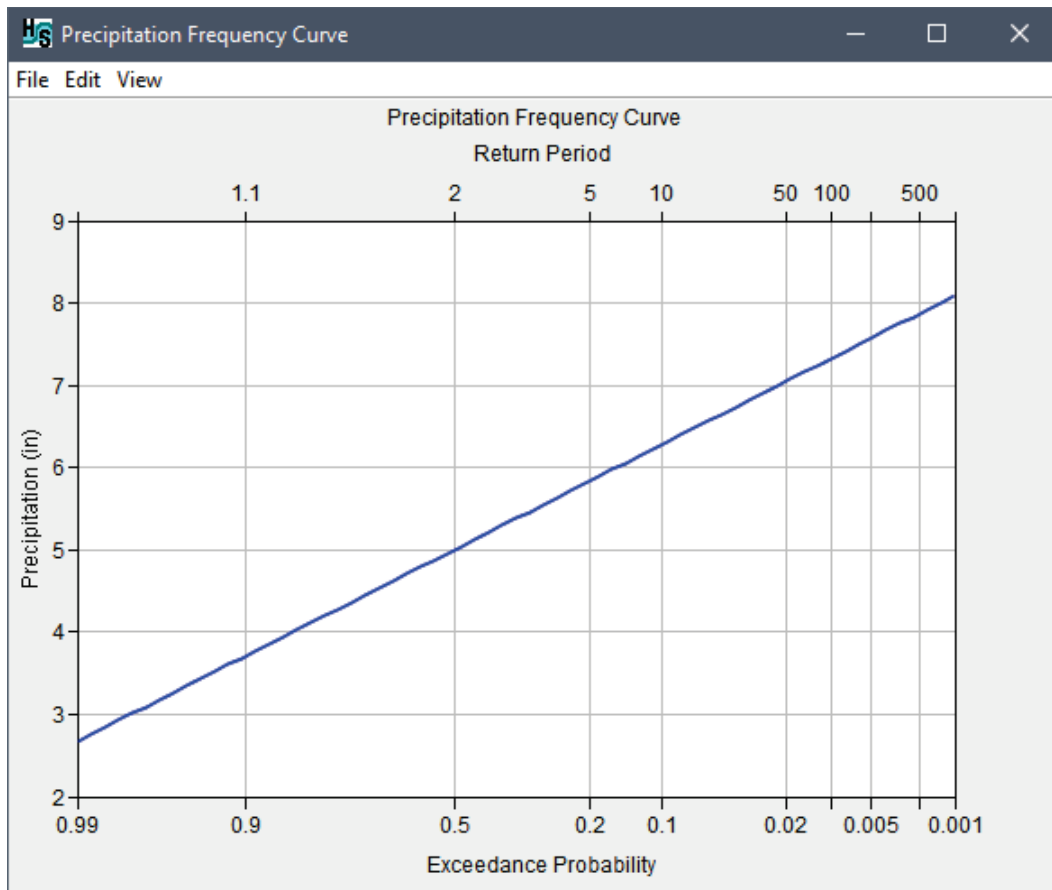


Figure 4-10 Precipitation Frequency Curve Plot

Default Exceedance Probability Ordinates

The **Define Ordinates and Tabulate Distribution** dialog (Figure 4-11) displays the probability versus precipitation table for the defined probability distribution. The displayed values represent both the original distribution and the result of imposed boundaries; i.e., the optional minimum or maximum clipping thresholds. The Hydrologic Sampler calculates the **Precipitation (in)** based on the entered distribution inputs and the default standard list of **Exceedance Probability** ordinates.

Changes made in this dialog do not affect the distribution entered in the **Precipitation Frequency Curve** panel in any way. However, changes are reflected in the **Precipitation Frequency Curve** graph and quantiles displayed.

Exceedance Probability	Precipitation (in)
0.001	13.04
0.002	12.49
0.005	11.71
0.01	11.09
0.02	10.42
0.05	9.45
0.1	8.62
0.2	7.65
0.5	5.90
0.8	4.29
0.9	3.51
0.95	2.89
0.99	1.79
0.999	0.66

Figure 4-11 Define Ordinates and Tabulate Distribution

If the user adds or removes ordinates from the table, they can display more or less of the frequency curve in the plot window. From the **Define Ordinates and Tabulate Distribution** dialog, users can view, modify, remove or add additional ordinates to the **Exceedance Probability** column regardless of the distribution type selected. To open and view, modify, remove or add ordinates:

1. From the **Precipitation Frequency Curve** panel (Figure 4-16); click **Define Ordinates and Tabulate**, the **Define Ordinates and Tabulate Distribution** dialog box will open (Figure 4-11).
2. Note, when editing the exceedance probability ordinates, it is not necessary to overwrite or add new exceedance probability ordinates in numerical order. When done with modifications to the exceedance probability ordinate, close the **Define Ordinates and Tabulate Distribution** dialog (Figure 4-11). When opening the dialog box, new/modified exceedance probabilities are automatically reordered, with corresponding precipitation generated.
3. To overwrite an existing **Exceedance Probability** ordinate, click inside the cell and enter the desired probability.
4. To remove existing exceedance probability ordinates, select the cell (or multiple cells) that contains the exceedance probability ordinate(s) to be deleted. Right-click on that cell, from the shortcut menu (Figure 1-3), click **Delete Row(s)**. The selected exceedance probability ordinate(s) are removed from the table.
5. To enter additional exceedance probability ordinates select a cell where the new exceedance probability ordinate(s) is to be added. Right-click on that cell, from the shortcut menu (Figure 1-3), click **Insert Row(s)**. The **Insert Rows** dialog box (Figure 1-2) will open, in the **Number to insert** box, enter the number of new rows needed. Click **OK**, the **Insert Rows** dialog box will close, and blank cell(s) will display above the cell that was selected. Enter exceedance probabilities in the new cell(s) and the **Precipitation (in)** column updates automatically.
6. Manual edits to the precipitation values are not allowed, as the precipitation values are calculated based on the exceedance probability distribution. However, the user can copy, print, or sum the **Precipitation (in)** column, by right-clicking on the column, and using the available shortcut menu commands (Section 1.2.4).
7. Once editing is complete, click **OK**, and the **Define Ordinates and Tabulate Distribution** dialog box will close (Figure 4-11). Modifications made to the exceedance probability ordinates(s), with resulting precipitation depth(s), will automatically save and update the **Precipitation Frequency Curve** plot.

Distribution Type – Pearson Type III

The default distribution type is **Pearson type III** (Figure 4-12). To define the Pearson type III distribution the user must enter the **Mean**, **St. dev** (standard deviation), and the **Skew**

distribution parameters. Changes made to the parameters immediately update the **Precipitation Frequency Curve** graph. Figure 4-12 provides an example of a completed Pearson Type III distribution and the resulting frequency curve graph. Note, the user can opt to clip the lower or upper tail of the distribution using the **Clip Min Value**, or **Clip Max Value**, or both (see the section on Clipping the Lower and/or Upper Tails of a Frequency Curve).

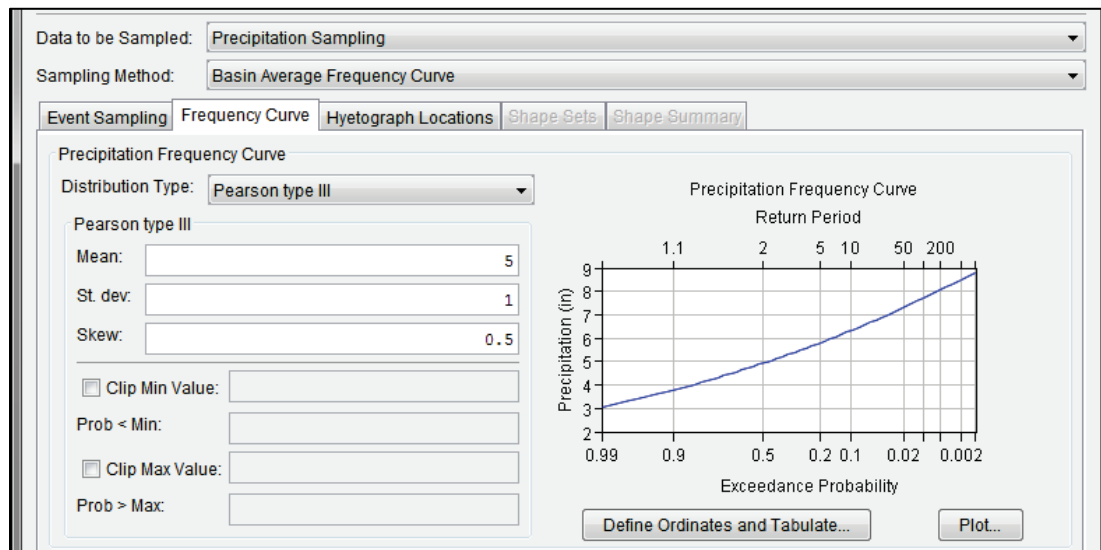


Figure 4-12 Precipitation Sampling – Frequency Curve Tab – Pearson type III Distribution

Distribution Type – Normal

To define the **Normal**, enter the **Mean** and **St. Dev** (standard deviation) distribution parameters (Figure 4-13). Changes made to the parameters immediately update the **Precipitation Frequency Curve** graph. Figure 4-13 provides an example of a completed normal distribution and the resulting frequency curve graph. Note, the user can opt to clip the lower or upper tail of the distribution using the **Clip Min Value**, or **Clip Max Value**, or both (see the section on Clipping the Lower and/or Upper Tails of a Frequency Curve).

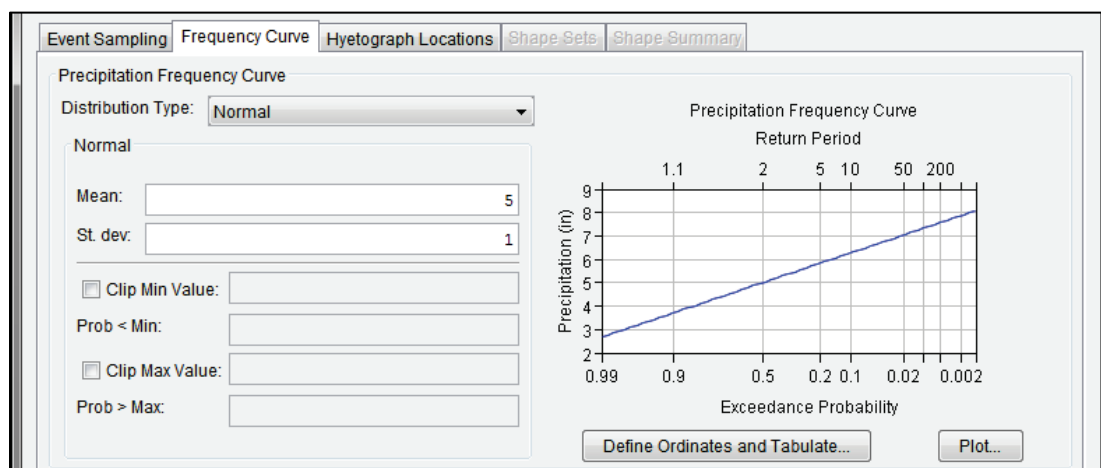


Figure 4-13 Precipitation Sampling – Frequency Curve Tab – Normal Distribution

Distribution Type – Generalized Extreme Value (GEV)

To define the **GEV** (Generalized Extreme Value), enter the **Location (ξ)**, **Scale (α)** and **Shape (κ)** distribution parameters (Figure 4-14). Changes made to the parameters immediately update the **Precipitation Frequency Curve** graph. Figure 4-14 provides an example of a completed GEV distribution and the resulting frequency curve graph. Note, the user can opt to clip the lower or upper tail of the distribution using the **Clip Min Value**, or **Clip Max Value**, or both (see the section on Clipping the Lower and/or Upper Tails of a Frequency Curve).

Note: GEV user parameters can be defined in more than one way. In HEC-WAT (Version 1.0) and HEC-SSP (Version 2.2 or greater) software, the GEV input parameters follow the description in the *Handbook of Hydrology* (Maidment Ed., 1993) and *Regional Frequency Analysis* (Hosking et. al., 1997).

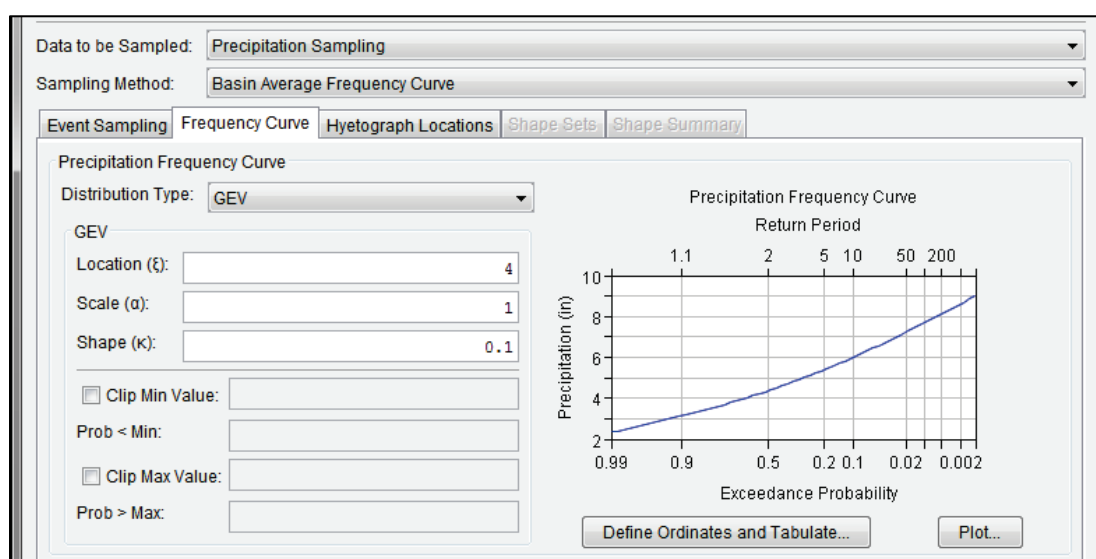


Figure 4-14 Precipitation Sampling – Frequency Curve Tab – GEV (Generalized Extreme Value) Distribution

Distribution Type – Empirical (graphical)

To define the **Empirical (graphical)** distribution type, complete the **Exceedance Probability** and **Precipitation (in)** table using manual entry, or copy in from another table. **Precipitation (in)** refers to precipitation total in inches. Figure 4-15 provides an example of a completed empirical (graphical) distribution and the resulting frequency curve graph.

Right-click inside the table to access the shortcut menu options available (e.g., cut, copy, paste, etc.) for editing the table (refer to Section 1.2.4 for shortcut options). Note, extrapolation does not occur beyond the user-defined minimum and maximum precipitation, so the curve must be defined for the desired sampling range. Changes made to the inputs immediately update the **Precipitation Frequency Curve** graph.

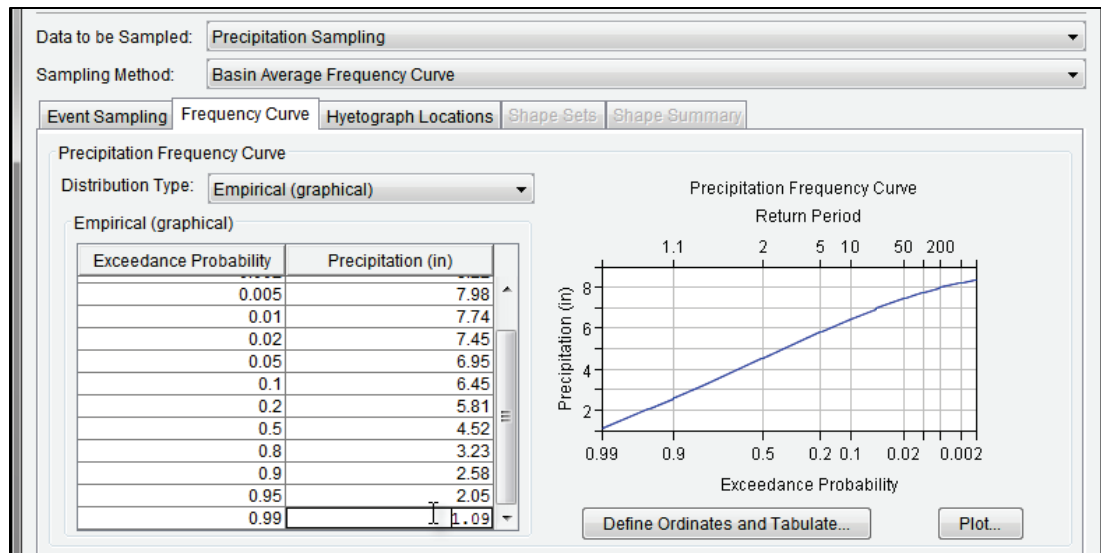


Figure 4-15 Precipitation Sampling – Frequency Curve Tab – Empirical Distribution

Clipping the Lower and/or Upper Tails of the Frequency Curve

For **Pearson type III**, **Normal**, and **GEV** distribution types, the user can opt to clip the lower or upper tail of a distribution using **Clip Min Value (Prob < Min)**, or **Clip Max Value (Prob > Max)**. For example, it is good practice to clip the lower tail at 0.0 to prevent negative values.

To create clipping threshold(s), check the checkbox ☒ next to the clipping option (**Clip Min Value** and/or **Clip Max Value**) to select it (Figure 4-16). Once selected, the value field is enabled. Enter the minimum or maximum value in the enabled field, and the corresponding **Prob < Min** or **Prob > Max** field updates showing the probability of the original distribution having a value beyond the clip threshold (and thus being clipped, or excluded from the precipitation frequency curve).

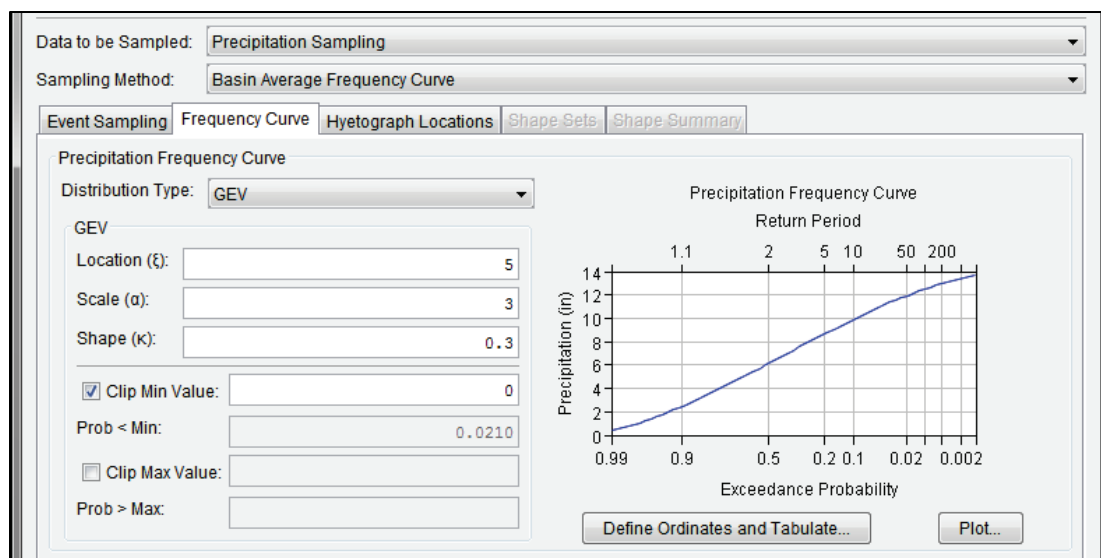


Figure 4-16 Precipitation Sampling – Frequency Curve Tab – Distribution Clipped – Example

Note, the calculated probability is displayed as a value between 0.0 – 1.0, not a percent. Figure 4-16 provides an example using the **Clip Min Value** option. In this example, the **Clip Min Value** of 0 inches results in a probability (**Prob > Min**) of 0.0210 (or 2.1 %). It is strongly recommended that a minimum clip value of 0.0 be defined for precipitation sampling, even if the frequency curve does not closely approach zero. This choice ensures that each re-sampled realization-specific frequency curve, which may be lower than the original user-entered curve, is also kept greater than zero.

