SAN BERNARDINO COUNTY

SAN BERNARDINO COUNTY FLOOD CONTROL DISTRICT
1939
CALIFORNIA

HEC-HMS (Hydrologic Engineering Center-Hydrologic Modeling System) Runoff Hydrograph and Detention Routing *User Guide*

2026 Edition

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1 INTRODUCTION

This user guide supports the development of Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) version 4.12 model components consistent with the unit hydrograph (UH) calculation and detention routing procedures and parameters in the San Bernardino County Hydrology Manual (March 2026), hereafter referred to as the “Manual.” The guide presents a comprehensive example workflow that links a watershed to a detention basin using a hydrologic routing reach (see **Figure 1**). Users are encouraged to implement any part that is relevant to their project.

Familiarity with HEC-HMS software is assumed for the steps presented below; if needed, users should reference the applicable U.S. Army Corps of Engineers (USACE) software manuals and training documents before preparing a UH and detention routing model.

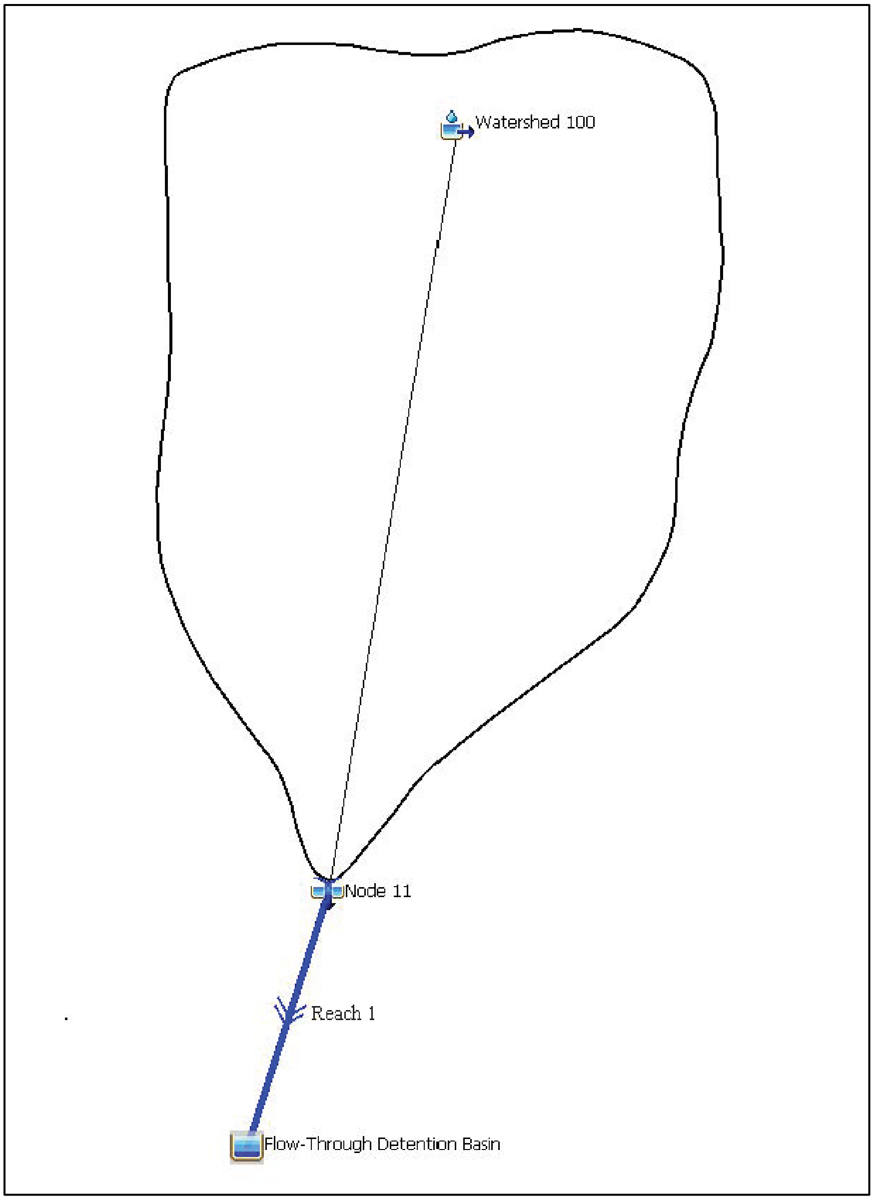


Figure 1. User Guide Example HEC-HMS Model Schematic

2 SYNTHETIC UNIT HYDROGRAPH DEVELOPMENT

Development of the synthetic UH is discussed conceptually in Section 5.3.1 of the Manual. Most of the parametric values used in this guide are from the synthetic UH example in Section 5.3.1.4 of the Manual.

The required HEC-HMS inputs to generate a synthetic UH are the watershed area (A), lag time (T_{lag}), unit time period (T_{unit}), and the appropriate study S-graph(s):

Watershed Area (A):	5.0 sq. mi.
Lag time (T_{lag}):	0.83 hours (50 minutes)
Unit time period (T_{unit}):	0.017 hours (1 minute)
S-graph:	Valley–Developed

- Watershed Area (A): Within the *Basin Model Manager→Subbasin* editor, the watershed (or subarea) area is entered.

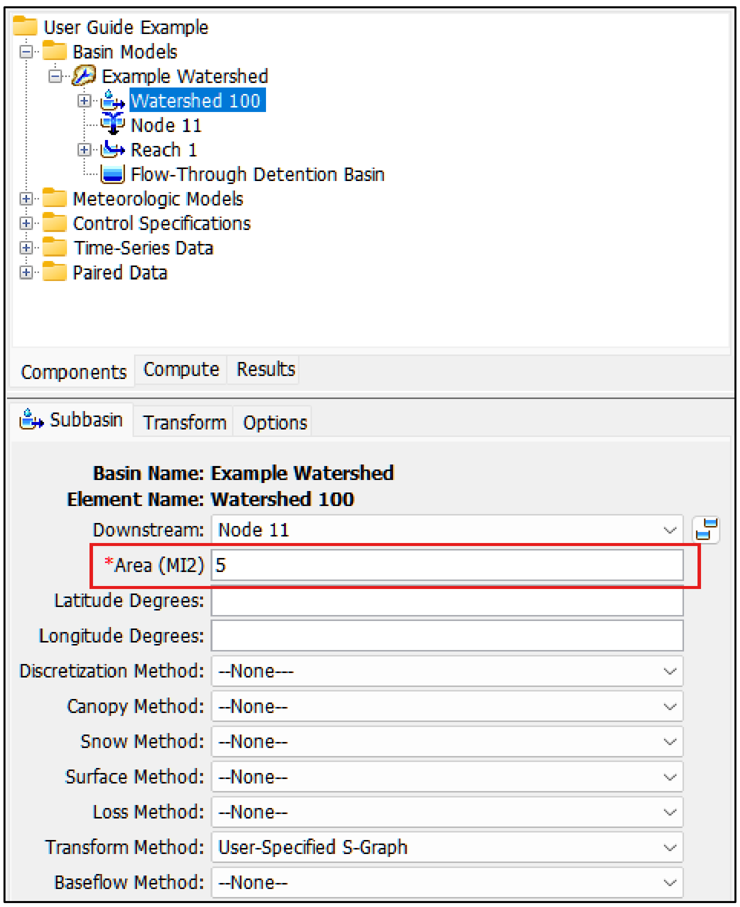


Figure 2. Basin Model Manager→Subbasin Editor – Watershed Area

- Lag time (T_{lag}): Within the *Basin Model Manager→Transform* editor, the lag time is entered.