4.3.2 Uncertainty

The Hydrologic Sampler includes the ability to capture uncertainty when the specified basin average precipitation frequency curve is not known precisely (e.g., due to limited available record length). This type of uncertainty is knowledge uncertainty (as described in the introduction to Chapter 1), and is addressed in the outer loop of HEC-WAT Flood Risk Analysis (FRA) nested Monte Carlo simulation, meaning it is sampled once per realization.

As noted in the introduction to this chapter, a new frequency curve is generated for each realization by parametrically bootstrapping, or randomly sampling N values (where N is the equivalent record length) from the original frequency curve, and then fitting a new frequency curve of the same distribution type with parameters estimated from that N-value sample. This new frequency curve is generated in the outer loop of the HEC-WAT Monte Carlo simulation. All event precipitation magnitudes are then sampled from this uncertainty-adjusted frequency curve, in the inner loop of the HEC-WAT Monte Carlo simulation (Chapter 1).

From the **Hydrologic Sampling Editor**, enter information about the uncertainty of the precipitation frequency curve from the **Uncertainty** panel (Figure 4-17) of the **Frequency Curve** tab (Figure 4-9). Generally, two uncertainty options are available for all distribution types that users may choose from: **No Uncertainty**, or a specified **Equivalent Years of Record** (default). A third option is available to define uncertainty for an **Empirical** (graphical) frequency curve (**User Defined Uncertainty**), which uses a normal distribution at each ordinate with a user-defined standard deviation, entered as a table.

Exceedance Probability	Standard Deviation
0.9	1.0
0.1	10.0

Figure 4-17 Precipitation Sampling – Frequency Curve Tab – Uncertainty Options

No Uncertainty

From the **Frequency Curve** tab (Figure 4-9); from the **Uncertainty** panel (Figure 4-17), select **No Uncertainty**. Choose this option to use the user-defined precipitation frequency curve for sampling events in every realization without adding uncertainty.

Equivalent Years of Record

From the **Uncertainty** panel (Figure 4-17), select **Equiv. years of record** (default) and enter the number of years in the box next to **Equiv. years of record**. An equivalent record length parameterizes uncertainty due to a limited record length. This uncertainty value is either the actual record length used to estimate the precipitation frequency curve, or an equivalent length based on the regional analysis used to develop the precipitation frequency curve.

For analytical distributions (**Uniform**, **Triangular**, **Normal** or **Gamma**), a new frequency curve is generated by creating a random "bootstrap" sample of size N (where N = specified equivalent record length) from the originally entered frequency curve, and re-estimating the distribution parameters from that sample.

User Defined Uncertainty

This option is only available when the selected **Distribution Type** is **Empirical (graphical)**. From the **Uncertainty** panel (Figure 4-17), select the **User Defined Uncertainty** option, this enables the provided table, which displays default values. If necessary, edit the default values to override the computed standard deviation of uncertainty for each frequency quantile (based on the order statistics method). Right-click inside the table to access the same shortcut menu options (e.g., cut, copy, paste, etc.) discussed Section 1.2.4.

Click the **Apply** button to save changes made to the **Frequency Curve** tab. Alternatively, if users are finished adding information or editing, then click the **OK** button to close the **Hydrologic Sampling Editor**. Users can click the **Data Check** button (Section 1.2.6) to determine if data consistency error(s) are present for the completed tab, before proceeding to the next tab, if desired. Note, the **Data Check** is generally used after all required inputs have been defined to avoid generating a long list of as-yet undefined inputs (e.g., undefined **Hyetograph Locations** and **Shape Sets** tabs).

4.4 Hyetograph Locations Tab

As discussed in the introduction to this chapter, the Hydrologic Sampler will generate precipitation hyetographs for each event at each location specified by the user, which are made available to the subsequent models in the HEC-WAT model sequence. From the **Hydrologic Sampling Editor**, the **Hyetograph Locations** tab (Figure 4-18) provides users with the ability to add hyetograph locations, or rename, copy or delete existing hyetograph locations. The user must specify a subbasin area in square miles for each location added to the table.

Figure 4-18 Precipitation Sampling – Hyetograph Locations Tab – Default View

4.4.1 Create and Define Hyetograph Locations

Create hyetograph locations for the hydrologic sampling alternative:


1. From the **Hyetograph Locations** tab, click on the **New Location** button to open the **Create New Hyetograph Location** dialog (Figure 4-19).
2. Enter a name for the new hyetograph location in the **Name** box. Enter a description in the **Description** box (optional, but recommended). To view the entire description for long descriptions, use the  button to open the description field in a new window.

Figure 4-19 Create New Hyetograph Location Dialog

3. Click **OK** to save the newly created hyetograph location, close the **Create New Hyetograph Location** dialog, and return to the **Hyetograph Locations** tab. The **Hyetograph Locations** tab updates with a hyetograph location table and the **Location** column displays the **Name** of the created hyetograph location.
4. The user must enter a subbasin area (in square miles) for every created hyetograph location. Manually enter the subbasin area (in square miles) in the **Override Area** column.

- Repeat Steps 1 through 4 to create and define as many hyetograph locations as required for the hydrologic sampling alternative. Figure 4-20 provides an example of a completed hyetograph locations table. Once hyetograph location(s) have been created, users can rename, copy, or delete individual locations (as described in Sections 4.4.2 through 4.4.4).

Location	Override Area
Brush Creek	100.0
Lake Mendocino	50.0
Oat Valley	25.0

Figure 4-20 Precipitation Sampling – Hyetograph Locations Tab – Example Completed

4.4.2 Rename a Hyetograph Location

From the **Hyetograph Location** tab (Figure 4-18), select the location of interest from the hyetograph location table (e.g., *Oat Valley* in Figure 4-20) and click **Rename Location**. The **Rename Location** dialog (Figure 4-21) opens. Enter the new **Name** for the hyetograph location and a **Description** (optional, but recommended). Click **OK** to save changes.

Figure 4-21 Rename Location Dialog

4.4.3 Copy a Hyetograph Location

From the **Hyetograph Location** tab (Figure 4-18), select the location of interest from the hyetograph location table and click **Save Location as**. The **Save Location As** dialog (Figure 4-22) opens. Enter the name for the copied hyetograph location in the **Name** box and a description in the **Description** box (optional, but recommended). Click **OK** to save changes.

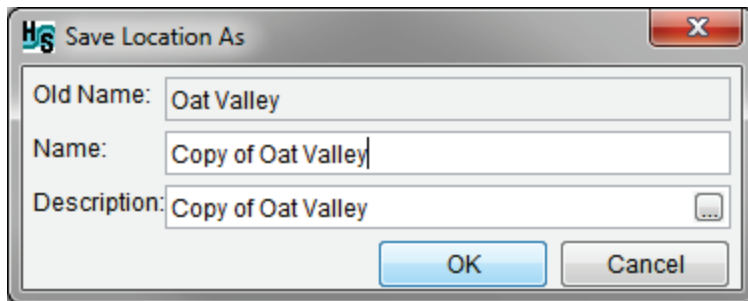


Figure 4-22 Save Location As Dialog

4.4.4 Delete a Hyetograph Location

From the **Hyetograph Location** tab (Figure 4-18), select the location of interest from the hyetograph location table and click **Delete Location**. The **Confirm delete** dialog (Figure 4-23) opens. Click **Yes** to delete the selected hyetograph location. Click **No** to close the **Confirm delete** dialog without deleting the hyetograph location.

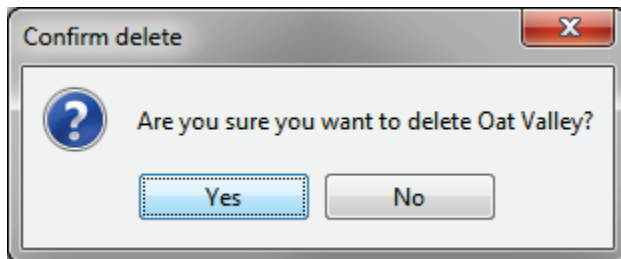


Figure 4-23 Confirm delete Dialog

4.5 Shape Sets Tab

From the **Hydrologic Sampling Editor**, the **Shape Sets** tab (Figure 4-24) allows the user to specify user-defined shape sets (time series), with DSS records for each hyetograph (subbasin) location that has been created in the **Hyetograph Locations** tab (refer to Section 4.4 for information on creating hyetograph location(s)). Each shape set must also have a weight for defining its relative likelihood among all shape sets, and a probability range within which it may be used.

A shape set is a collection of user-defined precipitation event hyetographs (time series) assigned to subbasin locations within a watershed. Shape sets are used to convert randomly sampled basin average precipitation depths into precipitation event hyetographs (time series). Each shape set inherently captures the temporal and spatial pattern of a particular precipitation event across a watershed, based on the occurrence of precipitation over time, and the relative magnitude of precipitation depth at various locations. Different shape sets will capture different examples of possible temporal and spatial patterns. A shape set inherently has no absolute magnitude, only relative magnitude between subbasin locations, and the set is scaled so the subbasin average (area-weighted average of all subbasin hyetographs) matches the sampled precipitation depth of each precipitation event.

Section 4.5.3 provides more information regarding DSS time series, and includes examples of shape set hyetographs. It is important to note that the DSS time-window (start and end dates and times) of each hyetograph shape *within all* shape sets must be the same for *all* subbasin locations. In other words, the time series start and end dates and times must all agree in the selected DSS file(s) for *all* shape sets. Furthermore, the time interval (e.g., 15 minutes, one hour, one day, etc.) for *all* hyetographs in *all* shape sets must be the same.

Figure 4-24 Hydrologic Sampling Editor – Precipitation Sampling – Shape Sets Tab – Default View

Moreover, the duration of effective precipitation (non-zero precipitation) within the shape set should match the duration of the basin average precipitation frequency curve. For example, the hyetographs should have 72 hours of non-zero precipitation when the duration of the basin average precipitation frequency curve is three days. Having more or less than three days of non-zero precipitation could result in improperly scaled precipitation depths. However, the overall time-window of the hyetographs should extend beyond the duration of the basin average precipitation frequency curve to allow the subsequent model compute to capture all of the resulting runoff.

Specifically, zero precipitation values can be added to the precipitation shape sets so computed runoff makes its way through the watershed (as required by subsequent models in the FRA compute sequence). For example, if an HEC-ResSim model requires a significantly long lookback period, each shape set should be defined with adequate time-steps (compute interval) for the lookback window before the start of the event (refer to Section 4.5.3 for examples). Refer to the HEC-WAT User's Manual or the HEC-ResSim User's Manual for more information on lookback periods.

Typically, actual (historical) precipitation events define shape sets in the watershed, with the hyetograph for each location used as it occurred. During the compute, the selected set of shapes

is scaled to match the new basin average precipitation depths for a sampled precipitation event. Artificial shape sets, or hyetographs from some other watershed or model, may also be used to supplement historical events, if the historical events do not provide all desired time and space distributions. A good practice is to include hyetograph shape sets that represent many possible variations of precipitation across the watershed.

The Hydrologic Sampler generates flood events across the range of very large to very small, defined by the randomly sampled exceedance probabilities. Some shapes are more appropriate for large events and some for small, and so an **Exceedance probability filter** (Figure 4-24) is defined for each shape set to specify the range of event magnitudes for which the set is appropriate. The exceedance probability sampled for the flood event limits the available shape sets to only those having that probability in their allowable range.

The shape sets **Weight** (Figure 4-24) defines the relative likelihood of each set (weight of set divided by sum of weights of available sets), used in randomly selecting a shape set for each event. The **Shape Set Summary** tab (refer to Section 4.6) shows the resulting relative likelihood for each range of exceedance probability, because likelihoods adjust for a range in which some sets are not available.

The structure of the **Shape Sets** tab (Figure 4-24) consists of one main section, the **Shape Set** section, and three panels: (1) the exceedance probability filter panel for setting the exceedance probability filter maximum and minimum, (2) the weight panel to set the weight of the shape set and view the resulting total weight and probability, and (3) the DSS time series panel for setting the DSS record pathname for all hyetograph locations. Users create shape set(s) in the **Shape Set** section, and enter information specific to each created shape set in the three panels.

4.5.1 Create Shape Sets

To complete the **Shape Sets** tab for the hydrologic sampling alternative, the user must create each desired shape set. For each new shape set, the user will specify its **Weight**, **Exceedance probability filter** and a **DSS record** for each hyetograph location:

1. From the **Shape Set** main section (Figure 4-24), click the **New Set** button, and the **Create New Shape Set** dialog box opens (Figure 4-25).

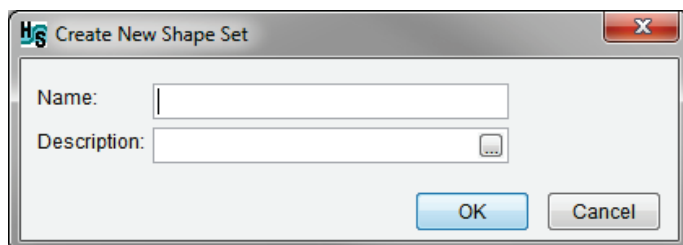


Figure 4-25 Create New Shape Set Dialog

2. Enter a **Name** (e.g., *1986 data*) and a **Description** (optional, but recommended) for the new shape set. To view the entire description for long descriptions, use the  button to

open the description field in a new window. **Note:** the **Name** (and description) can be used to match the correct DSS file (*.dss) with the correct **Shape Set**.

- Click **OK** to save the newly created shape set and close the **Create New Shape Set** dialog. The **Hydrologic Sampling Editor** updates with the created shape set (Figure 4-26). Created shape sets appear in the **Shape Set** list.

Data to be Sampled: Precipitation Sampling

Sampling Method: Basin Average Frequency Curve

Event Sampling | Frequency Curve | Hyetograph Locations | **Shape Sets** | Shape Summary

Shape Set: 1986 data

Description: Example for User's Manual

New Set... Rename Set... Save Set As ... Delete Set...

Location for Exc. Probability filter (same for all shape sets): WATERSHED

Exceedance probability filter: Exceedance Probability Max: 1 Exceedance Probability Min: 0

Weight: 1 Total Weight: 1 Probability (full range): 1

Location	Type	DSS File	Part A	Part B	Part C	Part E	Part F
Brush Creek	Hyetograph						
Lake Mendocino	Hyetograph						
Oat Valley	Hyetograph						

Plot... Tabulate... Select DSS Path...

Data Check OK Cancel Apply

Figure 4-26 Precipitation Sampling – Shape Sets Tab – Created Shape Set Example

As described in the following sections, the users can continue to complete the created shape set by assigning the exceedance probability filters and weight, and by selecting the DSS shape set time series.

4.5.2 Assign Shape Set Filters and Weight

From the **Shape Sets** tab (Figure 4-26); users can continue to define a created shape set or edit an existing shape set (selected from the **Shape Set** list) by entering exceedance probability filters and a weight for the selected shape set, as follows:

- From the exceedance probability filter panel, the **Location for Exc. Prob. filter (same for all shape sets)** is an option needed for flow sampling in the Hydrologic Sampler that is not used for precipitation sampling, as the random sampling is performed for the entire watershed at once with only one exceedance probability per event. Therefore, the location is automatically set to **WATERSHED** and does not need to be modified by the user.
- For individual shape sets, enter the **Exceedance probability filters** manually for **Max** and **Min** in the boxes provided, if the default values of **1.0** and **0.0** are not appropriate. To

modify the defaults for the **Exceedance Probability Max** or **Exceedance Probability Min** for the shape set, click inside the box provided and manually change the number.

3. The exceedance probability maximum and minimum values allow the user to define the appropriate probability range for each shape set, with the exceedance probability corresponding to the sampled precipitation depth. For example, some historical precipitation event shapes are reasonable only for a very large precipitation event (with small exceedance probability), and some are reasonable only for a smaller precipitation event (with large exceedance probability).
 - By default, the **Exceedance Probability Max** is *1.0* and **Exceedance Probability Min** is *0.0*. Use the default minimum and maximum, to allow the selected shape set to be chosen for any precipitation event.
 - To limit a shape set to only *large* events (that correspond to small exceedance probabilities), assign the **Exceedance Probability Max** value a probability smaller than 1.0.
 - To limit a shape set to only *small* events (that correspond to large exceedance probabilities), assign the **Exceedance Probability Min** value a probability larger than 0.0.
4. For individual shape sets, click inside the box provided and manually enter the **Weight** for the selected shape set, if the default value of *1.0* is not appropriate. The purpose of the weight is to define the relative likelihood of sampling individual shape sets. One shape set may be unusual for the watershed, and another might be quite common. Therefore, users can assign each shape set a weight; based on that weight the probability is automatically generated. The probability is computed, as the shape set's weight divided by the sum of the weights of all relevant shape sets. Equal weights will result in individual shape sets having equal likelihood of being sampled, while shape sets with higher weights result in a greater likelihood of being sampled.
 - By default, the **Weight** for a created shape set is a value of *1.0*, which results in the shape set having equal likelihood of being sampled. For example, if a hydrologic sampling alternative contains three shape sets and each shape set has a **Weight** value of one, then each will have a one-third chance of being selected for each precipitation event (weight 1.0 divided by total weight 3.0).
 - If one of the three shape sets has a **Weight** of 2.0, it will then have a probability of one-half of being chosen (weight 2.0 divided by total weight 4.0), and the other two shape sets will have a probability of one-quarter (weight 1.0 divided by total weight 4.0).

For convenience, users can view a list of all created and defined shape sets, with the exceedance probability bounds, the weight and resultant probability (full range) displayed for each shape set, from the **Shape Set Summary** tab (refer to Section 4.6).

4.5.3 Select Shape Set Time Series

A shape set is a collection of user-defined scalable hyetograph time series for every subbasin location that together capture the relative spatial and temporal distribution of rainfall throughout the watershed for a given event, which is usually defined by a large event from the historical record. Based on the user-defined area for each subbasin (refer to Section 4.4), the shape set time series is used in conjunction with a randomly sampled basin average precipitation depth to create a hyetograph for every subbasin area.