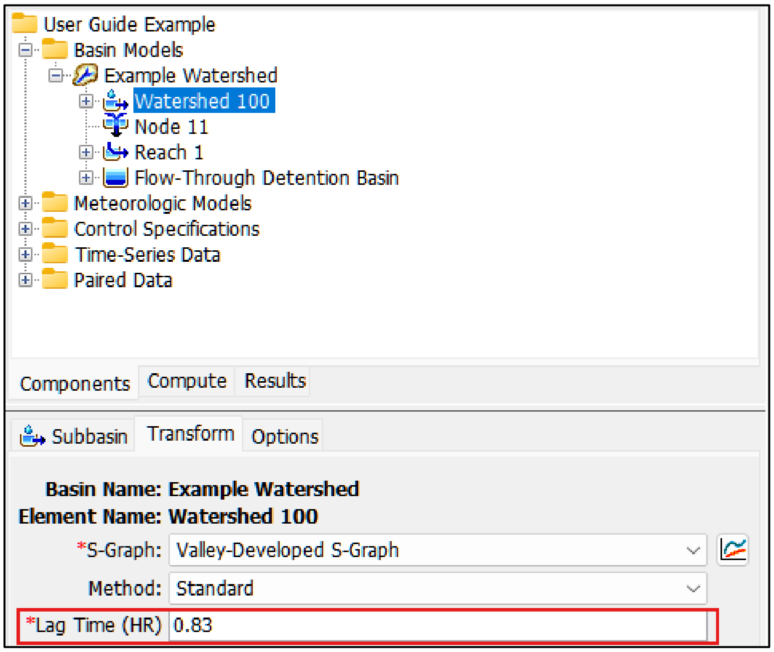


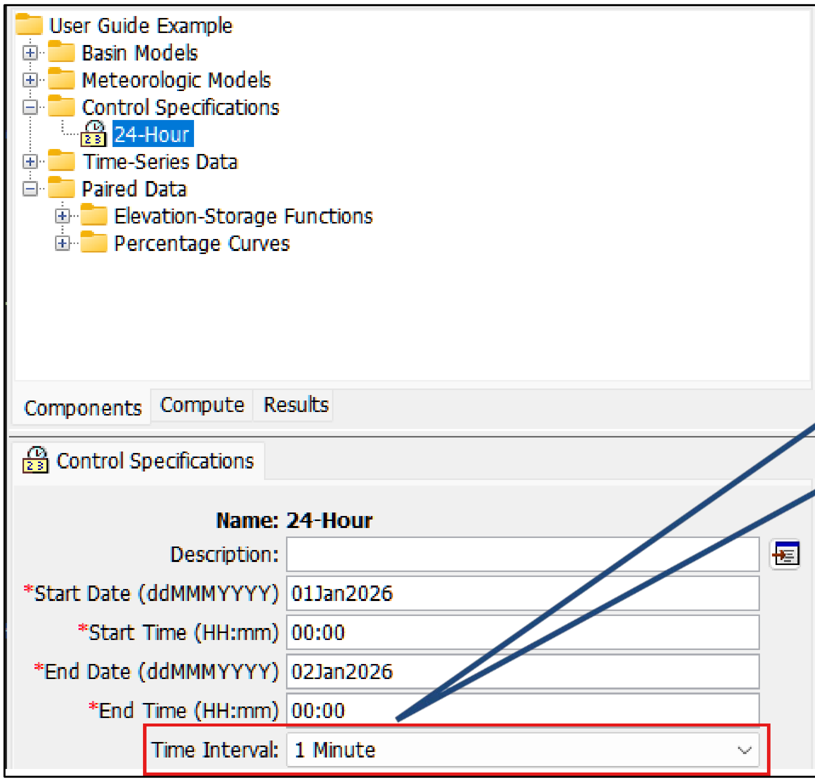
Figure 3. Basin Model Manager→Transform Editor – Lag Time

The *Synthetic Unit Hydrograph Tools→USACE Lag Time Calculation Tool* worksheet within the San Bernardino County UH Pre-Processor Tool can be used to calculate the watershed lag time (note: light orange cells require input values):

User Input Parameters for Lag Time Calculation			
Parameter	**Symbol**	**Value**	**Units**
Length of longest watercourse:	L	30096.0	Feet
		5.7	Miles
Length of longest watercourse, measured from the outlet upstream to a point opposite center of area:	L_{ca}	19008.0	Feet
		3.6	Miles
Headwater Elevation (Upstream):	El_{US}	1211.5	Feet
Collection Point Elevation (Downstream):	El_{DS}	100.0	Feet
Overall slope of drainage area between the headwaters and the collection point:	S	195.0	Feet/Mile
		0.037	Feet/Feet
Visually estimated basin factor of all collection streams and watershed channels:	$\bar{n}$	0.030	
Constants			
Constant determined by regional flood reconstitution studies:	m	0.38	
Constant (defined as $24\bar{n}$) :	C_t	0.72	
Lag Time Output			
Lag time:	T_{lag}	0.83	Hours
		50.0	Minutes

Figure 4. Synthetic Unit Hydrograph Tools – Lag Time Calculation

- Unit time period (T_{unit}): Within the *Control Specifications Manager,* the unit time interval (period) is entered.



Tip: Select the unit time interval (period) based on watershed lag (e.g., approximately 15% to 25% of T_{lag}), model stability, and other project objectives.

Figure 5. Control Specifications Manager – Unit Time Interval (Period)

- S-Graph: Within the *Paired Data Manager→Percentage Curves* editor, enter the S-graph ordinates. Users must enter the complete set of S-graph ordinate values (note that **Figure 6**, below, displays only a portion of the entered data as an example).

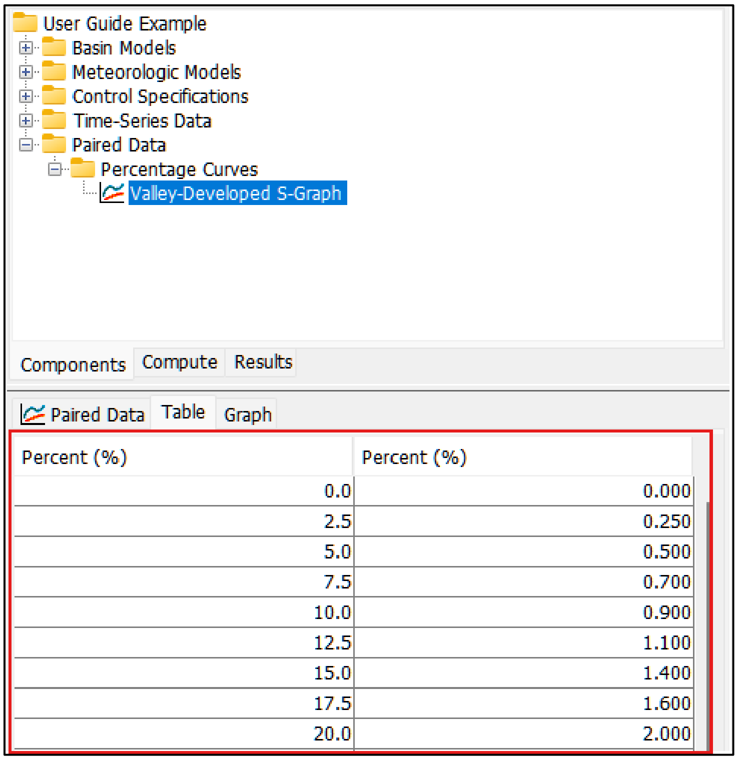


Figure 6. Paired Data Manager→Percentage Curves Editor – S-Graph

A project-specific S-graph can be created using the *Synthetic Unit Hydrograph Tools→Weighted S-Graph Tool* worksheet within the San Bernardino County UH Pre-Processor Tool as shown in **Figure 7** (note: light orange cells require weighted values such that they sum to 1.0). The tabular output can be copied from the *Summary Sheet→Weighted S-Graph Summary* worksheet and pasted into the HEC-HMS *Paired Data Manager→Percentage Curves* editor.

User Input Weighted S-Graph Selections	
S-Graph	Weight
Valley-Developed:	1.00
Valley-Undeveloped:	
Foothill Areas:	
Desert Areas:	
Mountain Areas:	
Valley-Developed S-Graph is Selected	

Tip: Calculate the weight values applicable to the project watershed(s) using GIS and/or CAD tools.