Several important aspects should be considered when defining the shape set hyetograph time series for each subbasin location. For example, the type of storm, the speed, and the direction it travels across the watershed often affects the duration of the resulting peak streamflow and relative timing of the peak flow at various locations in the watershed. Shape sets should capture the “critical” duration for the watershed, which reflects the duration of extreme precipitation events that have the greatest effect on the resulting peak streamflow. The duration of effective, non-zero precipitation in each shape set must match the critical duration of the basin average precipitation frequency curve.

Several historical flood events should be chosen that collectively capture an array of possible precipitation event patterns. Figure 4-27 provides two different example shape sets, each with three hyetographs from an historical precipitation event. The three individual hyetographs in each figure together form one shape set for a hydrologic sampling alternative that contains three hyetograph locations.

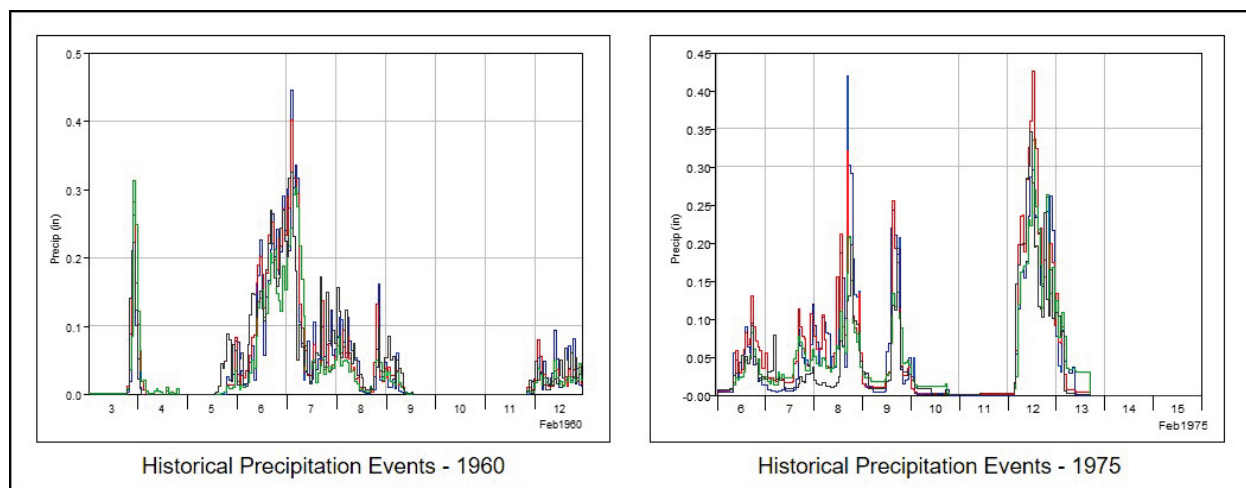


Figure 4-27 Hyetograph Shape Sets –DSS Time Series for Historical Precipitation Events from 1960 and 1975

Important: The DSS time-window (start and end dates and times) of each hyetograph shape must be the same for *all* subbasin locations *within* a shape set, but can be different *between* shape sets (e.g., Figure 4-27). However, the time interval (e.g., 15 minutes, 1 hour, 1 day, etc.) and the number of event ordinates must be the same for *all* hyetographs in *all* shape sets.

Note: If an HEC-ResSim model requires a significantly long lookback period, each shape set should be defined with adequate time-steps (compute interval) for the lookback window before

the start of the event. In other words, all hyetographs in the shape set must have a time-window appropriate for the HEC-ResSim model's lookback window. Figure 4-28 provides an example of three hyetographs in a shape set with added time-steps to extend the start of the time-window. Refer to the HEC-WAT User's Manual or the HEC-ResSim User's Manual for more information on lookback periods and time-steps.

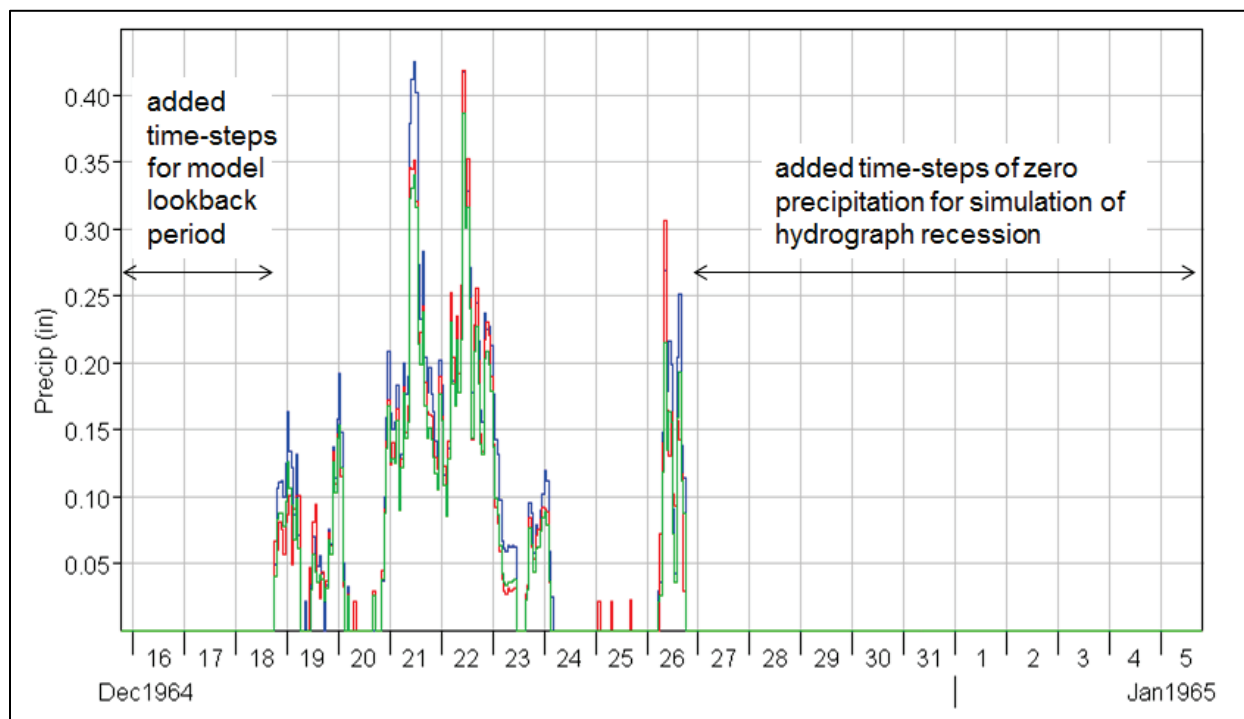


Figure 4-28 Example – Precipitation Sampling – Time-Steps Added to Extend Hyetographs in a Shape Set for HEC-ResSim

Each individual hyetograph time series must be stored as a DSS record, most conveniently in the same HEC-DSS file (*.dss). Refer to the *HEC-DSSVue User's Manual* for more information regarding HEC-DSS files. Users select the stored DSS records through the **Hydrologic Sampling Editor** interface, from the **Shape Sets** tab (Figure 4-26), which is then referenced by the Hydrologic Sampler during an FRA compute.

The next steps describe selecting the DSS record pathnames for shape hyetographs for all hyetograph locations, from the DSS time series panel (Figure 4-29). A hyetograph must be defined for each subbasin hyetograph location (as defined in Section 4.4) listed in the DSS input table. DSS records must be specified for all created shape sets (as selected from the **Shape Set** list).

Complete the DSS input table for shape set locations:

1. For each hyetograph **Location** listed in the DSS input table (Figure 4-29), a DSS path must be identified (**DSS File** and pathname **Parts A – F**). To set the DSS path, click any cell in the row for the hyetograph location of interest, and the location-specific **Select DSS Path** button will be enabled (Figure 4-29).

Note that the time-step (or time interval) for the time series DSS records must be the same for all locations. In other words, **Part E** (e.g., 1HOUR) must be the same for all locations in all shape sets contained in the **Shape Sets** dropdown list. Similarly, the DSS record length (time-window: start and end dates and times) must be the same for every record in the shape set. All shape sets (contained in the **Shape Sets** list) must also have the same DSS record lengths, i.e., all must have the same number of ordinates.

Figure 4-29 Precipitation Sampling – Shape Sets Tab – Example Location – Select DSS Path


- To select a DSS path for a location, click any cell in the row of a location; click **Select DSS Path** (Figure 4-29). An **HEC-DSSVue** dialog box will open (Figure 4-30). Refer to the HEC-DSSVue User's Manual for more information regarding DSS pathnames and HEC-DSSVue.
- From the **HEC-DSSVue** dialog box, click  (Figure 4-30); the **Open HEC-DSS File** browser will open (Figure 2-37). Browse to the location of a DSS file (*.dss) that contains the time series shape set hyetographs. Click on the appropriate *.dss file, the **File name** box now contains the name of the selected file (e.g., 1986_Shape.dss).

Figure 4-30 HEC-DSSVue Dialog Box

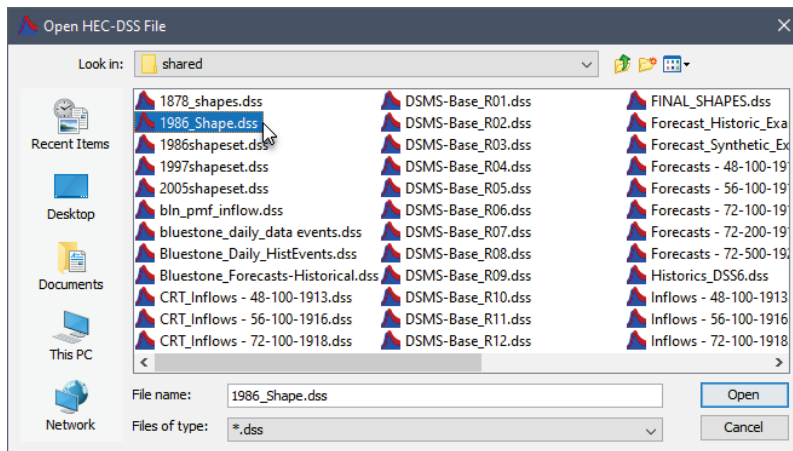


Figure 4-31 Open HEC-DSS File Browser

4. Click **Open**, the **Open HEC-DSS File** browser will close (Figure 4-31). The **HEC-DSSVue** dialog box (Figure 4-30) now displays the DSS records for the selected DSS file.
5. For the location (e.g., *Brush Creek*) that was selected in the DSS input table in the **Hydrologic Sampling Editor** (Figure 2-30), find and select the proper pathname (record) from the list of DSS records in the **HEC-DSSVue** dialog box (Figure 4-30), click **Set Pathname**. From the **Hydrologic Sampling Editor** (Figure 4-29), the DSS input table now contains the **DSS File** pathname (Parts A – F) for the selected **Location** (e.g., *Brush Creek*).
6. Select the next location, from the **HEC-DSSVue** dialog box (Figure 4-30), find and select the proper pathname (record) from the list of DSS records in the **HEC-DSSVue** dialog box (Figure 4-30), click **Set Pathname**. Repeat this step until all locations in the DSS input table (Figure 4-28) contain the correct DSS filename and the DSS pathnames. Figure 4-32 provides an example of a completed DSS input table.

Data to be Sampled: **Precipitation Sampling**

Sampling Method: **Basin Average Frequency Curve**

Event Sampling | **Frequency Curve** | Hyetograph Locations | Shape Sets | Shape Summary

Shape Set: **1986 data**

Description:

New Set... Rename Set... Save Set As... Delete Set...

Location for Exc. Probability filter (same for all shape sets): **WATERSHED**

Exceedance probability filter: Exceedance Probability Max: Exceedance Probability Min:

Weight: Total Weight: Probability (full range):

Location	Type	DSS File	Part A	Part B	Part C	Part E	Part F
Brush Creek	Hyetograph	shared/1986_Shape.dss		BRUSH CK	PRECIP-INC	1HOUR	RUN:50YRS
Lake Mendocino	Hyetograph	shared/1986_Shape.dss		LAKE MENDOCINO	PRECIP-INC	1HOUR	RUN:50YRS
Oat Valley	Hyetograph	shared/1986_Shape.dss		OAT VALLEY CK	PRECIP-INC	1HOUR	RUN:50YRS

Plot... Tabulate... Select DSS Path...

Data Check OK Cancel Apply

Figure 4-32 Precipitation Sampling – Shape Sets Tab – Example Completed

- Click **Apply** (Figure 2-30). Next, the user can choose to define the DSS records for the other shape sets selected from the **Shape Set** list (and repeating Steps 1 through 6), move onto reviewing the shape sets and making adjustments (Section 4.6), or click **OK** (Figure 2-30) to save the selected hydrologic sampling alternative and close the **Hydrologic Sampling Editor**. Recall that **Data Check** (Section 1.2.6) can be used to search for data consistency error(s) prior to closing the editor.

4.5.4 Rename a Shape Set

To rename an existing shape set selected from the **Shape Set** list, from the **Shape Set** main section (Figure 4-32), click the **Rename Set** button to open the **Rename Shape Set** dialog (Figure 4-33). Enter the new name for the shape set in the **Name** box and a description in the **Description** box (optional, but recommended). Click **OK** to save changes.

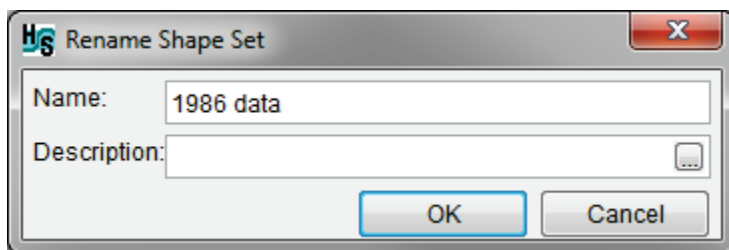


Figure 4-33 Rename Shape Set Dialog

4.5.5 Copy a Shape Set

Copy a selected shape set, from the **Shape Set** main section (Figure 4-32), click **Save Set As** to open the **Save Shape Set As** dialog (Figure 4-34). Either use the default name or manually enter the name for the copied shape set in the **Name** box and a description in the **Description** box (optional, but recommended). Click **OK** to save changes.

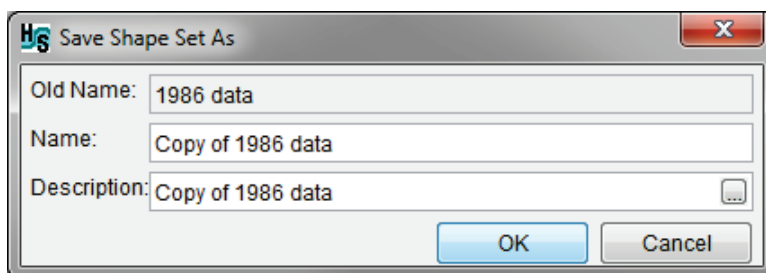


Figure 4-34 Save Shape Set As Dialog

4.5.6 Delete a Shape Set

To delete an existing shape set selected from the **Shape Set** list, from the **Shape Set** main section (Figure 4-32), click **Delete Set** to open the **Confirm delete** dialog (Figure 4-35). Click **Yes** to delete the selected shape set. Click **No** to close the **Confirm delete** dialog without deleting the shape set.

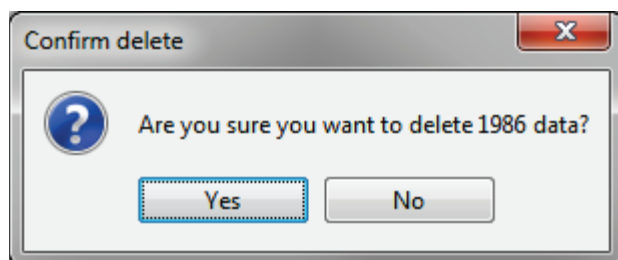


Figure 4-35 Confirm delete Dialog

4.6 Shape Summary Tab

From the **Hydrologic Sampling Editor**, the **Shape Summary** tab (Figure 4-36) displays all shape sets at the same time, rather than one at a time as in the **Shape Set** tab (refer to Section 4.5). The **Shape Summary** tab consists of two main sections: a shape set summary table and summary plot. The summary table lists the shape sets created and defined in the **Shape Sets** tab, with the weight and resultant probability displayed for each shape set. The displayed shape set **Exceedance Probability Minimum** and **Maximum** and **Weight** values are editable on this tab, and edits automatically update in the **Shape Sets** tab (Figure 4-32) and the graphical display at the bottom of the **Shape Summary** tab.

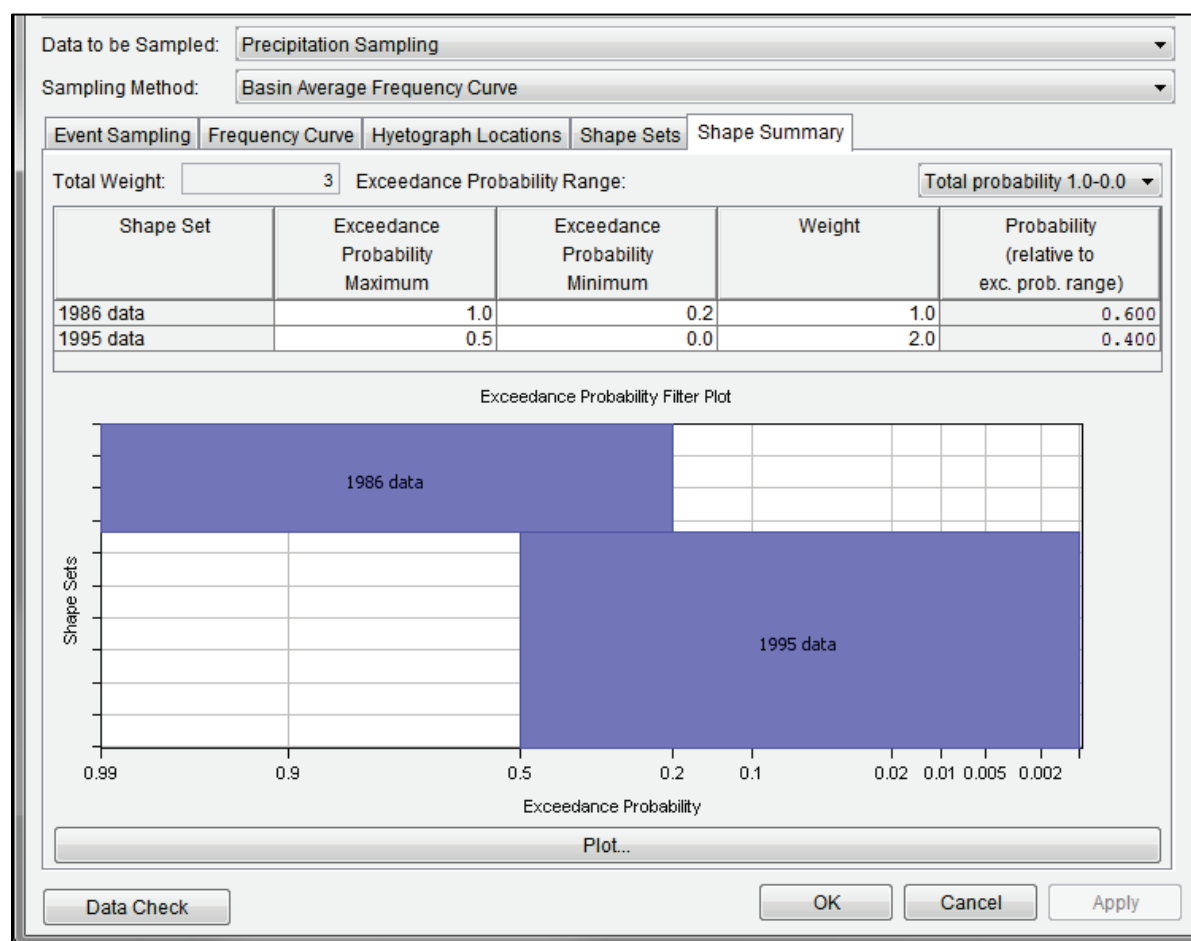


Figure 4-36 Precipitation Sampling – Shape Summary Tab – Example

In the **Shape Summary** tab (Figure 4-36), users can manually edit the exceedance probability (minimum and/or maximum) or weight values for a shape set in the summary table. To edit a cell and overwrite an existing value, click once and type in the new number. Select a cell (or multiple cells, columns or rows) and right-click to access the shortcut menu options to copy, paste, fill, etc. (refer to Section 1.2.4 for shortcut options).

The shape set summary plot section contains the **Exceedance Probability Filter Plot** at the bottom of the tab (Figure 4-36). Click **Plot** to open the **Exceedance Probability Filter Plot** in a new window. The plot illustrates the relative selection probability of each shape set, as well as the exceedance probability range in which each shape set can be selected. Each box's vertical thickness reflects its relative probability of being randomly selected (as defined by the **Weights**). Each box's horizontal span depicts the range (between 0.0 and 1.0) of the **Exceedance Probability Range** that applies to each shape set, on a normal probability axis. The vertical order of the shape sets corresponds to the order in which they were created (top to bottom, first to last).

As can be seen in the **Exceedance Probability Filter Plot**, the result of limiting the exceedance probability ranges of shape sets is that the complete 0.0 to 1.0 range is divided at all bounding values, creating sub-ranges in which some shape sets are excluded. Therefore, the relative probability of a given shape set (defined as its weight divided by the total weight of all available shape sets) may be different in each sub-range. Users can view modified probabilities for different preset sub-ranges in the shape set table by selecting a sub-range from the **Exceedance Probability Range** dropdown list (Figure 4-37). Note, selecting different exceedance probability ranges does not change the **Exceedance Probability Filter Plot**; instead, the selection only updates the last column in the summary table (Figure 4-38).

The screenshot shows the 'Shape Summary' tab in the HEC-WAT software. At the top, 'Data to be Sampled' is set to 'Precipitation Sampling' and 'Sampling Method' is 'Basin Average Frequency Curve'. Below these are tabs for 'Event Sampling', 'Frequency Curve', 'Hyetograph Locations', 'Shape Sets', and 'Shape Summary'. The 'Shape Summary' tab is active, showing a table with columns: 'Shape Set', 'Exceedance Probability Maximum', 'Exceedance Probability Minimum', and 'Weight'. The table contains two rows: '1986 data' with values 1.0, 0.2, and 1, and '1995 data' with values 0.5, 0.0, and 2. To the right of the table is a dropdown menu for 'Exceedance Probability Range:' with a list of options: 'Total probability 1.0-0.0', 'Total probability 1.0-0.0', '1.0-0.5', '0.5-0.2', '0.2-0.0', and 'No-interval probability'. The 'Total probability 1.0-0.0' option is currently selected.

Shape Set	Exceedance Probability Maximum	Exceedance Probability Minimum	Weight
1986 data	1.0	0.2	1
1995 data	0.5	0.0	2

Figure 4-37 Precipitation Sampling – Shape Summary Tab – Exceedance Probability Range List

With a sub-range selected (e.g., 0.2-0.05), the **Probability (relative to exc. prob. range)** column of resultant relative probability displays the values for the selected sub-range, with excluded shape sets having a probability of zero, and others having probability based on the total weight of active shape sets. Figure 4-38 displays an example dropdown selection of a probability sub-range resulting from the collection of ranges, and the subsequent probability of each shape set. The **No-interval probability** option in the dropdown list (Figure 4-37) provides the relative probabilities of the shape set(s) if not modified by the probability filters.

Data to be Sampled: **Precipitation Sampling**

Sampling Method: **Basin Average Frequency Curve**

Event Sampling | **Frequency Curve** | Hyetograph Locations | Shape Sets | Shape Summary

Total Weight: **3** Exceedance Probability Range: **0.2-0.0**

Shape Set	Exceedance Probability Maximum	Exceedance Probability Minimum	Weight	Probability (relative to exc. prob. range)
1986 data	1.0	0.2	1.0	0.000
1995 data	0.5	0.0	2.0	1.000

Figure 4-38 Precipitation Sampling – Shape Summary Tab – Example Exceedance Probability Range Selection

When only one shape set exists, its **Exceedance Probability** must span from 0.0 to 1.0. When two or more shape sets exist, the exceedance probability range for all shape sets must together span the range from 0.0 to 1.0. If the full range for the exceedance probability is not spanned, the missing probability range will be marked in red in the summary table and with an “ERROR” label in the **Exceedance Probability Filter Plot** (Figure 4-39). In this case, at least one shape set must be redefined to span that range, or another shape set added for the missing exceedance probability range.

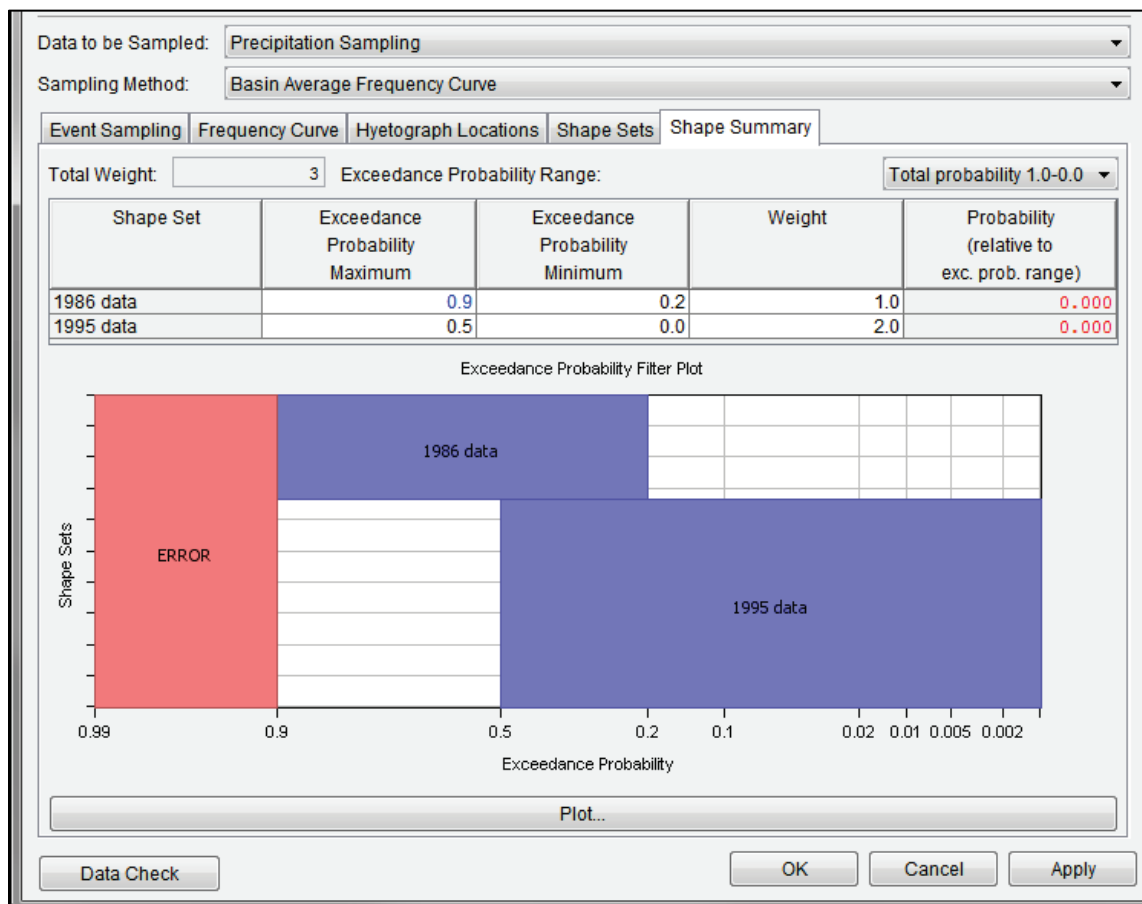


Figure 4-39 Precipitation Sampling – Shape Summary Tab – Example Error

Click **Apply** to save changes in the **Shape Summary** tab when navigating between hydrologic sampling alternatives. Alternatively, click **OK** to save the hydrologic sampling alternative and close the **Hydrologic Sampling Editor**. Recall the **Data Check** button (refer to Section 1.2.6) can be used to search for data consistency error(s) prior to closing the editor.

CHAPTER 5

Hydrologic Sampler Results

It is important for the user to be able to verify that the Hydrologic Sampler outputs reproduce the probability distribution inputs the user defined in a Hydrologic Sampling alternative used for a Flood Risk Analysis (FRA) simulation. Therefore, in HEC-WAT Version 1.0, certain Hydrologic Sampler results are available within the HEC-WAT Framework for comparison to those probability distributions, and the user is encouraged to examine these after a simulation has successfully computed. Results can be accessed using two methods: viewing Hydrologic Sampler **Results** menu items (accessed from the HEC-WAT menu bar), outlined in this chapter (Section 5.3); and using the more generalized **Output Variable Editor** (accessed from the HEC-WAT toolbar), described in Chapter 16 of the HEC-WAT User's Manual.

A generated flood event includes a maximum flow at each location, with specified cross-correlation between primary locations, a shape set to transform these maximum flows into hydrographs, and a date to place the event in time. Hydrologic Sampler results (accessed from the **Results** menu, from the HEC-WAT menu bar) include plots and tables that allow the user to verify each aspect of this flood event generation as follows:

- A histogram of sampled event dates, for comparison to the input flood season distribution.
- Sampled annual maximum flows, for comparison to input frequency curves.
- Correlations between maximum flows at different primary flow locations, for comparison to the input cross correlation matrix.
- Shape set frequencies, for comparison to the combination of input weights and exceedance probability filters.

The user may also choose to view individual event hydrographs, having chosen a realization, lifecycle and event number. Finally, the Hydrologic Sampler output file is available for the lifecycle of that chosen event if the prerequisite steps have been completed (Section 5.1).

Due to the nature of Monte Carlo simulations, the results will match the input distribution more closely as the total number of simulated events increases. A poor match may occur when few events are computed (resulting either from few events per realization, or few realizations). Any obvious failures to match input distributions, given adequate simulated events, should be explored more closely.

5.1 Prerequisites

As a component of the HEC-WAT framework, the Hydrologic Sampler will generate hydrologic data for an FRA study. However, several steps are required before users can obtain and view Hydrologic Sampler results from the HEC-WAT main window (Figure 5-1). This manual is supplemental to the HEC-WAT User's Manual. Refer to Chapter 15, Section 15.5 of the HEC-WAT User's Manual for a list of steps (with chapter references) to create an FRA study.

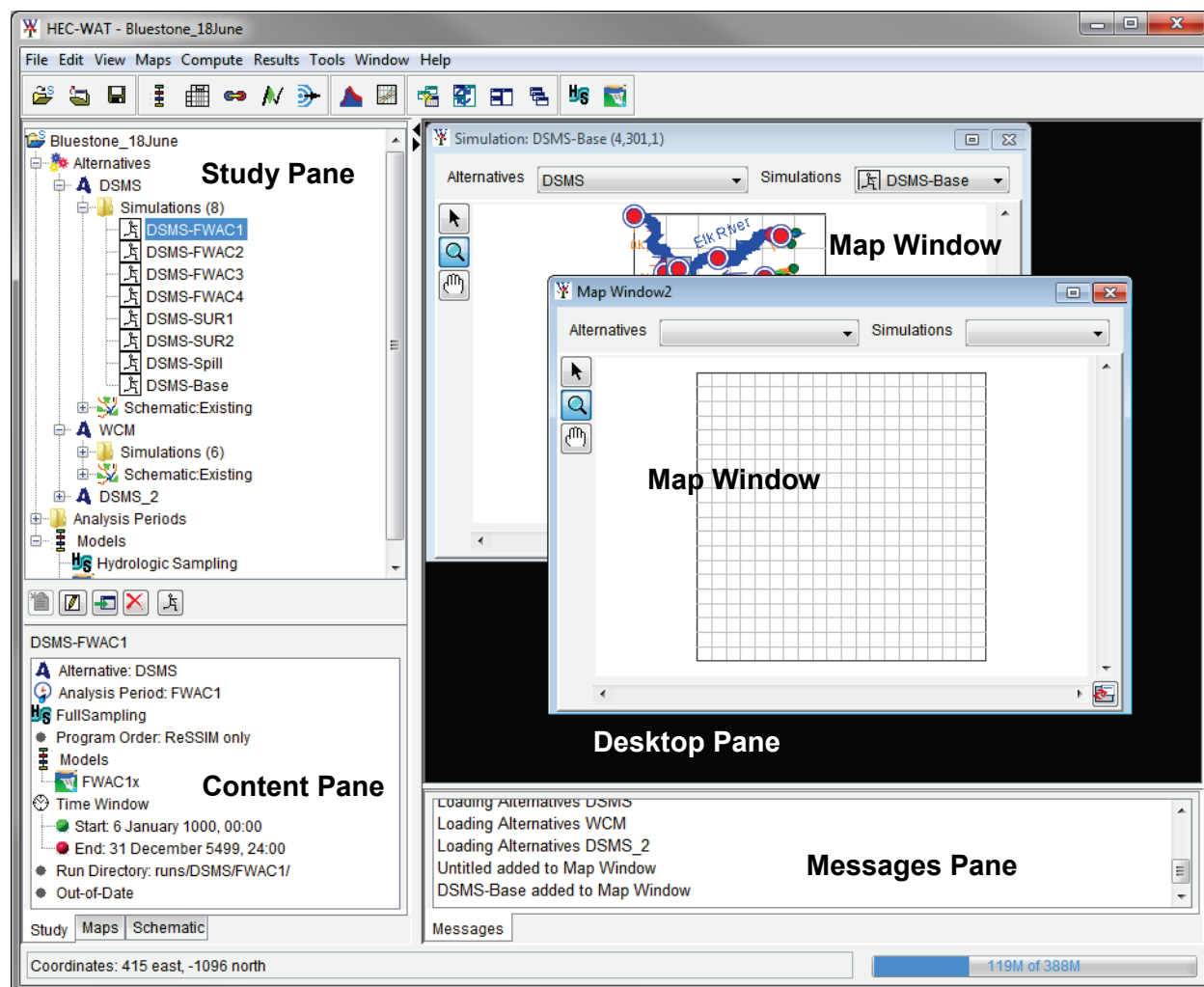


Figure 5-1 HEC-WAT Main Window

5.1.1 Overview

The specific steps are required prior to computing an FRA simulation in order to view the Hydrologic Sampler results options. During an FRA compute the Hydrologic Sampler output is stored in different files, as displayed in Table 5-1. The steps provided in the following section are required for obtaining all essential Hydrologic Sampler output files. These prerequisite steps are necessary because, by default, HEC-WAT automatically deletes all simulation output files during the compute to reduce computational storage demands.

Table 5-1 Hydrologic Sampler Output Files

Results	Stored in...
Plot Hydrograph	The output for this results option is saved in the lifecycle DSS (*.dss) file (Section 5.1.2), which is located in each <i>lifecycle</i> folder.
Plot Event Distribution, Plot Maximum Flows, Correlation Table, and Plot Shape Set Frequency.	The output for these results options are saved in the *.hsx file (Section 5.1.2), which is located in the <i>Hydrologic Sampling</i> folder contained within each <i>lifecycle</i> folder.
Output Report	The output for this results option is saved in the *.hsr file (Section 5.1.2), which is located in the <i>Hydrologic Sampling</i> folder contained within each the <i>lifecycle</i> folder.

5.1.2 Save Model Folders

The simplest way to ensure that all Hydrologic Sampler results are available for an FRA simulation is to choose the option **Save Model Folders** from the **Run FRA Simulation** dialog box. If the user selects **Save Model Folders**, then *all* output information from all models in the compute sequence will be retained for each event. In this case, all lifecycle files and folders (which includes all event folders and the Hydrologic Sampler folder) will be retained during the compute and the results will be accessible from the HEC-WAT interface.

Compute time and storage may become an issue when using this option. For some model simulations, it might not be possible to save time series results due to storage limitations. The FRA simulation allows the user to compute all or specified lifecycle(s), which can be used to evaluate the size of the lifecycle DSS file.

The steps to ensure that Hydrologic Sampler results are available for an FRA simulation are as follows:

1. From the HEC-WAT main window (Figure 5-1), from the **Study Tree**, from the **Alternative** node, from the **Simulation** folder, right-click on an FRA simulation of interest (e.g., *DSMS-FWACI* in Figure 5-2). From the shortcut menu (Figure 5-2), point to **Compute**, and click **Simulation (Ctrl to force)**.
2. The **Run FRA Simulation** dialog box will open (Figure 5-3).
3. Locate the **Save Model Folders** checkbox and click the checkbox ☒ to select that option (Figure 5-3). Note, model output files are not saved by default; if the user wishes to save all output data written (by all models in the compute sequence) for each realization, lifecycle and event, the **Save Model Folders** option must be selected.