Figure 7. Synthetic Unit Hydrograph Tools – S-Graph Creation

The user must also link the S-graph to the basin transform; this is done in two locations: (1) the *Basin Model Manager→Subbasin* editor where the "Transform Method" is set to "User-Specified S-Graph," and (2) the *Basin Model Manager→Transform* editor where the "S-Graph" is set to the name of the appropriate percentage curve (e.g., Valley–Developed S-Graph).

1. *Basin Model Manager→Subbasin* editor

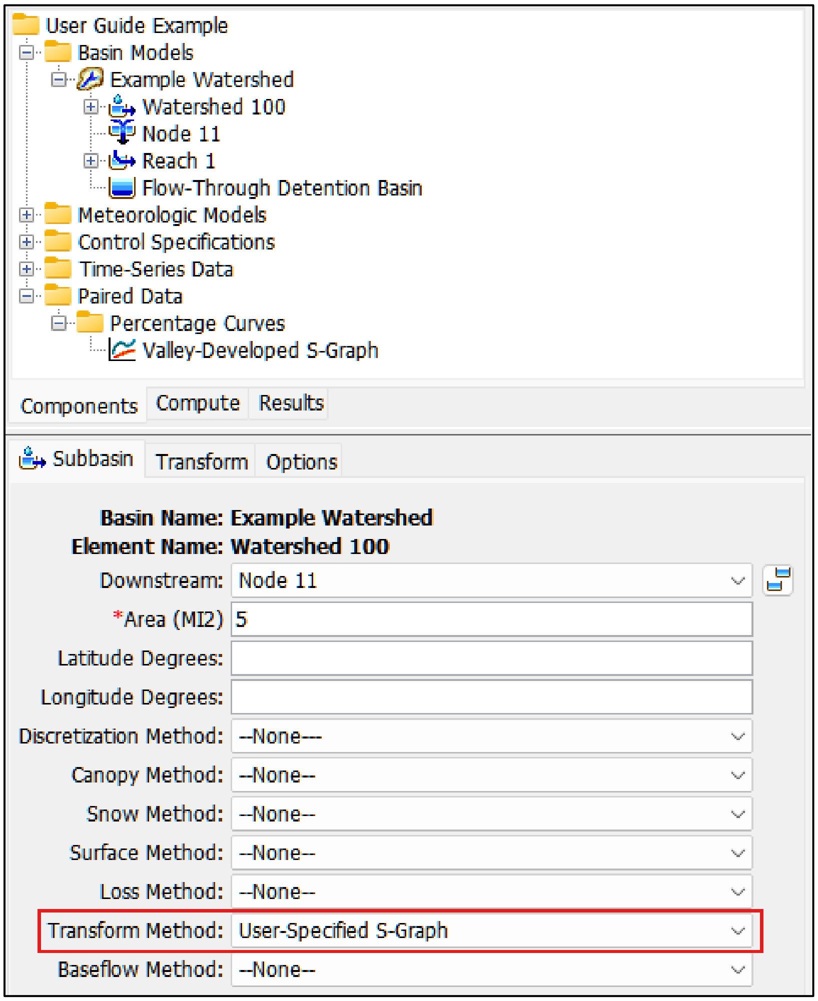


Figure 8. Basin Model Manager→Subbasin Editor – Transform Method

2. *Basin Model Manager→Transform* editor

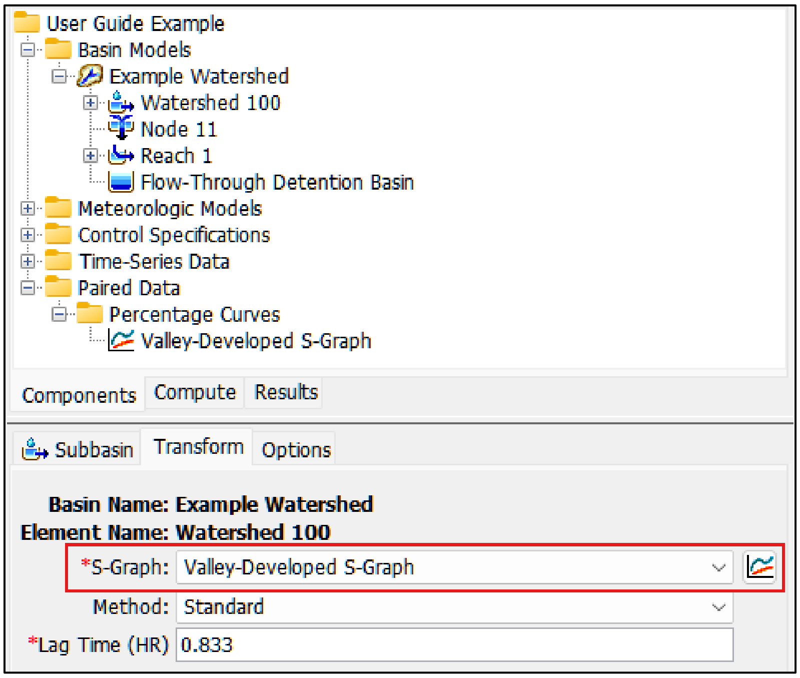


Figure 9. Basin Model Manager→Transform Editor – S-Graph

3 EFFECTIVE DESIGN STORM HYETOGRAPHS

The calculation of effective rainfall for a watershed is presented in Section 5.3.2 of the Manual. The effective design storm hyetograph example in Manual Section 5.3.2.5 has a 3-hour duration for brevity; the calculations in this guide are based on a 24-hour duration.

The depth-area adjusted precipitation values can be calculated using the *Effective Hyetograph Tools→Precipitation Depth Adjustment Tool* worksheet within the San Bernardino County UH Pre-Processor Tool (note: light orange cells require input values) as shown in **Figure 10**. Refer to Chapter 2 in the Manual for guidance on obtaining the National Oceanic and Atmospheric Administration (NOAA) precipitation data.

User Input Storm Data		
Average Recurrence Interval:	100	Years
Storm Duration:	24-Hour	
User Input NOAA Precipitation Data		
5-minute:	0.393	Inches
10-minute:	0.564	Inches
15-minute:	0.682	Inches
30-minute:	0.932	Inches
1-hour:	1.100	Inches
2-hour:	1.410	Inches
3-hour:	1.630	Inches
6-hour:	2.220	Inches
12-hour:	3.120	Inches
24-hour:	4.520	Inches
User Input Depth Area Reduction Factor (DARF) Data		
Adjust Precipitation with DARF?:	Yes	
Storm Duration:	24-Hour	
Watershed Area, A:	3200.0	Acres
	5.0	Sq. Mi.
DARF Adjusted Precipitation Values		
5-minute:	0.346	Inches
10-minute:	0.497	Inches
15-minute:	0.603	Inches
30-minute:	0.830	Inches
1-hour:	0.986	Inches
2-hour:	1.317	Inches
3-hour:	1.583	Inches
6-hour:	2.198	Inches
12-hour:	3.095	Inches
24-hour:	4.497	Inches

Figure 10. Effective Hyetograph Tools – DARF Adjustment

Adjusting the precipitation for losses as described in Manual Chapter 3 can be performed using the *Effective Hyetograph Tools→Watershed Losses Tool* worksheet within the San Bernardino County UH Pre-Processor Tool. As shown in **Figure 11** for the Commercial development type (see Manual Table 5-4), the user enters the calculated curve number (CN) and selects the antecedent moisture condition (AMC) value; the storm runoff yield fraction is then calculated using Manual Equation 3-3.

The watershed maximum loss rate (F_m) is also a required input for the UH Pre-Processor Tool to correctly calculate the effective hyetograph. In this example, 0.213 inches/hour was calculated by area-weighting the F_m from Manual Table 5-4.