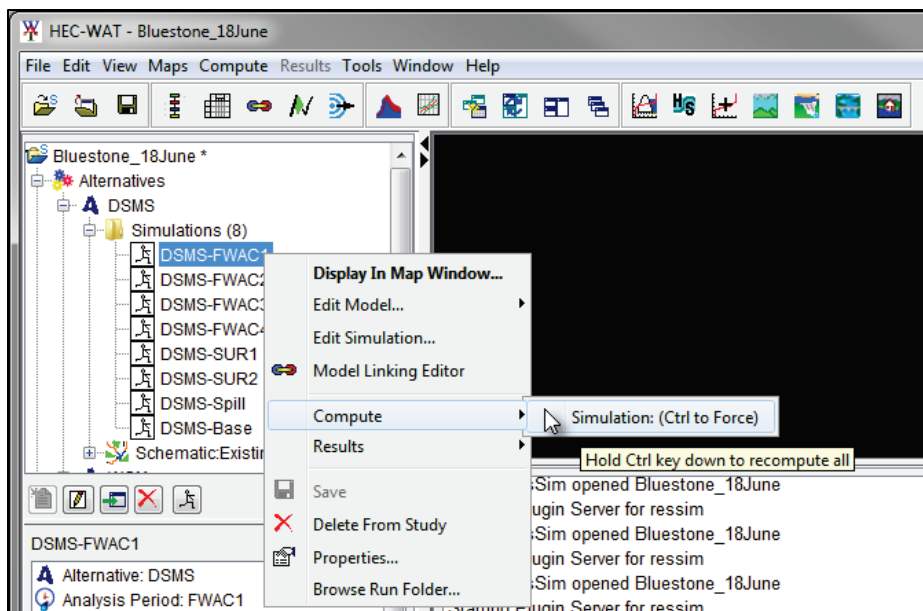


Figure 5-2 Study Tree – FRA Compute

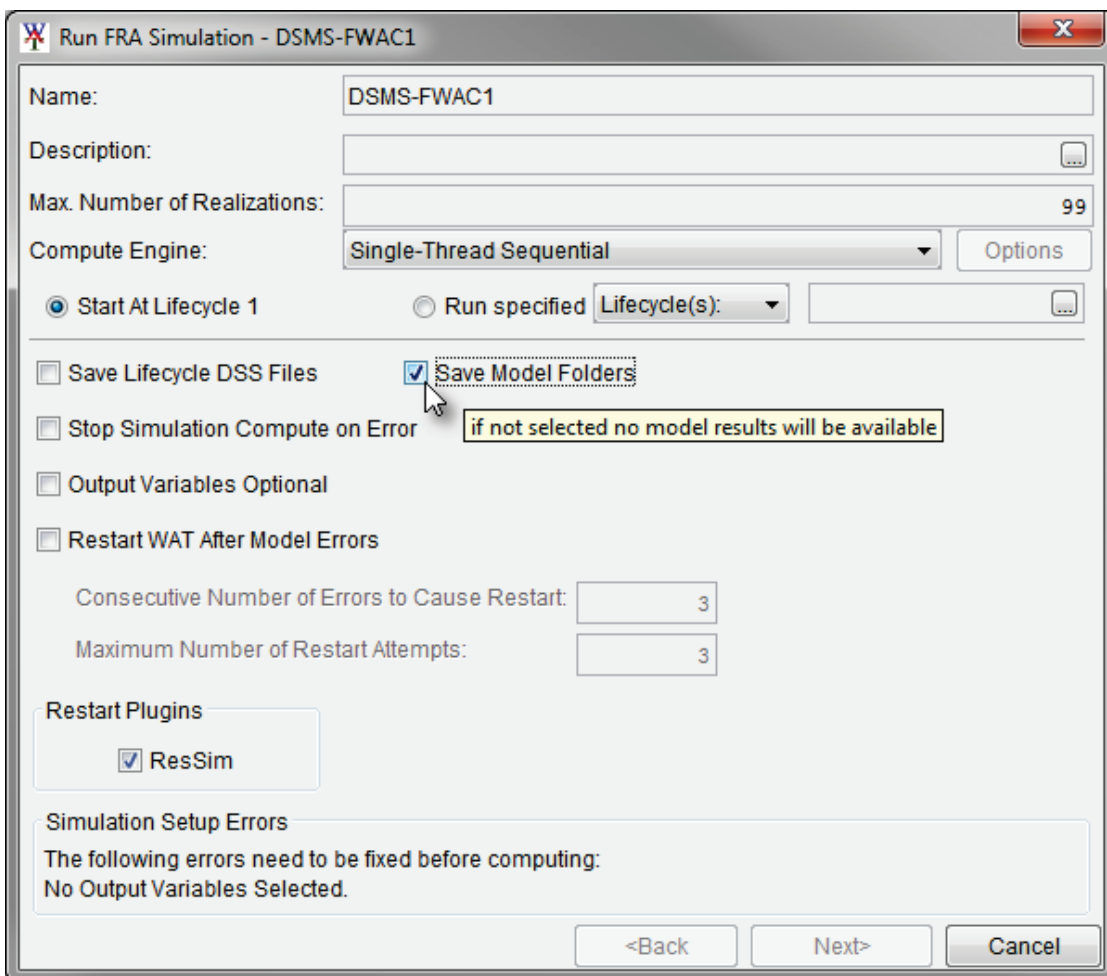


Figure 5-3 Run FRA Simulation Dialog Box – Save Lifecycle DSS Files

Note, for the example FRA simulation provided in Figure 5-3, the user would also need to either click the **Output Variables Optional** checkbox or add Output Variables before the simulation could be computed. For further details on Output Variables or the **Run FRA Simulation** dialog, refer to the HEC-WAT User's Manual Chapter 16 or Chapter 21, respectively.

5.2 Accessing Results

To view Hydrologic Sampler flow sampling results, the simulation of interest must either be selected from the **Study Tree** in the **Study Pane** or open in the active map window in the **Desktop Pane** in the HEC-WAT main window (Figure 5-1). Each active map window displays results for a selected simulation, including some of the results available for the Hydrologic Sampling alternative contained in the selected simulation.

The user can select specific event results to view from the **Select Event Results** dialog (Figure 5-4). It is important to note that selecting the event results is required before a Hydrologic Sampler results option can be viewed. The Hydrologic Sampler results are available either from the HEC-WAT main window **Results** menu, the **Study Pane**, the **Content Pane**, or interactively from an active map window schematic.

5.2.1 Select Event Results

As described in Section 5.1.2, the step of clicking the **Save Model Folder** option (from the **Run FRA Simulation** dialog) during an FRA compute will retain all of the Hydrologic Sampler output files listed in Table 5-1. The next required step for viewing Hydrologic Sampler results from the HEC-WAT interface is to select a realization, lifecycle and event from the **Select Event Results** dialog (Figure 5-4).

Users can access the **Select Event Results** dialog box from the **Study Tree**, from the **Simulations** folder right-click the simulation of interest, point to **Results** and click **Select Results** from the simulation shortcut menu (Figure 5-2). Use the lists to select the **Realization**, **Lifecycle**, and **Event** of interest in the **Select Event Results** dialog box (Figure 5-4). Then click **OK** to close the **Select Event Results** dialog box.

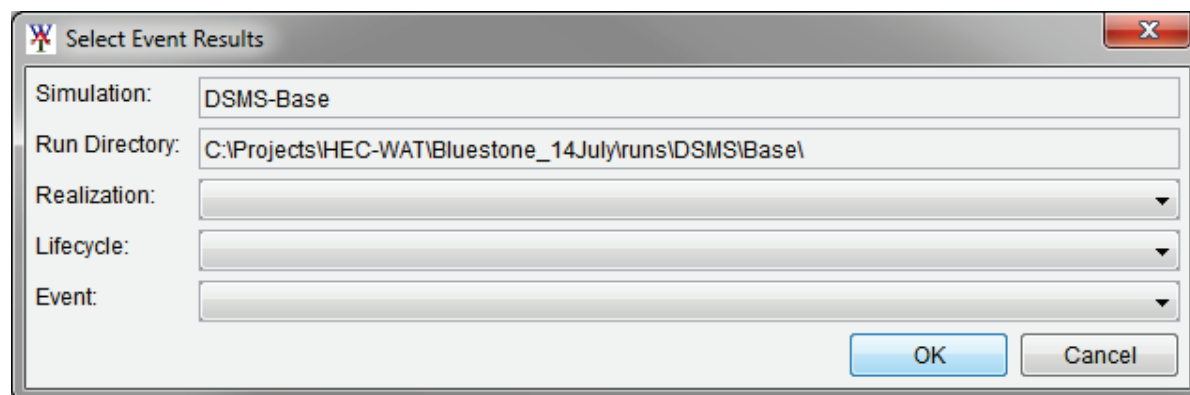


Figure 5-4 Select Event Results Dialog Box

Alternatively, users can open the **Select Event Results** dialog box from the HEC-WAT main window (Figure 5-1) from the **Results** menu (Figure 5-5), click **Select Results**, and the **Select Event Results** dialog box will open.

Note: If a Hydrologic Sampler results option is selected (which requires the user to define specific results to view), but the user has not completed the **Select Event Results** dialog box, then the **Select Event Results** dialog will open automatically and the user must complete the dialog before the selected results will open.

5.2.2 Results Menu

From the HEC-WAT main window, the **Results** menu can be different based on the simulation type (deterministic or FRA simulation), the state of the HEC-WAT interface (simulation selected or not selected), and the state of the simulation (compute completed or event results selected). When an FRA simulation is selected from the **Study Tree** and computed (Section 5.1.2) or selected in an open map window (Section 5.2.3), then the Hydrologic Sampler results will be accessible from the **Results** menu (Figure 5-5). Otherwise, the **Results** menu will contain only one command, **Select Simulation**, which opens the **Select Simulation Results** dialog (Figure 5-6).

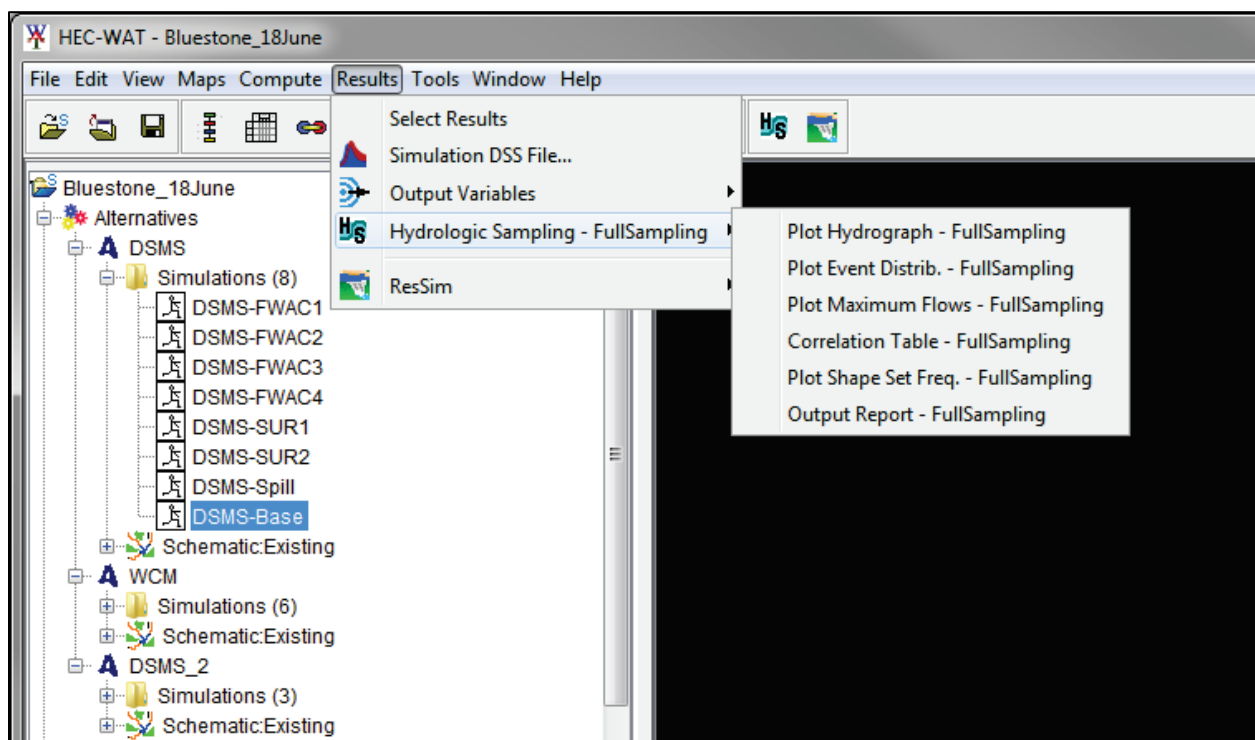


Figure 5-5 HEC-WAT Main Window – Results Menu – Hydrologic Sampling Results Options

Users can access the Hydrologic Sampler results for an FRA simulation from the **Results** menu after selecting a simulation:

1. From the HEC-WAT main window, select the **Results** menu (Figure 5-1) and click the **Select Simulation** command. The **Select Simulation Results** dialog opens (Figure 5-6).

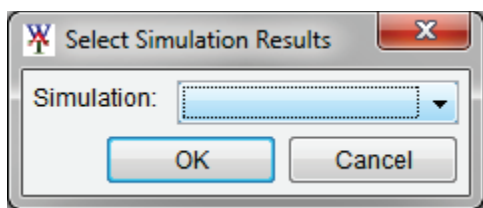


Figure 5-6 Select Simulation Results Dialog

2. From the **Simulation** list, select the FRA simulation of interest. Click **OK** to close the **Select Simulation Results** dialog box and the selected simulation will open in a map window in the **Desktop Pane** (Figure 5-1). Refer to Section 5.2.3 for more information on simulation map windows.
3. Next, from the HEC-WAT main window, select the **Results** menu and click on **Hydrologic Sampling – {Name}** and the submenu opens. Select the Hydrologic Sampler results option of choice from the submenu.

Important: If a simulation map window is open in the **Desktop Pane** and a different simulation is selected from the **Study Tree**, the **Results** menu will only provide the results for the simulation open in the active map window and not for the simulation selected in the **Study Tree**. In this case, users can access the second simulation's results from the **Study Tree** in the **Study Pane** (Section 5.2.4). In other words, it is important to pay close attention to the results being accessed from the **Results** menu.

5.2.3 Simulation Map Window

A simulation map window allows users to view results, which includes the results for the Hydrologic Sampling alternative contained in the simulation. Hydrologic Sampler results are available from the **Results** menu and from the simulation map window. Note, for the **Results** menu, the active simulation map window overrides simulations selected in the **Study Tree**.

Open a Simulation Map Window

In addition to the steps described in Section 5.2.2, several other ways are available to open a simulation in a map window in the **Desktop Pane** (Figure 5-1):

1. From the HEC-WAT main window, from the **Study Tree**, double-click on a simulation of interest to open the simulation in a map window in the **Desktop Pane** (e.g., *DSMS-FWACI* in Figure 5-7).
2. Alternatively, from the HEC-WAT main window, from the **Study Tree**, right-click on the simulation of interest (e.g., *DSMS-Base*) and the shortcut menu opens (Figure 5-7). From the shortcut menu, click **Display In Map Window** and the selected simulation opens in the **Desktop Pane**.

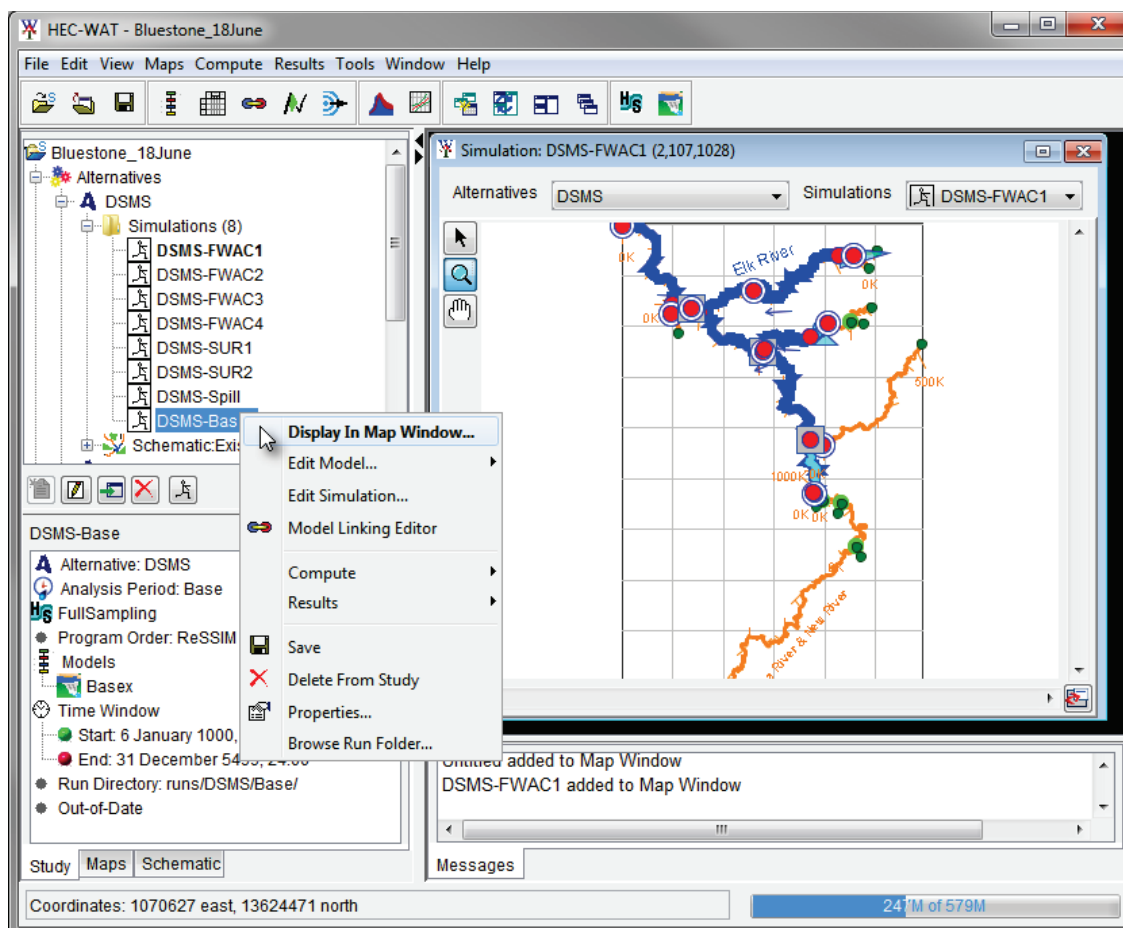


Figure 5-7 Study Pane – Display In Map Window – Shortcut Menu

3. To open a different simulation in a new map window, follow either Step 1 or Step 2 and prior to the simulation opening in a map window, a **Select Map** dialog box opens (Figure 5-8). In the **Select Map** dialog box, click the radio button to select the **New Map Window** option. Click **OK** and the simulation opens in the **Desktop Pane** on top of the existing map window.
4. Alternatively, from the **Select Map** dialog, click the radio button to select the **Existing Map Window** option, and click **OK** to open the selected simulation in the **Desktop Pane** in the currently open simulation map window.

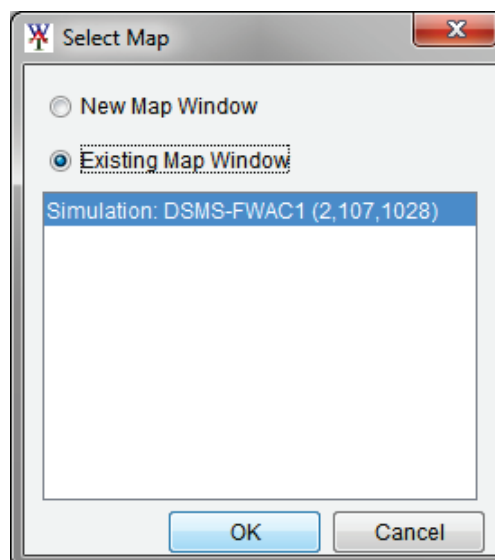


Figure 5-8 Select Map Dialog

Note, if a simulation map window is open in the **Desktop Pane** and a different simulation is selected from the **Study Tree**, then the **Results** menu will provide results for the

simulation in the active map window. Figure 5-9 displays an example with the **Results** menu linked to the active map window (*DSMS-FWAC1*) and not the simulation selected in the **Study Tree** (*DSMS-Base*); therefore, care must be taken when accessing the Hydrologic Sampler results from the **Results** menu.