User Input Area-Averaged Maximum Loss Rate			
Parameter	**Symbol**	**Value**	**Units**
Maximum Loss Rate:	F_m	**0.213**	Inches/Hour
User Input X-hour Storm Runoff Yield Fraction Parameters			
Parameter	**Symbol**	**Value**	**Units**
X-hour Storm Rainfall:	P_x	**4.497**	Inches
AMC-II Curve Number:	CN	**92**	
Antecedent Moisture Condition:	AMC	**AMC-II**	
Adjusted Curve Number Based on AMC:	CN	**92.0**	
Total Soil Capacity:	S	**0.870**	
Initial Abstraction:	I_a	**0.174**	
Final Output			
X-Hour Storm Runoff Yield Fraction:	Y_j	**0.800**	

Figure 11. Effective Hyetograph Tools – Loss Calculations

After the storm runoff yield fraction values are computed for each watershed component, the area-averaging (see Manual Equation 3-4) functionality of the *Watershed Losses Tool* can be used to calculate the area-averaged Y_j and low loss fraction for the watershed as shown in **Figure 12**. In this example, the areas and corresponding CNs from Manual Table 5-4 were used to calculate each Y_j value for the respective development type.

Input Y_j and Area Values for Area-Averaging			
Subarea	**Y_j**	**Area**	**Y_j x Area**
1	**0.626**	**320.0**	200.320
2	**0.455**	**1920.0**	873.600
3	**0.800**	**960.0**	768.000
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

Final Output	
Area-Averaged Y_j:	0.576
Watershed Low Loss Fraction ($\overline{Y}$):	0.424

Figure 12. Effective Hyetograph Tools – Runoff Yield Weighting

As shown in **Figure 13**, the effective rainfall tabular output in the *Summary Sheet→Effective Design Storm Hyetograph Summary* worksheet (partial data output shown as an example) incorporates the Depth-Area Reduction Factor (DARF) adjustments (if applicable), loss inputs, and the 67% intensity position according to the left, left, right placement scheme described in Manual Section 5.3.2.5, Step 5. This output can be copied and pasted into the HEC-HMS *Time-Series Data Manager→Precipitation Gages* editor. **Figure 14** shows a portion of the entered data as an example.

Effective Design Storm Hyetograph Data			
Time	Incremental Rainfall Depth	Loss Depth	Effective Rainfall Depth
Minutes	Inches	Inches	Inches
1	0.001684	0.000714	0.000970
2	0.001685	0.000714	0.000970
3	0.001686	0.000715	0.000971
4	0.001686	0.000715	0.000971
5	0.001687	0.000715	0.000972
6	0.001688	0.000716	0.000972
7	0.001689	0.000716	0.000973
8	0.001690	0.000716	0.000973
9	0.001691	0.000717	0.000974
10	0.001691	0.000717	0.000974

Figure 13. Summary Sheet – Effective Design Storm Hyetograph Data

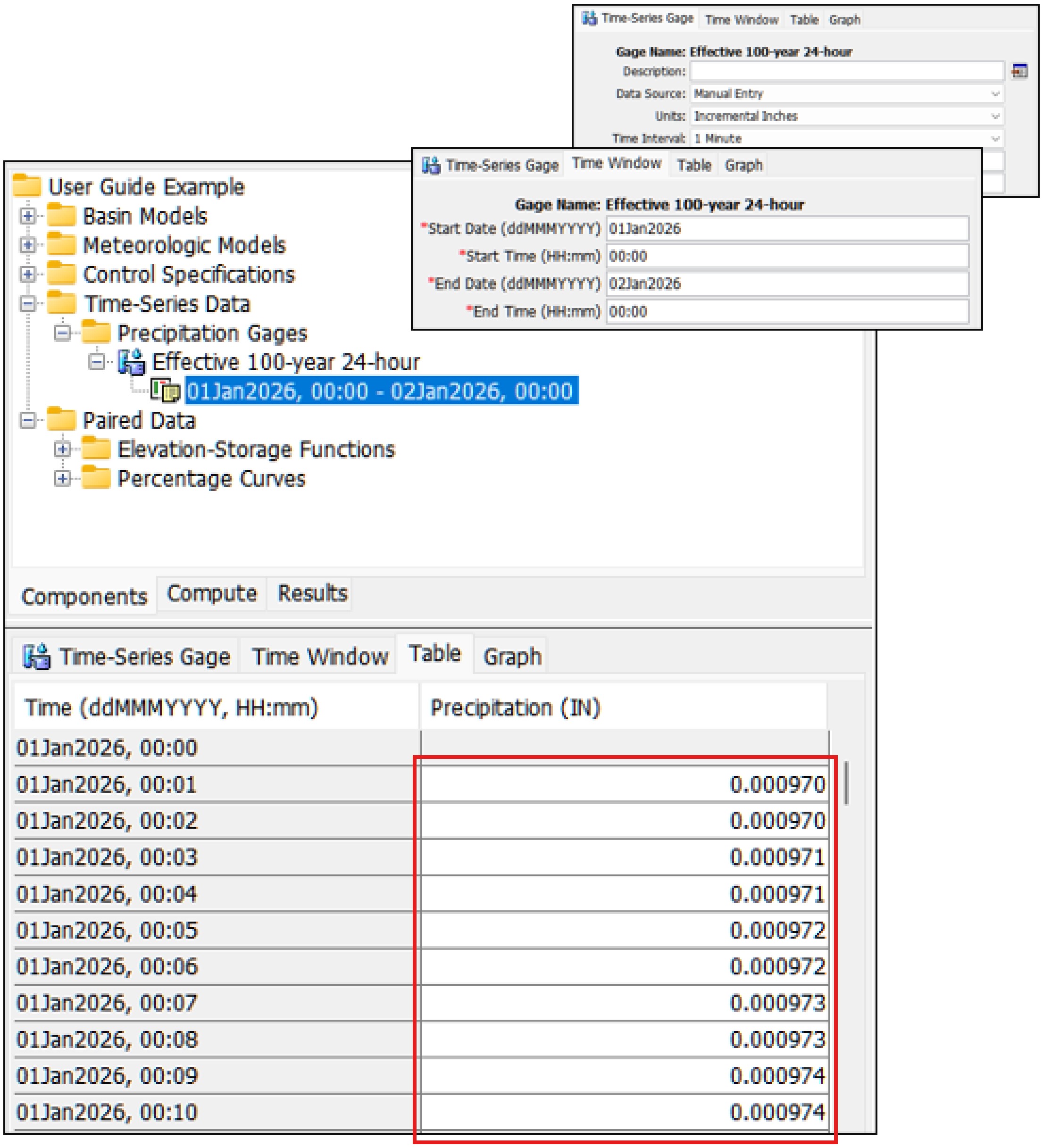


Figure 14. Time-Series Data Manager→Precipitation Gages Editor – Hyetograph

The units (incremental inches), time interval (1 minute), time window (start/end date and time), and effective hyetograph ordinates are also specified.

If the simulation length is greater than the hyetograph length (e.g., 24 hours), a placeholder value of 0 is entered from the end of the hyetograph to the end of the simulation time.

The user must also link the precipitation data to the meteorologic components; this is done in three locations: (1) the *Meteorologic Model Manager→Meteorology Model* editor, (2) the *Meteorologic Model Manager→Basins* editor, and (3) the *Meteorologic Model Manager→Specified Hyetograph* editor.

1. *Meteorologic Model Manager→Meteorology Model* editor

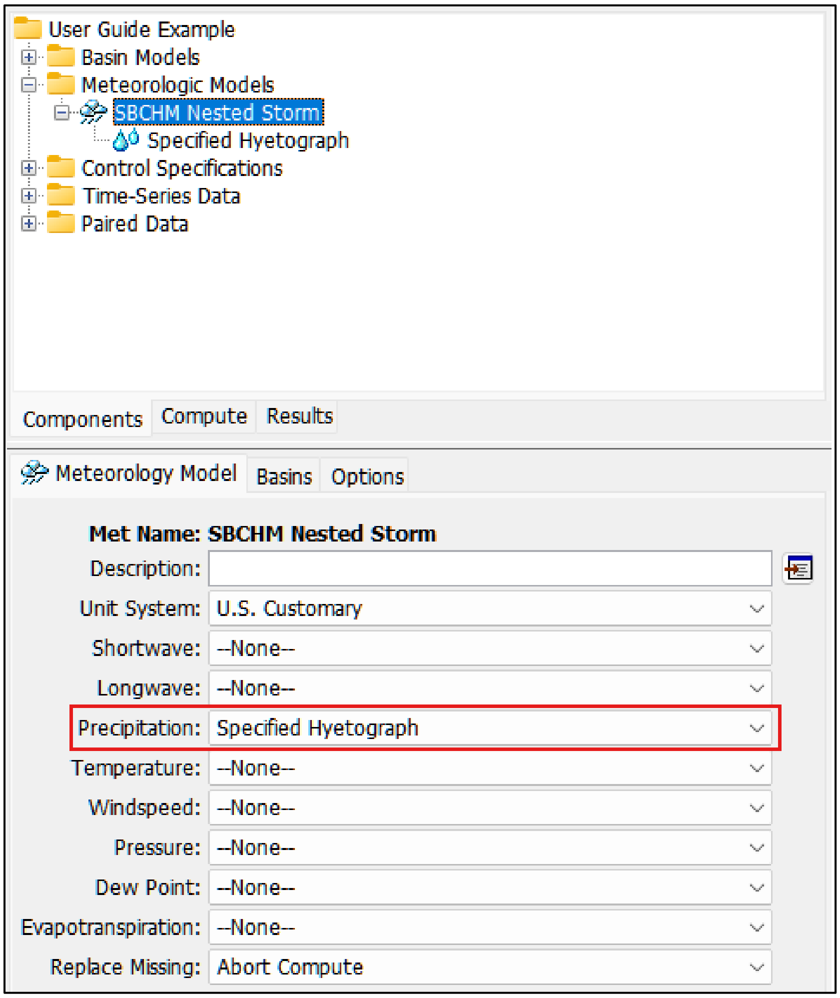


Figure 15. Meteorologic Model Manager→Meteorology Model Editor – Hyetograph

2. *Meteorologic Model Manager→Basins* editor

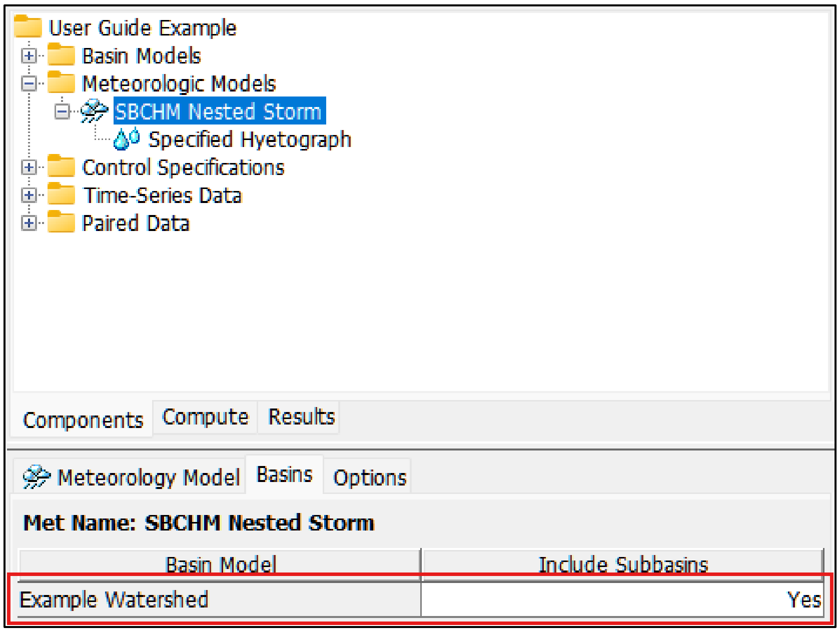


Figure 16. Meteorologic Model Manager→Basins Editor – Hyetograph

3. *Meteorologic Model Manager→Specified Hyetograph* editor

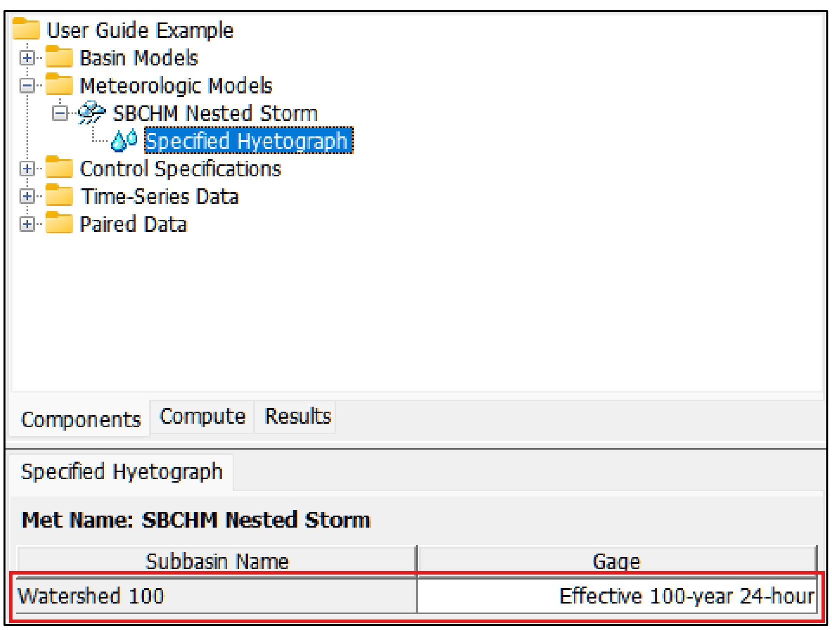


Figure 17. Meteorologic Model Manager→Specified Hyetograph Editor – Hyetograph

4 RUNOFF HYDROGRAPH CALCULATIONS

To perform the runoff hydrograph calculations in HEC-HMS, the user must create a simulation run file consisting of the basin model, meteorologic model, and control specifications. The run file can be developed using the *Compute→Create Compute→Simulation Run* manager.

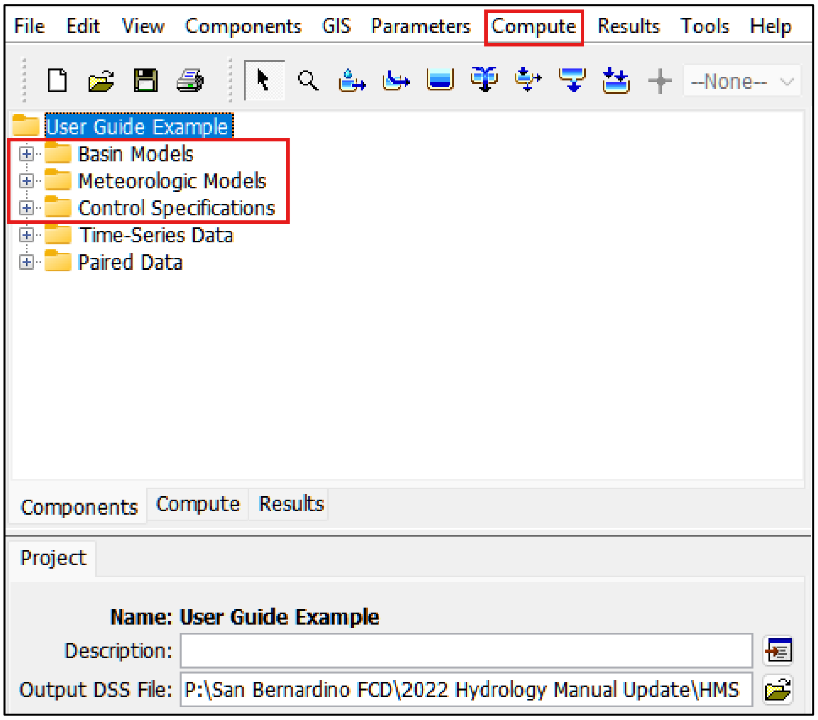


Figure 18. Simulation Run Manager

The watershed runoff results can be viewed within the basin model results tab (see **Figure 19**) or using USACE HEC-DSSVue software. The 100-year, 24-hour peak flow rate from the example watershed is 2,636.3 cfs.