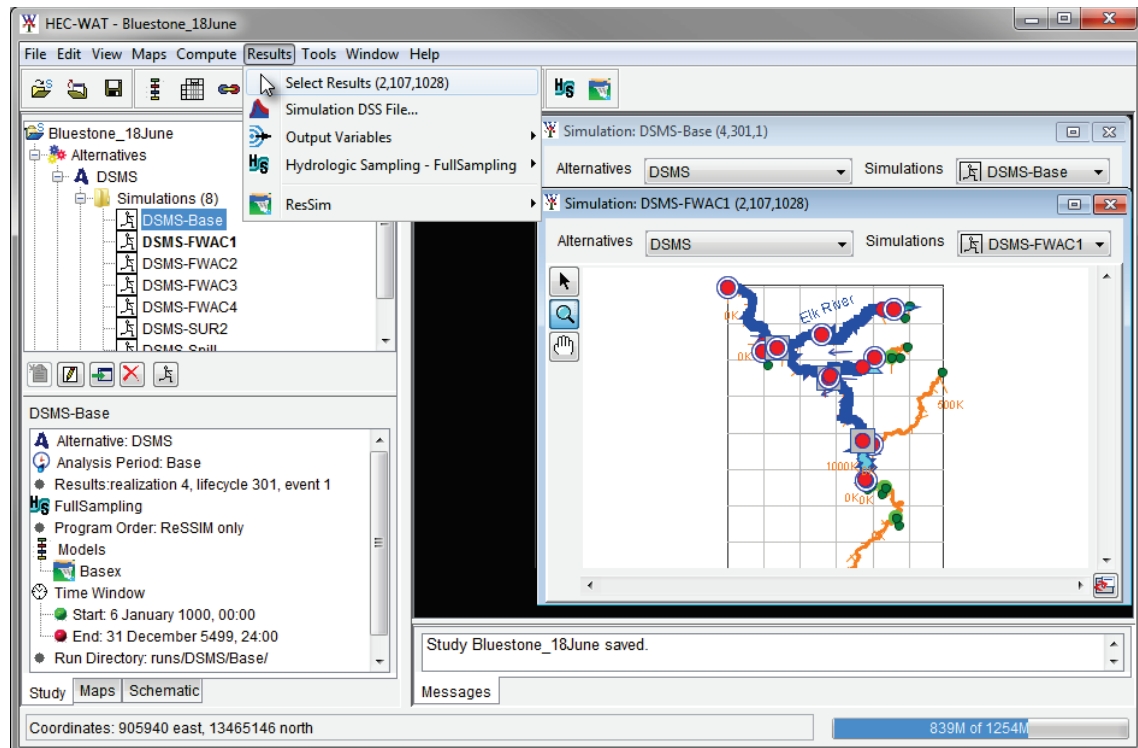


Figure 5-9 Example – Multiple Open Map Windows – Results Menu

Simulation Map Window Results

View location-specific Hydrologic Sampler results from the active simulation map window:

1. From the **Desktop Pane**, from the active simulation map window (Figure 5-10), click the **Select Tool** from the **Study Element Tools**. For further details on the **Study Element Tools**, refer to the HEC-WAT User's Manual, Chapter 6.
2. With the **Select Tool** active, hover over a model element to view the tooltip (light-yellow box) for the element (e.g., *Tornado* in Figure 5-10).

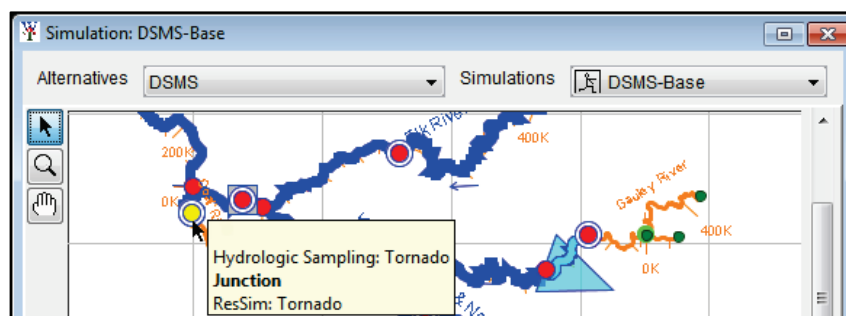


Figure 5-10 HEC-WAT Schematic Tooltip

3. If the tooltip indicates that Hydrologic Sampler results are available at an element, right-click on the element, point to the **Hydrologic Sampling** option and the shortcut submenu opens. Select an item from the **Hydrologic Sampling: {Name}** list (Figure 5-11).

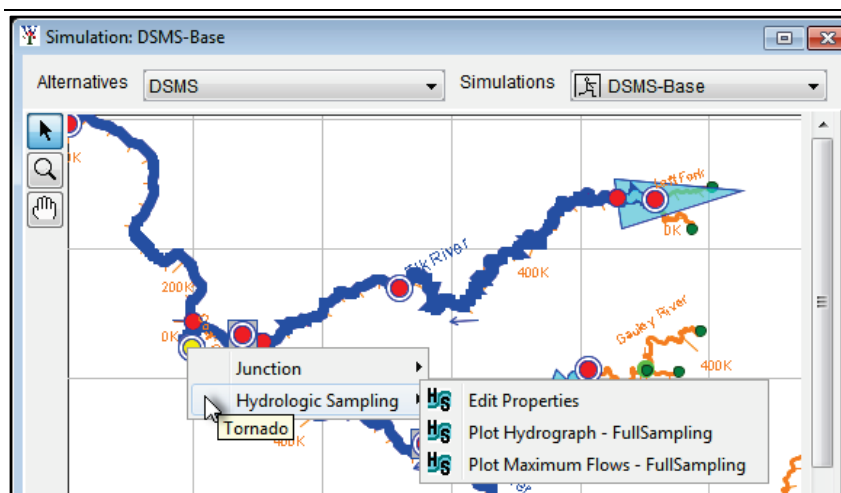


Figure 5-11 HEC-WAT Schematic Shortcut Menu – Hydrologic Sampling Results

Note, only location-specific results are relevant for individual locations, and consequently available in the simulation map window shortcut menu: plot hydrograph and plot maximum flows. To view other Hydrologic Sampler results options that are not location-specific (plot event distribution, correlation table, plot shape set frequency, or view the output report), utilize one of the previously listed options (Sections 5.2.2 through 5.2.5).

4. If the realization, lifecycle, and event results have not been selected before the Hydrologic Sampler results option is selected from the **Hydrologic Sampling** submenu, the **Select Event Results** dialog box opens (Figure 5-4). Use the lists to select the **Realization**, **Lifecycle**, and **Event** of interest in the **Select Event Results** dialog box. Click **OK** to close the **Select Event Results** dialog box and the selected results plot opens.

5.2.4 Study Pane

View the Hydrologic Sampler results from the **Study Pane**:

1. From the HEC-WAT main window, from the **Study Tree** in the **Study Pane** (Figure 5-1), expand an **Alternatives** folder, and expand a **Simulations** folder for a simulation of interest (Figure 5-12). In the **Simulations** folder, right-click on the simulation of interest (e.g., *DSMS-FWACI*) and the shortcut menu opens.
2. In the shortcut menu, point to **Results**, from the **Results** submenu point to **Hydrologic Sampling – {Name}**, and the Hydrologic Sampling results submenu opens (Figure 5-12). Select the Hydrologic Sampler results option of choice from the **Hydrologic Sampling – {Name}** submenu.

Note, opening the Hydrologic Sampler results from the **Study Pane** allows users to access and view Hydrologic Sampler results for FRA simulations (and for alternatives) that are not currently displayed in an active map window in the **Desktop Pane**.

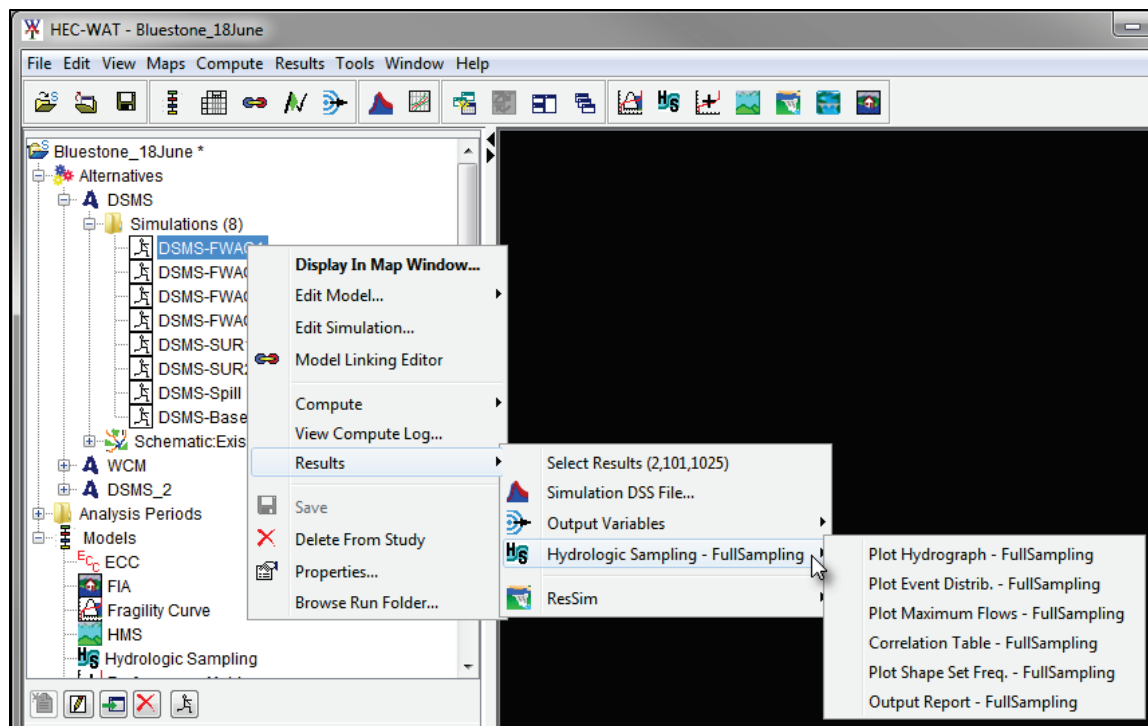


Figure 5-12 Study Pane – Shortcut Menu – Hydrologic Sampling Results

5.2.5 Content Pane

View the Hydrologic Sampler results from the **Content Pane**:

1. From the HEC-WAT main window (Figure 5-1), from the **Study Tree** in the **Study Pane** (Figure 5-12), expand an **Alternatives** folder (e.g., *DSMS* in Figure 5-12), and expand a **Simulations** folder. In the **Simulations** folder, select the simulation of interest (e.g., *DSMS-FWAC1* in Figure 5-12) and the **Content Pane** updates with the content for the selected simulation (Figure 5-13).

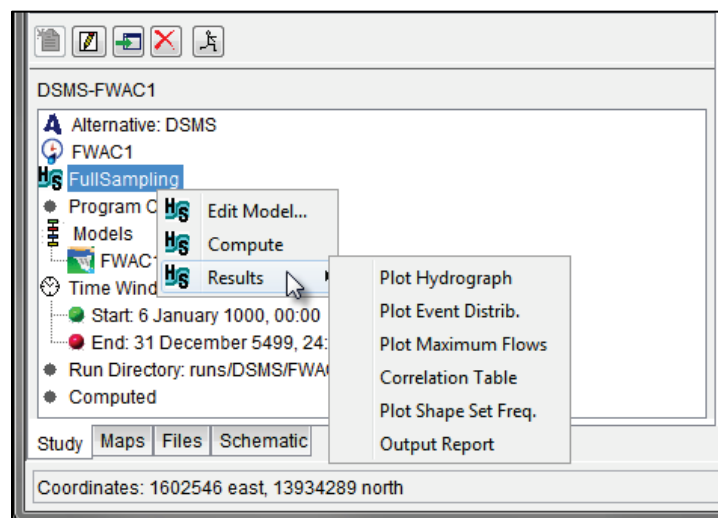


Figure 5-13 Content Pane – Shortcut Menu – Hydrologic Sampler Results

2. In the **Content Pane**, right-click on the Hydrologic Sampling alternative name (e.g., *FullSampling*) and the shortcut menu opens (Figure 5-13).

3. As with the **Study Pane**, Hydrologic Sampler results opened from the **Content Pane** allow users to view results without first opening a map window.

5.3 Results

In HEC-WAT Version 1.0, certain Hydrologic Sampler results are available for Flood Risk Analysis (FRA) computes within the HEC-WAT Framework. Results can be accessed using two methods: viewing Hydrologic Sampler **Results** menu items (accessed from the HEC-WAT menu bar), outlined in this chapter (refer to Section 5.3); and using the more generalized **Output Variable Editor** (accessed from the HEC-WAT toolbar), outlined in Chapter 16 of the HEC-WAT User's Manual.

The Hydrologic Sampler **Results** menu items will only provide results if the Hydrologic Sampler output files are saved for each lifecycle and event. Certain results require all lifecycle DSS files to be saved as well (Table 5-1). Although the **Results** menu items are limited to flow sampling results, the **Output Variable Editor** can provide Hydrologic Sampler output both flow and precipitation sampling results (Table 5-2).

Table 5-2 Available Output Variables by Hydrologic Sampling Method

Selected Method	Output Variable(s)
Flow Sampling – Correlated Flow Frequency Curves	Primary and Secondary locations: MAX FLOW, PEAK FLOW MAX, and any user added flow (e.g., AVG 3 DAY MAX)
Flow Sampling – Bootstrapping Basin-wide Events	Hydrograph locations (Flow) and Forecast locations (Stor)
Precipitation Sampling – Basin Average Frequency Curve	Hyetograph locations (Precip)

This section describes the six standard Hydrologic Sampler **Results** menu options provided by the HEC-WAT Framework:

1. **Plot Hydrograph** (Section 5.3.1): displays individual event hydrographs generated by the Hydrologic Sampler.
2. **Plot Event Distribution** (Section 5.3.2): provides a histogram of the dates of sampled flood events, compared to the defined flood season distribution.
3. **Plot Maximum Flows** (Section 5.3.3): displays the frequency curve of sampled flows for each realization compared to the defined frequency curves, at specified locations.
4. **Correlation Table** (Section 5.3.4): provides the computed correlation of base 10 logs of flow sampled, compared to the defined cross-correlations.

5. **Plot Shape Set Frequency** (Section 5.3.5): displays the histogram of sampled shape sets, compared to defined relative probabilities (based on weights and exceedance probability range) for each.
6. **Output Report** (Section 5.3.6): contains values for event date, shape set, and flood flow magnitudes randomly sampled for each event at each location for each lifecycle.

All six items are available for the Flow Sampling – Correlated Frequency Curves method, while only two of the items are available for the Flow Sampling – Bootstrapping Historical/Synthetic Basin-wide Events method (**Plot Hydrograph** and **Output Report**).

5.3.1 Plot Hydrograph

The **Plot Hydrograph** option plots an individual hydrograph generated by the Hydrologic Sampler within an FRA study. This results option is available for both the Flow Sampling – Correlated Frequency Curves method and the Flow Sampling – Bootstrapping Historical/Synthetic Basin-wide Events method. Open the plot hydrograph simulation results:

1. Utilize one of the methods provided in Section 5.2 to access the results options for the Hydrologic Sampling alternative of interest. Then select the **Plot Hydrograph** option from the **Hydrologic Sampling** submenu, and the **Select Event Results** dialog box opens (Figure 5-4), if the results have not been selected already. If necessary, use the lists to select the **Realization**, **Lifecycle**, and **Event** of interest in the **Select Event Results** dialog box. Then click **OK** to close the **Select Event Results** dialog box.
2. An HEC-WAT **Progress** window opens displaying the "Building Plot" progress (Figure 5-14). Once HEC-WAT has completed building the plot, the progress window closes and the **Plot Hydrograph** window opens (Figure 5-15).

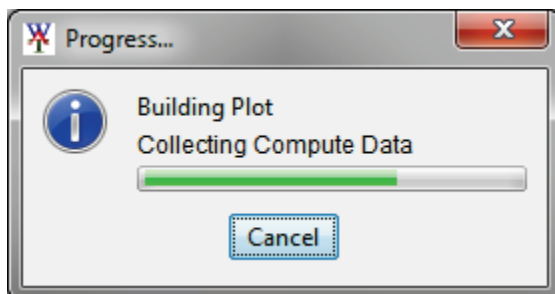


Figure 5-14 Progress Window - Building Plot

3. Note, the **Plot Hydrographs** window has lists for: **Realization**, **Lifecycle**, **Event**, and **Location**. Users can utilize the first three dropdown lists to change the selected the realization, lifecycle and/or event (previously selected from the **Select Event Results** dialog box). The last dropdown list is for changing the hydrograph plot **Location**. The hydrograph plot automatically updates when one of these selections is modified (e.g., *Sutton Inflow* in Figure 5-16).