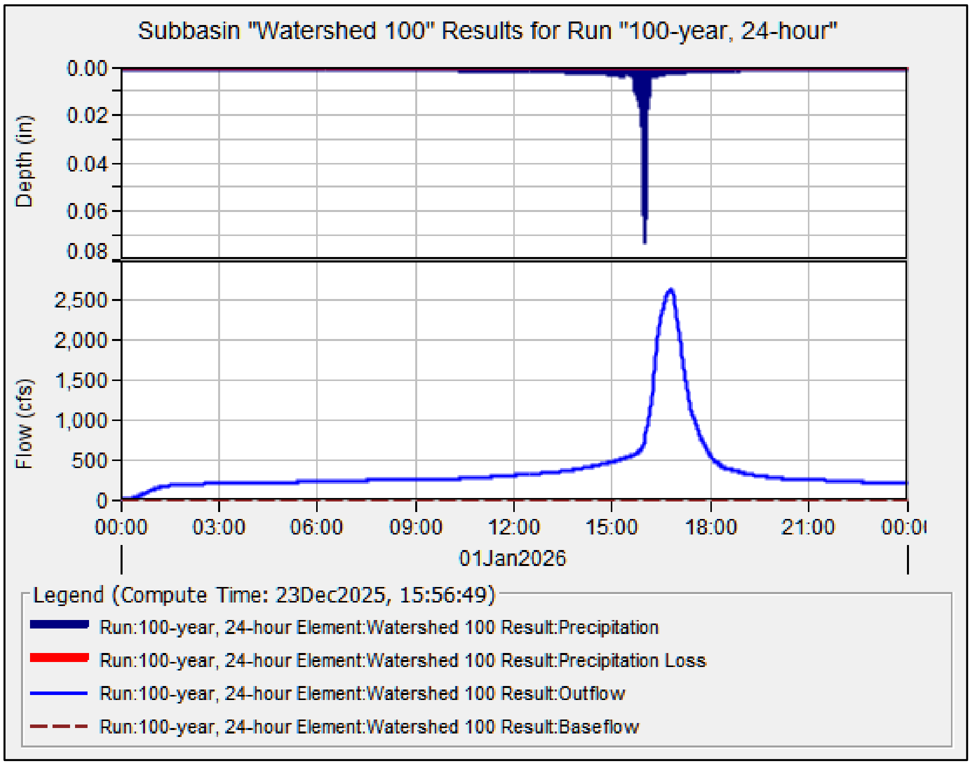


Figure 19. Simulation Results Window

5 CHANNEL ROUTING ANALYSIS

Routing channelized flow via a channel into a flow-through detention basin in HEC-HMS typically involves creating a reach element followed by a reservoir element with a controlled outflow.

After the reach and reservoir elements are created, the downstream connection point (e.g., detention basin or junction) and routing method are selected in the *Basin Model Manager→Reach* editor (see **Figure 20**). Manual Section 5.5 briefly describes commonly used routing methodologies. Users should refer to the most current HEC-HMS User's Manual and Technical Reference Manual for detailed guidance in selecting an appropriate routing method based on the watershed characteristics and modeling objectives.

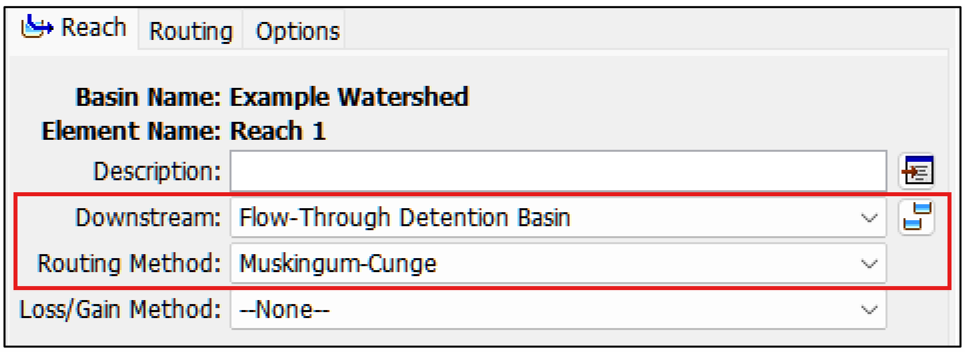


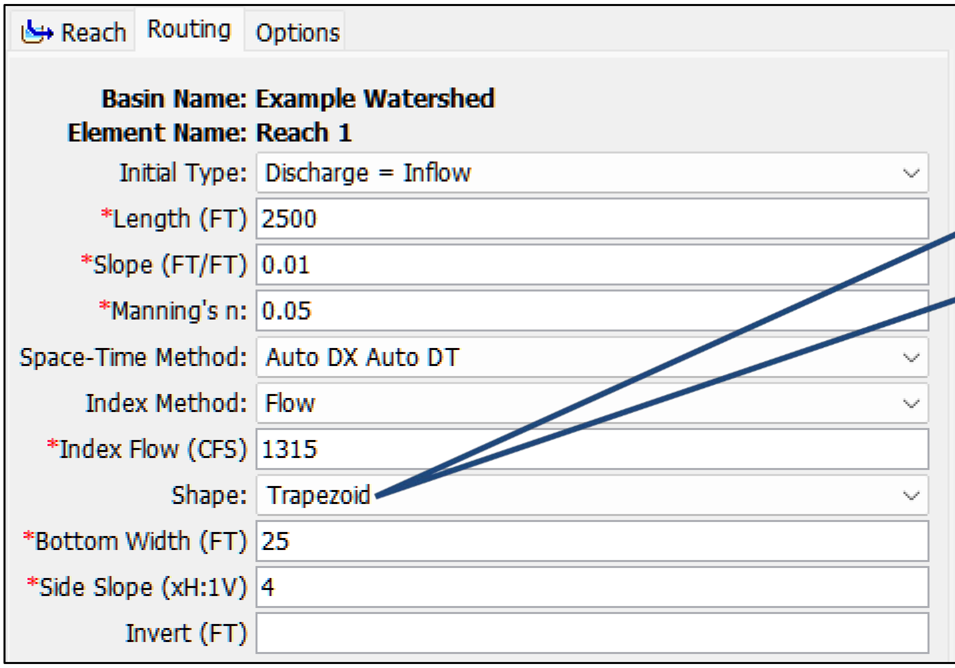
Figure 20. Basin Model Manager→Reach Editor – Downstream and Routing Method

In this example, the Muskingum-Cunge routing method was selected. The *Routing* editor is shown in **Figure 21** with values entered for example purposes.

There are two options for Initial Type: (1) Discharge = Inflow, and (2) Specified Discharge.

1. Discharge = Inflow: Assumes that the initial outflow is the same as the initial inflow to the reach from upstream elements. This will be a typical selection when the HEC-HMS model is also used to perform the watershed rainfall-runoff calculations.
2. Specified Discharge: Requires a user supplied discharge value.

The length (feet), slope (feet/feet), Manning's n value, Space-Time Method, Index Method, and shape are also required. Depending upon certain parametric selections, other input values may be needed.



Tip: For a more detailed cross-section, select the "Eight Point" shape and define the geometry in the *Paired Data Manager→Cross Section* editor.

Figure 21. Basin Model Manager→Routing Editor – Input Parameters

Similar to the watershed runoff results, the reach routing results can be viewed within the reach results tab (see **Figure 22**) or using USACE HEC-DSSVue software. The peak flow rate attenuation in this routing reach was calculated to be approximately 4.3 cfs (i.e., the difference between the dashed and solid blue lines).

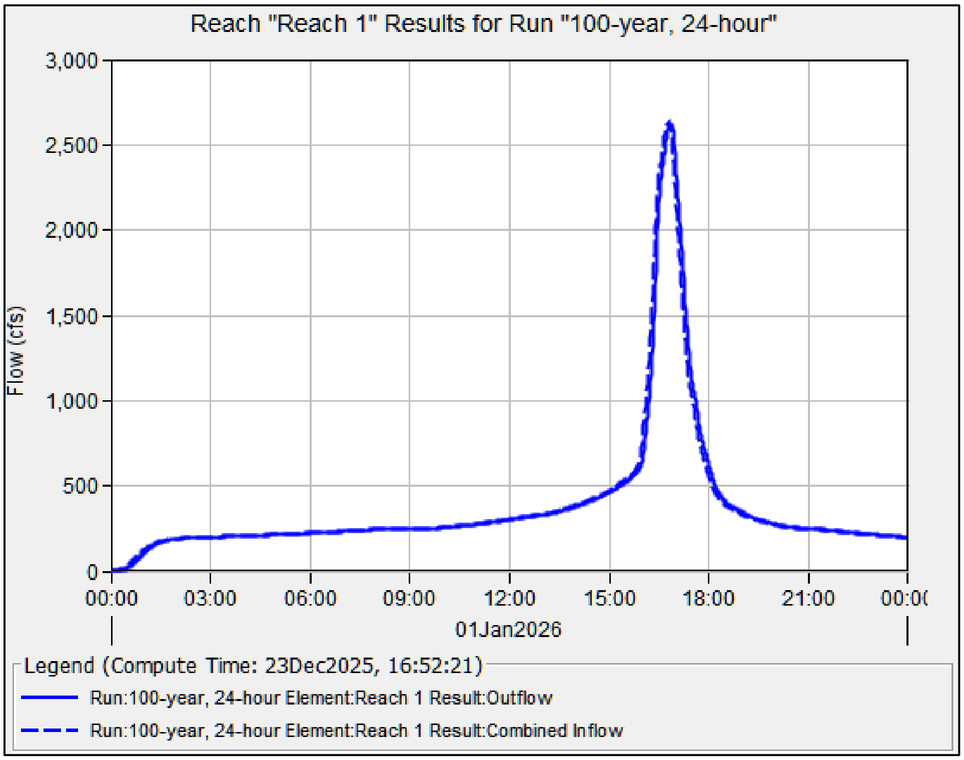


Figure 22. Reach Routing Results

6 FLOW-THROUGH DETENTION BASIN ROUTING ANALYSIS

A flow-through detention basin is represented in HEC-HMS using a reservoir element. The software performs the calculations using the Modified Puls method (see Manual Section 8.5.2.1). The detention basin typically receives inflow from an upstream channel represented as a reach element in HEC-HMS (as in this example). Once the reservoir element is created, the downstream connection feature (if applicable) and storage-routing method must be selected (see **Figure 23**).

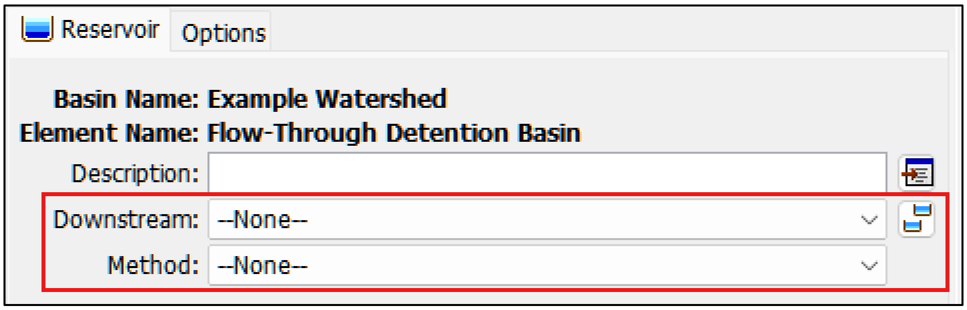


Figure 23. Basin Model Manager→Reservoir Editor – Downstream and Storage Method

If sediment and debris bulking are considered (see Manual Chapter 7 and Section 8.4.4), the outflow hydrograph shown in **Figure 22** would be bulked outside of HEC-HMS, entered as a source flow, and connected directly to the reservoir element (see **Figure 24**).

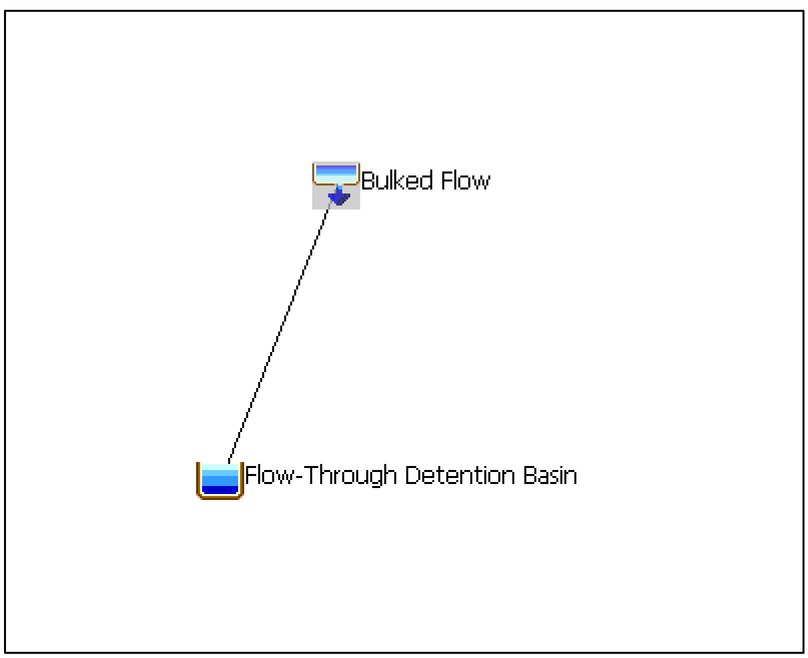


Figure 24. Bulked Flow HEC-HMS Model Schematic

There are four reservoir routing method options: (1) Outflow Curve, (2) Specified Release, (3) Outflow Structures, and (4) Rule-Based Operations. All of the options require a storage-area relationship (see the *Paired Data Manager→Elevation-Area Functions* editor shown in **Figure 25**); other inputs depend on the method selected, as shown below.

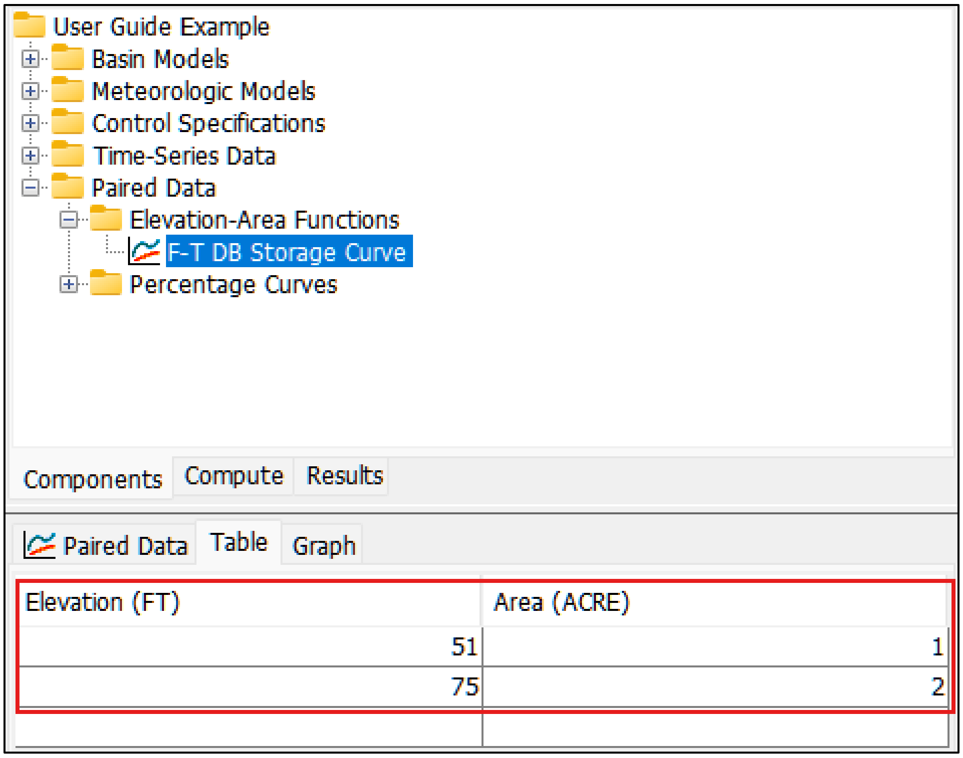


Figure 25. Paired Data Manager→Elevation-Area Functions Editor

1. Outflow Curve: The user develops the storage-discharge curve externally and enters it via the *Paired Data Manager* editor (see **Figure 26**).