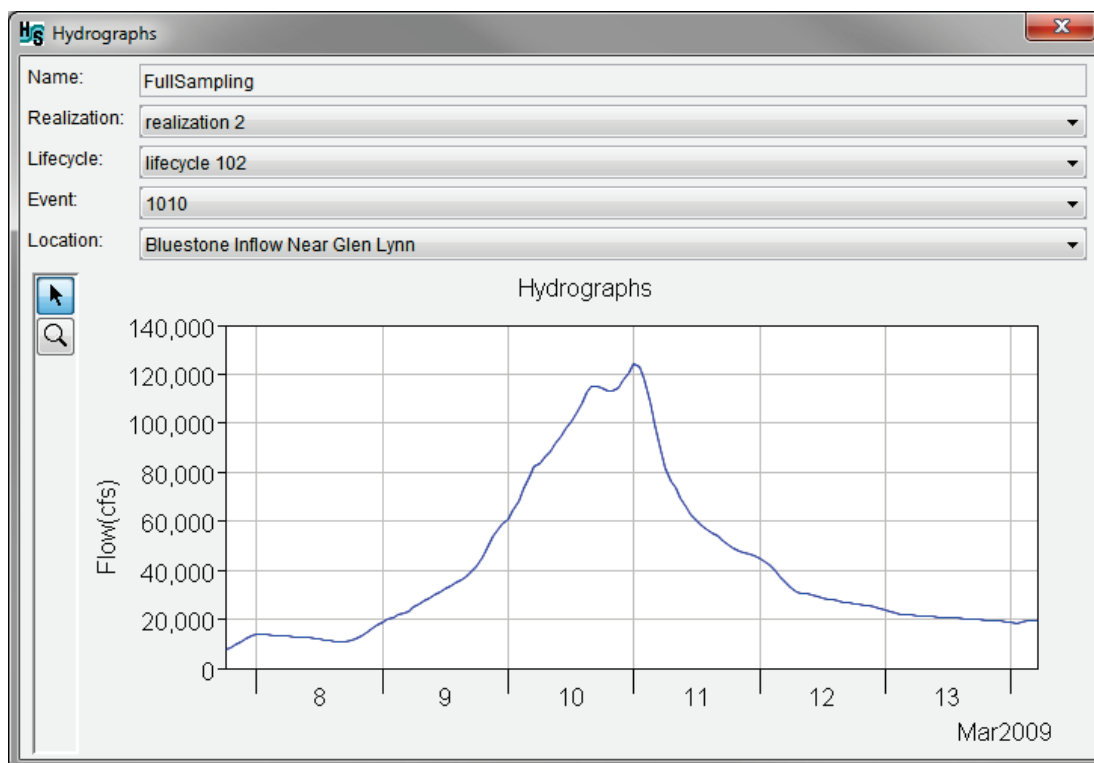


Figure 5-15 Plot Hydrographs – Example Plot

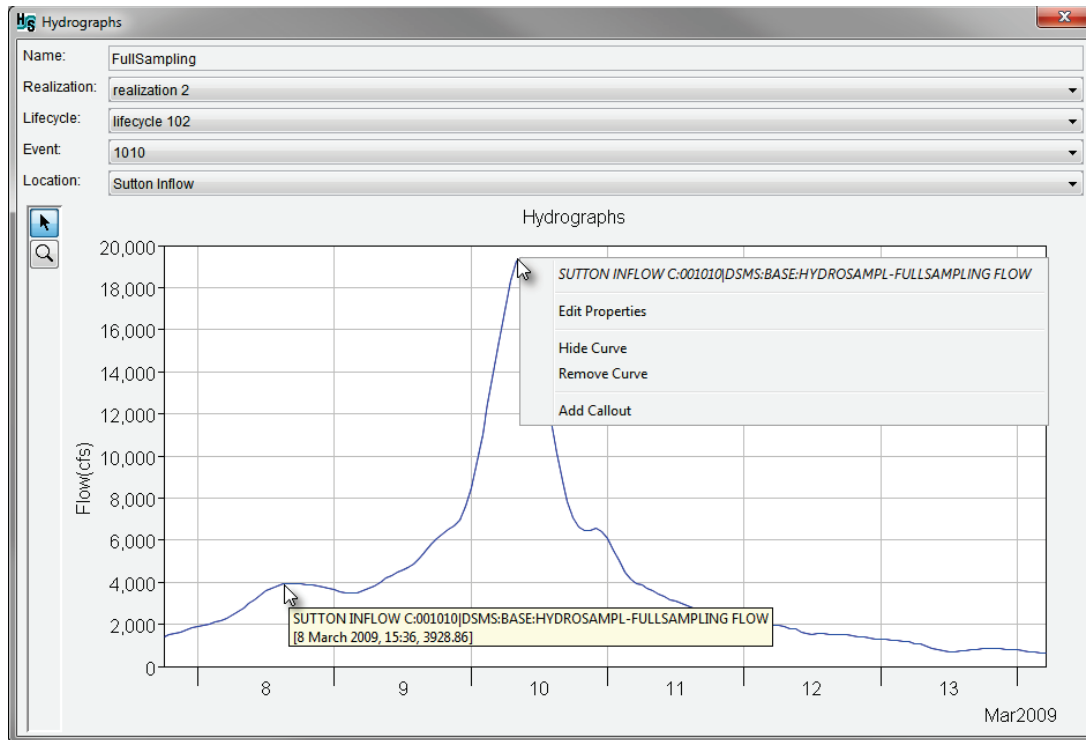




Figure 5-16 Plot Hydrographs – Example Plot with Callout Information Box

4. The Hydrologic Sampler plot window comes equipped with two tools. The first tool is the  **Select Tool**, which allows users to right-click on the hydrograph to open the

callout information box (light-gray box) and other shortcut options (Figure 5-16). The second tool is the  **Zoom Tool** which will zoom-in (left-click and drag a box) or zoom-out (right-click). Figure 5-16 also displays the ability to access tooltips (light-yellow box) when the **Select Tool** is active and users hover over graph elements.

5. The callout plot shortcut options are:

- **Edit Properties** – This option opens the **{Name} Properties** box (Figure 5-17), which allows users to modify the color, style, weight, and other graphical properties. Click **OK** to close the **{Name} Properties** box and update the hydrograph plot.

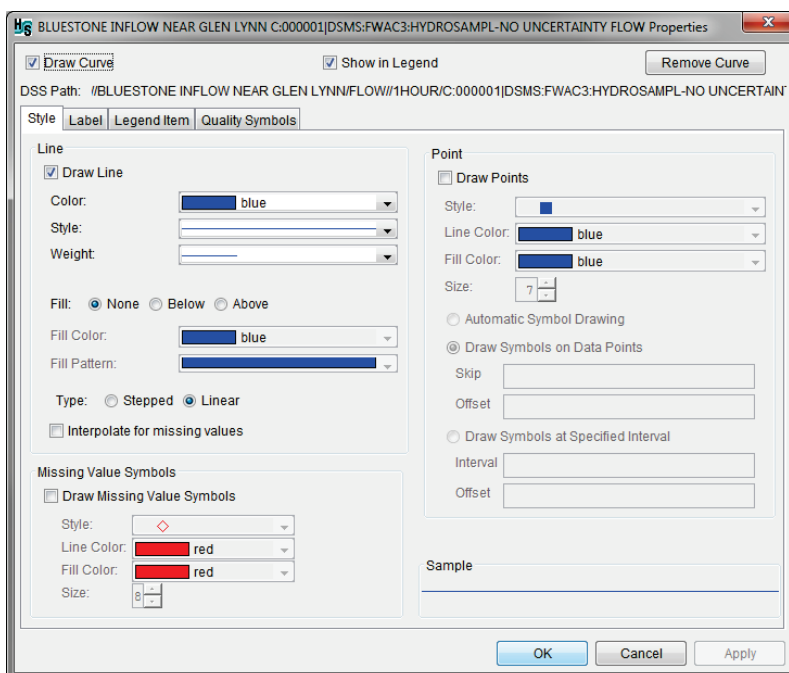


Figure 5-17 Plot Window Properties Box

- **Hide Curve** – This option hides the selected curve from view.
- **Remove Curve** – This option removes the selected curve from the plot.
- **Add Callout** – This option opens the **Add Callout** dialog box (Figure 5-18), which allows users to manually enter information to add to the plot in a callout box.

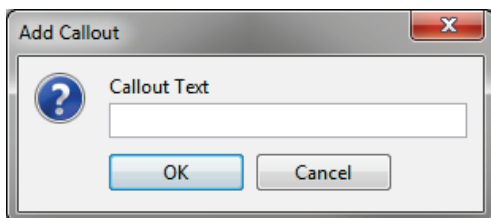


Figure 5-18 Add Callout Dialog Box

- When finished reviewing the plot, close the plot window by clicking the window close button.

5.3.2 Plot Event Distribution

The **Plot Event Distribution** option plots a histogram of the event dates of all sampled floods generated by the Hydrologic Sampler within an FRA study. Each sampled date is used to place the peak of the flood event hydrograph in time, on a month and day. This results option is only available for the Flow Sampling – Correlated Frequency Curves method because the Flow Sampling – Bootstrapping Historical/Synthetic method leaves events on the month and day they historically occurred.

Open the plot of the event-date distribution simulation results:

- Utilize one of the methods provided in Section 5.2 to access the Hydrologic Sampler results options for the Hydrologic Sampling alternative of interest (e.g., *FullSampling* in Figure 5-5). Then select the **Plot Event Distribution** option from the **Hydrologic Sampling** submenu, and the **Select Event Results** dialog box opens (Figure 5-4), if the results have not been selected already.

If necessary, use the lists to select the **Realization**, **Lifecycle**, and **Event** of interest in the **Select Event Results** dialog box (Figure 5-4). Then click **OK** to close the **Select Event Results** dialog box.

- An HEC-WAT **Progress** window opens displaying the "Building Plot" progress (Figure 5-14), and the **Flood Season** plot window opens (Figure 5-19).

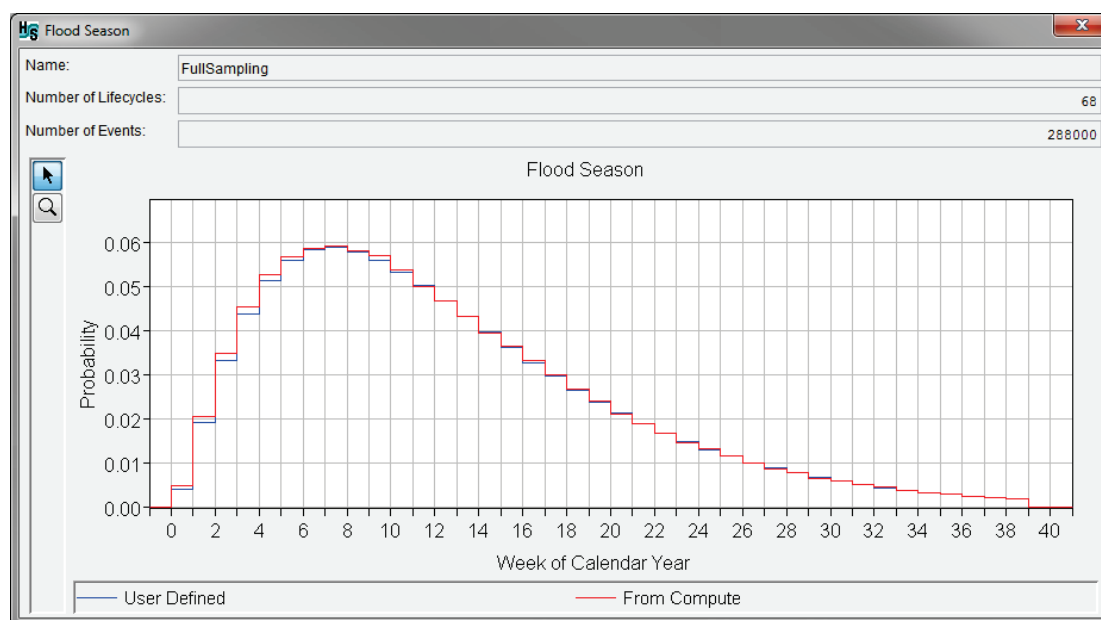





Figure 5-19 Plot Event Distribution – Flood Season Example

3. The **Flood Season** plot window displays the user-defined probability distribution function (PDF) in blue and the histogram of simulation results from the compute in red.

The more events computed in the simulation, the closer these curves should match. While the user-defined distribution is generally continuous (unless the selection was for empirical (graphical) distribution), the PDF is discretized to plot with the results histogram. Refer to Section 2.2 and Section 4.2 for more information regarding **Event Sampling**.

4. As explained in Section 5.3.1, the Hydrologic Sampler plot windows have two tools. The first tool being the  **Select Tool**, which allows users to right-click on the hydrograph to open the callout information box and other shortcut options (Figure 5-16). The second tool is the  **Zoom Tool** will zoom-in (left-click and drag a box) or zoom-out (right-click).
5. When finished reviewing the plot, close the plot window by clicking the window close  button.

5.3.3 Plot Maximum Flows

The **Plot Maximum Flow** option creates a frequency plot of the sampled maximum flow of all flood events at each primary location generated by the Hydrologic Sampler within an FRA study. A peak flow magnitude is generated for every event at each primary location based on correlated sampling from all locations' user-defined frequency curves. The results of this sampling are compared to the user-defined curve on a frequency plot. This results option is only available for the Flow Sampling – Correlated Frequency Curves sampling method.

Open the plot maximum flows simulation results:

1. Utilize one of the methods provided in Section 5.2 to access the Hydrologic Sampler results options for the Hydrologic Sampling alternative of interest (e.g., *FullSampling* in Figure 5-5). Then select the **Plot Maximum Flows** option from the **Hydrologic Sampling** submenu, and the **Select Event Results** dialog box opens (Figure 5-4), if the results have not been selected already.

If necessary, use the lists to select the **Realization**, **Lifecycle**, and **Event** of interest in the **Select Event Results** dialog box (Figure 5-4). Then click **OK** to close the **Select Event Results** dialog box.

2. A **Progress** window opens displaying the "Building Plot" progress (Figure 5-14), and the **Primary Maximum Flow Frequency** plot window opens (Figure 5-20).
3. The **Primary Maximum Flow Frequency** plot window provides the **User Defined** and **From Compute** maximum flow frequency return period for the selected primary **Flow Location**. Select a **Flow Location** from the provided list (Figure 5-20). The flow frequency plot automatically updates when the **Flow Location** selection is set to a new location.

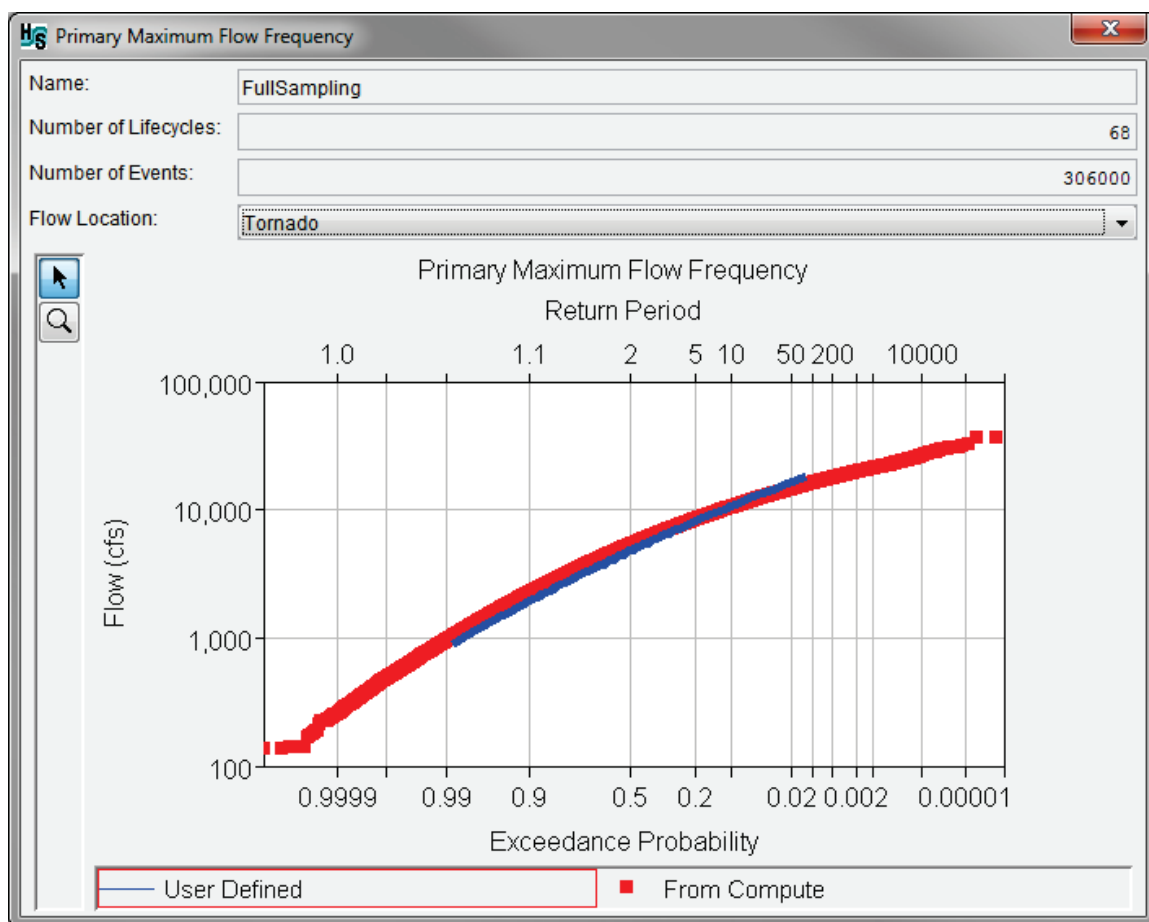





Figure 5-20 Example – Primary Maximum Flow Frequency Plot

Events are sampled from a different uncertainty-adjusted frequency curve in each realization, and the plot includes the events from all realizations (Figure 5-20). The maximum flow plot for a given location ranks all of the sampled flows and plots them versus an estimated exceedance probability (the Weibull plotting position), shown in red.

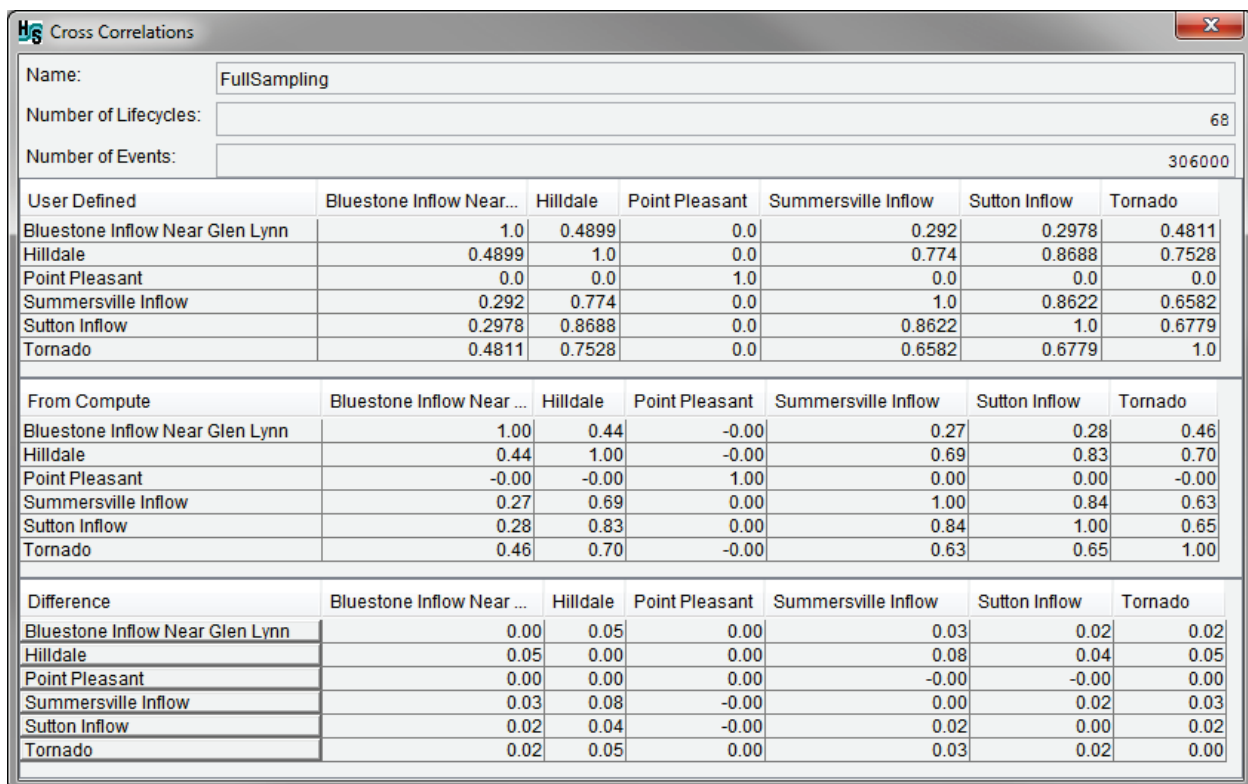
The user-defined frequency curve for the specified location is shown in blue. Results from a single realization will echo the specific uncertainty-adjusted frequency curve that was sampled, while results from many realizations will more closely match the user-entered frequency curve, since they reflect a combination of many uncertainty-adjusted frequency curves.

4. The Hydrologic Sampler plot windows have two tools. The first tool is the  **Select Tool**, which allows users to right-click on the hydrograph to open the callout information box and other shortcut options (Figure 5-16). The second tool is the  **Zoom Tool** will zoom-in (left-click and drag a box) or zoom-out (right-click).
5. When finished reviewing the plot, close the plot window by clicking the window close  button.

5.3.4 Correlation Table

The **Correlation Table** command is only available for Hydrologic Sampling alternatives, which applied the Flow Sampling – Correlated Frequency Curves sampling method. The **Correlation Table** option contains the computed correlation coefficient for every pair of primary location maximum flows. Correlation is the degree to which flow magnitudes at two locations have a linear relationship, with positive correlation if they tend to be large or small at the same time. Maximum flows for each event are generated by correlated random sampling from the frequency curves at every location, maintaining cross-correlations entered by the user in the **Cross Correlation Matrix** tab of the **Hydrologic Sampling Editor**.

Utilize one of the methods provided in Section 5.2 to access the Hydrologic Sampler results options for the Hydrologic Sampling alternative of interest (e.g., *FullSampling* in Figure 5-5). Then select the **Correlation Table** option from the **Hydrologic Sampling** submenu, and the **Select Event Results** dialog box opens (Figure 5-4), if the results have not been selected already.



The screenshot shows a window titled "Cross Correlations" with a close button (X) in the top right corner. Inside the window, there are three input fields at the top: "Name:" with the value "FullSampling", "Number of Lifecycles:" with the value "68", and "Number of Events:" with the value "306000". Below these fields are three tables. The first table, "User Defined", shows correlation coefficients for six locations. The second table, "From Compute", shows correlation coefficients for the same six locations. The third table, "Difference", shows the difference between the first two tables for the same six locations.

User Defined	Bluestone Inflow Near...	Hilldale	Point Pleasant	Summersville Inflow	Sutton Inflow	Tornado
Bluestone Inflow Near Glen Lynn	1.0	0.4899	0.0	0.292	0.2978	0.4811
Hilldale	0.4899	1.0	0.0	0.774	0.8688	0.7528
Point Pleasant	0.0	0.0	1.0	0.0	0.0	0.0
Summersville Inflow	0.292	0.774	0.0	1.0	0.8622	0.6582
Sutton Inflow	0.2978	0.8688	0.0	0.8622	1.0	0.6779
Tornado	0.4811	0.7528	0.0	0.6582	0.6779	1.0


From Compute	Bluestone Inflow Near ...	Hilldale	Point Pleasant	Summersville Inflow	Sutton Inflow	Tornado
Bluestone Inflow Near Glen Lynn	1.00	0.44	-0.00	0.27	0.28	0.46
Hilldale	0.44	1.00	-0.00	0.69	0.83	0.70
Point Pleasant	-0.00	-0.00	1.00	0.00	0.00	-0.00
Summersville Inflow	0.27	0.69	0.00	1.00	0.84	0.63
Sutton Inflow	0.28	0.83	0.00	0.84	1.00	0.65
Tornado	0.46	0.70	-0.00	0.63	0.65	1.00

Difference	Bluestone Inflow Near ...	Hilldale	Point Pleasant	Summersville Inflow	Sutton Inflow	Tornado
Bluestone Inflow Near Glen Lynn	0.00	0.05	0.00	0.03	0.02	0.02
Hilldale	0.05	0.00	0.00	0.08	0.04	0.05
Point Pleasant	0.00	0.00	0.00	-0.00	-0.00	0.00
Summersville Inflow	0.03	0.08	-0.00	0.00	0.02	0.03
Sutton Inflow	0.02	0.04	-0.00	0.02	0.00	0.02
Tornado	0.02	0.05	0.00	0.03	0.02	0.00

Figure 5-21 Example – Cross Correlations Table

If necessary, use the lists to select the **Realization**, **Lifecycle**, and **Event** of interest in the **Select Event Results** dialog box (Figure 5-4). Then click **OK** to close the **Select Event Results** dialog box. A **Progress** window opens displaying the "Building Plot" progress (Figure 5-14), and the **Cross Correlations** window opens (Figure 5-21). This window displays the cross correlation matrices for all computed lifecycles (e.g., *68 lifecycles*) and events (e.g., *306,000 events*).

The **Cross Correlations** window provides three tables: **User Defined**, **From Compute** and **Difference**. The **User Defined** table provides the cross correlation table the user specified in the

Hydrologic Sampling Editor on the **Cross Correlation Matrix** tab (refer to Section 2.5 for more information). The **From Compute** table displays the cross correlation matrix from computed simulation results, and the **Difference** table displays the computed difference between the user-defined and computed cross correlation matrices, which allows the user to spot discrepancies. When finished reviewing the table, click the close window  button to close the **Cross Correlations** window.

5.3.5 Plot Shape Set Frequency

The **Plot Shape Set Frequency** option plots a histogram of the event dates of all sampled floods generated by the Hydrologic Sampler within a Flood Risk Analysis (FRA) compute. Each sampled date is used to place the peak of the flood event hydrograph in time, on a month and day. This results option is only available for the Flow Sampling – Correlated Frequency Curves sampling method.

In the Correlated Flow Frequency Curves sampling method, each sampled flood event is comprised of flood flow hydrographs at all primary and secondary locations, scaled to match maximum flow values generated for that event. The hydrographs are scaled from one of the hydrograph shape sets defined by the user on the **Hydrologic Sampling Editor – Shape Sets** tab (Section 2.6), which has been randomly selected for that event. Defined shape sets can be limited for use only in a specified exceedance probability range, and are also assigned weights to define their relative likelihood among other shape sets available in that range. Across the full range of probability from 0.0 to 1.0, these limited ranges and weights result in a likelihood of each shape set being chosen (computed with the total probability theorem).

Review Section 2.7 for more information regarding that likelihood relative to a selected sub-range (e.g., 0.2-0.05 as displayed in Figure 2-31). The likelihood is displayed as the blue user-defined curve on the Hydrologic Sampler **Shape Set Frequency** results plot (Figure 5-22). The histogram resulting from the sampled shape set for every event is displayed in red. The table at the bottom of the shape set frequency plot provides a list of the shape sets used in the sampling.

To open the **Shape Set Frequency** plot for simulation results:

1. Utilize one of the methods provided in Section 5.2 to access the Hydrologic Sampler results options for the Hydrologic Sampling alternative of interest. Then select the **Plot Shape Set Freq.** option from the **Hydrologic Sampling** submenu, and the **Select Event Results** dialog box opens (Figure 5-4), if the results have not been selected already.

If necessary, use the lists to select the **Realization**, **Lifecycle**, and **Event** of interest in the **Select Event Results** dialog box (Figure 5-4). Then click **OK** to close the **Select Event Results** dialog box.

2. An HEC-WAT **Progress** window opens displaying the "Building Plot" progress (Figure 5-14), and the **Shape Set Frequency** plot dialog box opens (Figure 5-22).

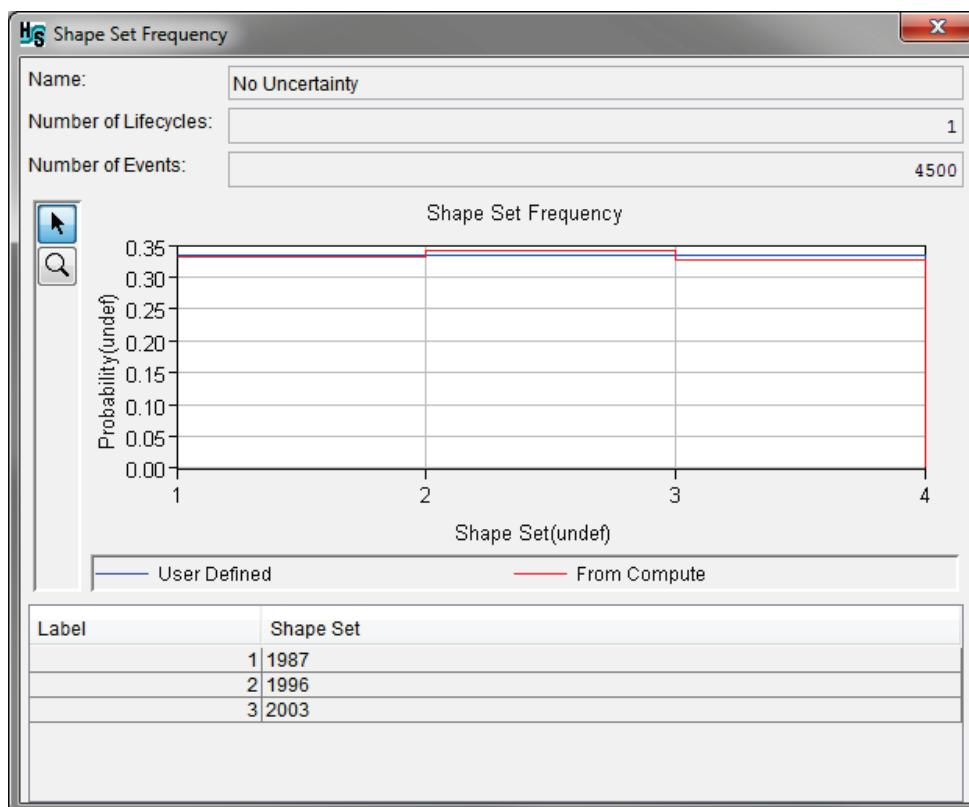





Figure 5-22 Example – Shape Set Frequency Plot Window

3. The Hydrologic Sampler results plot windows have two tools. The first tool being the  **Select Tool**, which allows users to right-click on the histogram to open the callout information box and other shortcut options (Figure 5-16). The second tool is the  **Zoom Tool** will zoom-in (left-click and drag a box) or zoom-out (right-click).
4. Additionally, the **Shape Set Frequency** plot window has a table at the bottom of the plot window providing the shape set name (e.g., Shape Set: 1987) based on the shape set index number (e.g., Label: 1). Recall that the shape set name is the name provided by the user in the **Hydrologic Sampling Editor** in the **Shape Sets** tab when the shape set was created (refer to Section 2.6 and Section 4.5 for more information on the **Shape Sets** tab).
5. When finished reviewing the plot, click the window close  button to close the **Shape Set Frequency** plot window.

5.3.6 Output Report

The Hydrologic Sampler **Output Report** is available for both the Flow Sampling – Correlated Frequency Curves sampling method and the Flow Sampling – Bootstrapping Historical/Synthetic Basin-wide Events sampling method. The Hydrologic Sampler **Output Report** is opened from *.hsr file is stored in the *Hydrologic Sampling* folder under each lifecycle folder (see Table 5-1), and contains values for event date, shape set, and flood flow magnitudes randomly sampled for each event at each location. The *.hsr file is created at the lifecycle level because the Hydrologic Sampler generates output for an entire lifecycle at a time.

Open the **Output Report** simulation results:

1. Utilize one of the methods provided in Section 5.2 to access the Hydrologic Sampler results options for the Hydrologic Sampling alternative of interest (e.g., *DSMS-FWACI*). Then select the **Output Report** option from the **Hydrologic Sampling** submenu. If the results have not been selected already, the **Select Event Results** dialog box opens (Figure 5-4).

If necessary, use the lists to select the **Realization**, **Lifecycle**, and **Event** of interest in the **Select Event Results** dialog box (Figure 5-4). Then click **OK** to close the **Select Event Results** dialog box.

2. A **Progress** window opens displaying the "Building Plot" progress (Figure 5-14) and the **Output Report** window opens (Figure 5-23) in the **Desktop Pane** (Figure 5-1).

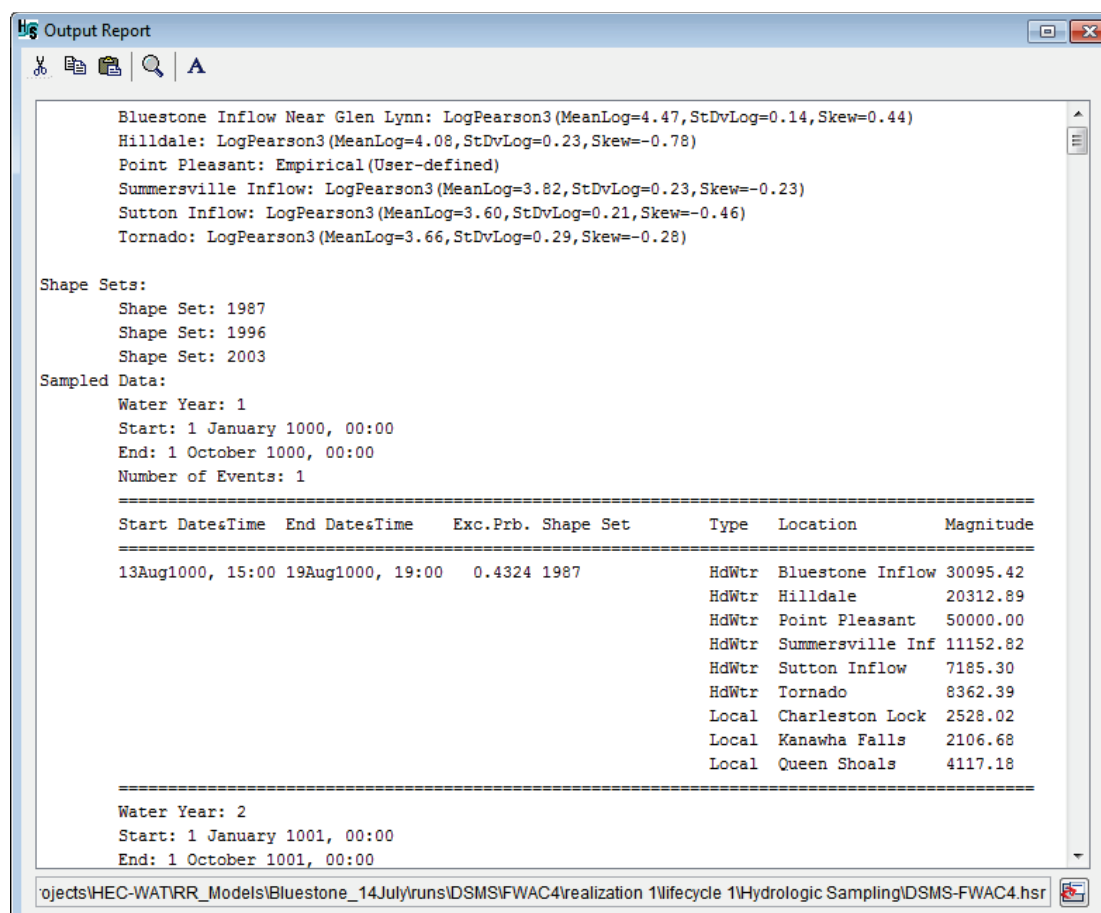









Figure 5-23 Hydrologic Sampling – Output Report Results – Example

- The **Output Report** window provides a detailed account of the Hydrologic Sampling alternative set parameters and the generated results. The **Output Report** opens to the lifecycle selected in the **Select Event Results** dialog. Use the vertical scroll bar located on the right-side of the report to view the entire report.

- Note the tools at the top of the **Output Report** window, which are: the **Cut**  tool, **Copy**  tool, **Paste**  tool, **Find**  tool, and the **Select Font**  tool.
3. To open the **Output Report** window outside of the HEC-WAT **Desktop Pane**, click the **Detach Window Tool**  icon located in the bottom right corner of the window (Figure 5-23), and the report opens in a new window outside of the **Desktop Pane**.
 4. When finished reviewing the report, click the window close  button to close the **Output Report** window.

CHAPTER 6

References

England, J.F. Jr., Cohn, T.A., Faber, B.A., Stedinger, J.R., Thomas Jr., W.O., Veilleux, A.G., Kiang, J.E., and Mason, R.R., 2017. *Guidelines for Determining Flood Flow Frequency – Bulletin 17C*: U.S. Geological Survey Techniques and Methods book 4, chap. B5, 228 p., <https://dx.doi.org/10.3133/tm4-B5/>.

Faber, Beth, December 2016. Method for generating random Snowmelt forecasts that maintains monthly serial-correlation and error statistics, and spatial cross-correlation, HEC-WAT Documentation, U.S. Army Corps of Engineers, Davis, CA.

Hosking, J.R.M., and Wallis, J.R., April 1997. *Regional Frequency Analysis*, First Edition, Cambridge University Press.

Hydrologic Engineering Center, July 2009. HEC-DSSVue, *HEC Data Storage System Visual Utility Engine*, User's Manual, CPD-79, U.S. Army Corps of Engineers, Davis, CA.
http://www.hec.usace.army.mil/software/hec-dssvue/documentation/User'sManual_2.0/HEC-DSSVue_20_Users_Manual.pdf

Hydrologic Engineering Center, December 2013. HEC-ResSim, *Reservoir System Simulation*, User's Manual, CPD-82, U.S. Army Corps of Engineers, Davis, CA.
http://www.hec.usace.army.mil/software/hec-ressim/documentation/HEC-ResSim_31_UsersManual.pdf

Hydrologic Engineering Center, February 2016. HEC-RAS, *River Analysis System*, User's Manual, CPD-68, U.S. Army Corps of Engineers, Davis, CA.
<http://www.hec.usace.army.mil/software/hec-ras/documentation/HEC-RAS%205.0%20Users%20Manual.pdf>

Hydrologic Engineering Center, August 2016. HEC-HMS, *Hydrologic Modeling System*, User's Manual, CPD-74A, U.S. Army Corps of Engineers, Davis, CA.
http://www.hec.usace.army.mil/software/hec-hms/documentation/HEC-HMS_Users_Manual_4.2.pdf

Hydrologic Engineering Center, July 2016. HEC-SSP, *Statistical Software Package*, User's Manual, CPD-86, U.S. Army Corps of Engineers, Davis, CA.
http://www.hec.usace.army.mil/software/hec-ssp/documentation/HEC-SSP_21_Users_Manual.pdf

Hydrologic Engineering Center, September 2017. HEC-WAT, *HEC Watershed Analysis Tool*, User's Manual, CPD-88, U.S. Army Corps of Engineers, Davis, CA.
<http://www.hec.usace.army.mil/software/hec-wat/documentation/CPD-88.pdf>

Hydrologic Engineering Center, September 2017. HEC-WAT, *HEC Watershed Analysis Tool*, Quick Start Guide, CPD-88a, U.S. Army Corps of Engineers, Davis, CA.
<http://www.hec.usace.army.mil/software/hec-wat/documentation/CPD-88a.pdf>

Interagency Advisory Committee on Water Data, March 1982. Bulletin 17B, *Guidelines for Determining Flood Flow Frequency*, Published by the U.S. Department of the Interior, Geological Survey.

Maidment, D.R., Editor, February 1993. *Handbook of Hydrology*, McGraw-Hill.

Microsoft Corporation, 2015, Microsoft *products, software, and services*, One Microsoft Way, Redmond, WA.