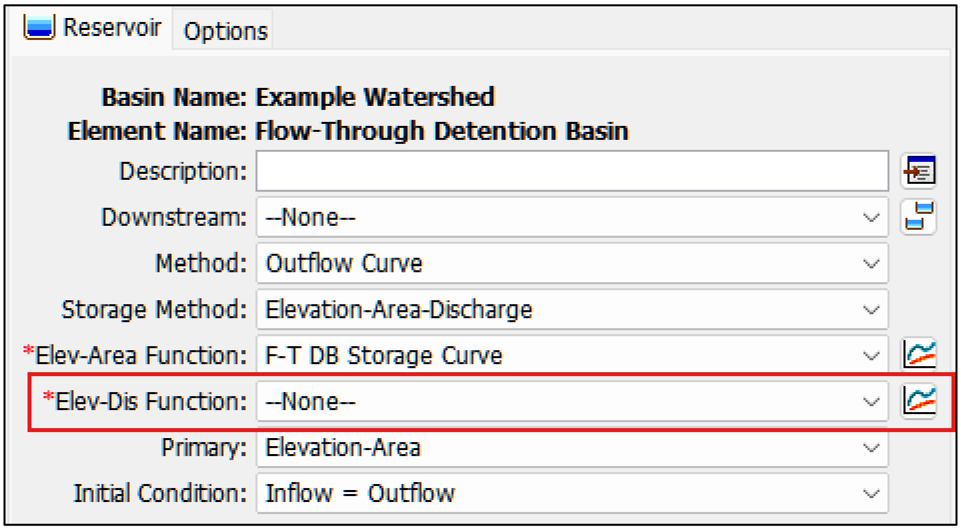


Figure 26. Basin Model Manager→Reservoir Editor – Outflow Curve Method

2. Specified Release: This can be used to set a known discharge rate applied over the simulation period (see **Figure 27**).

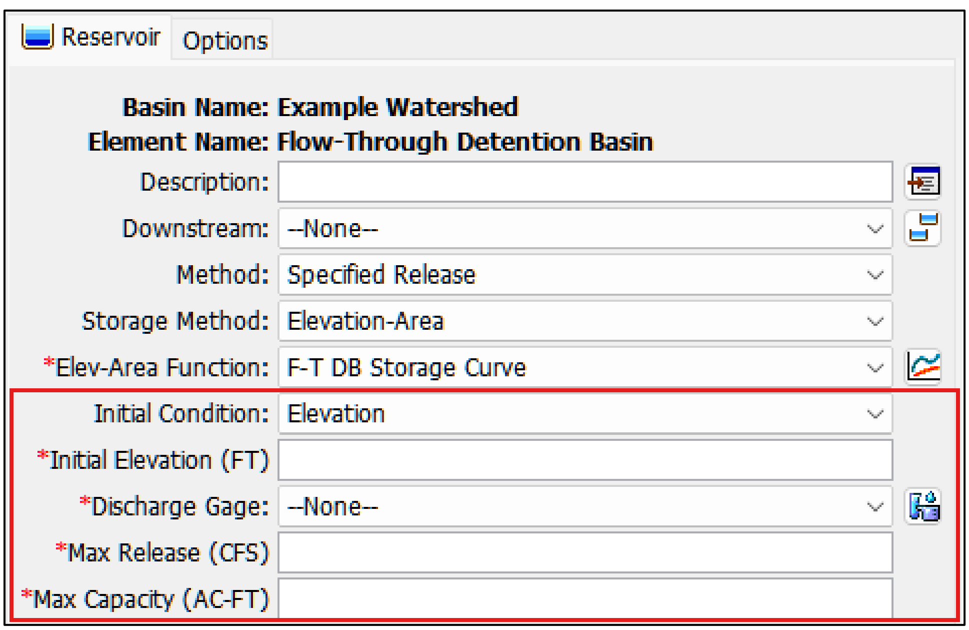


Figure 27. Basin Model Manager→Reservoir Editor – Specified Release Method

3. Outflow Structures: The user can regulate outflow via various structures (e.g., small pipes and/or culverts). Spillways and overtopping crest geometry can also be included as shown in
4. Figure 28.

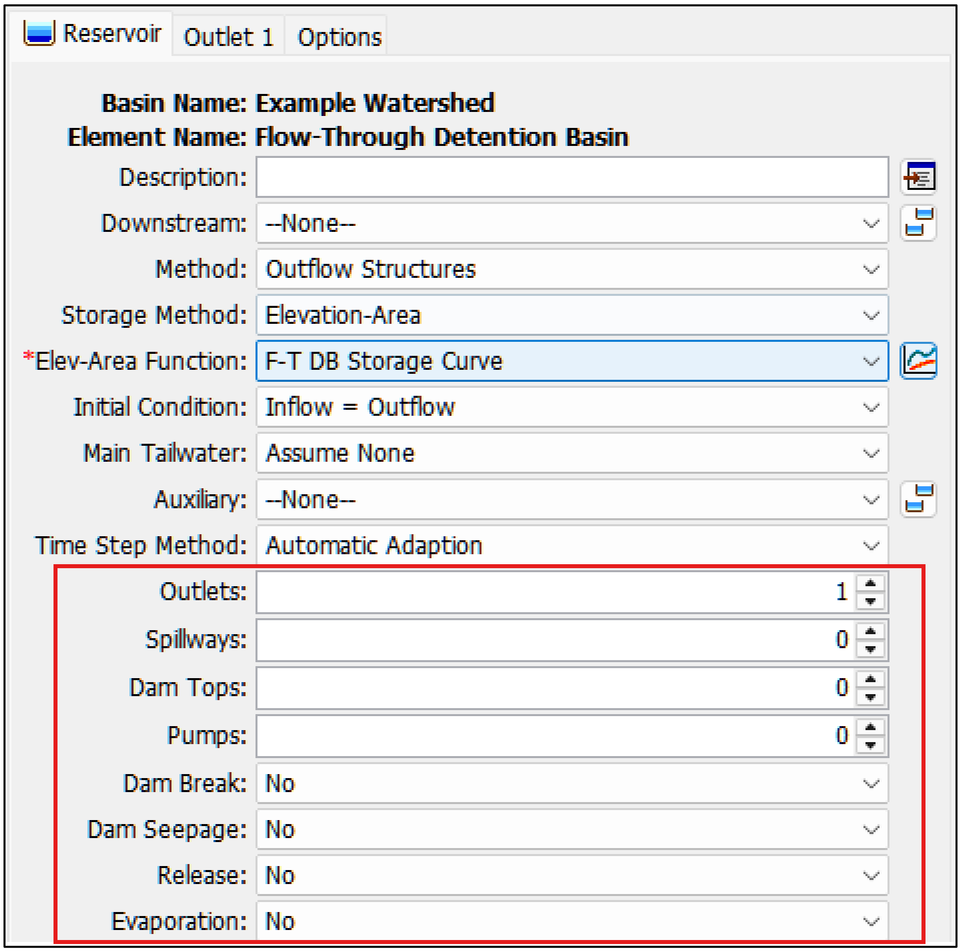


Figure 28. Basin Model Manager→Reservoir Editor – Outflow Structures Method

5. Rule-Based Operations: This method supplements the Outflow Structures Method, allowing operation rules to be configured (see the Zones setting in **Figure 29**).

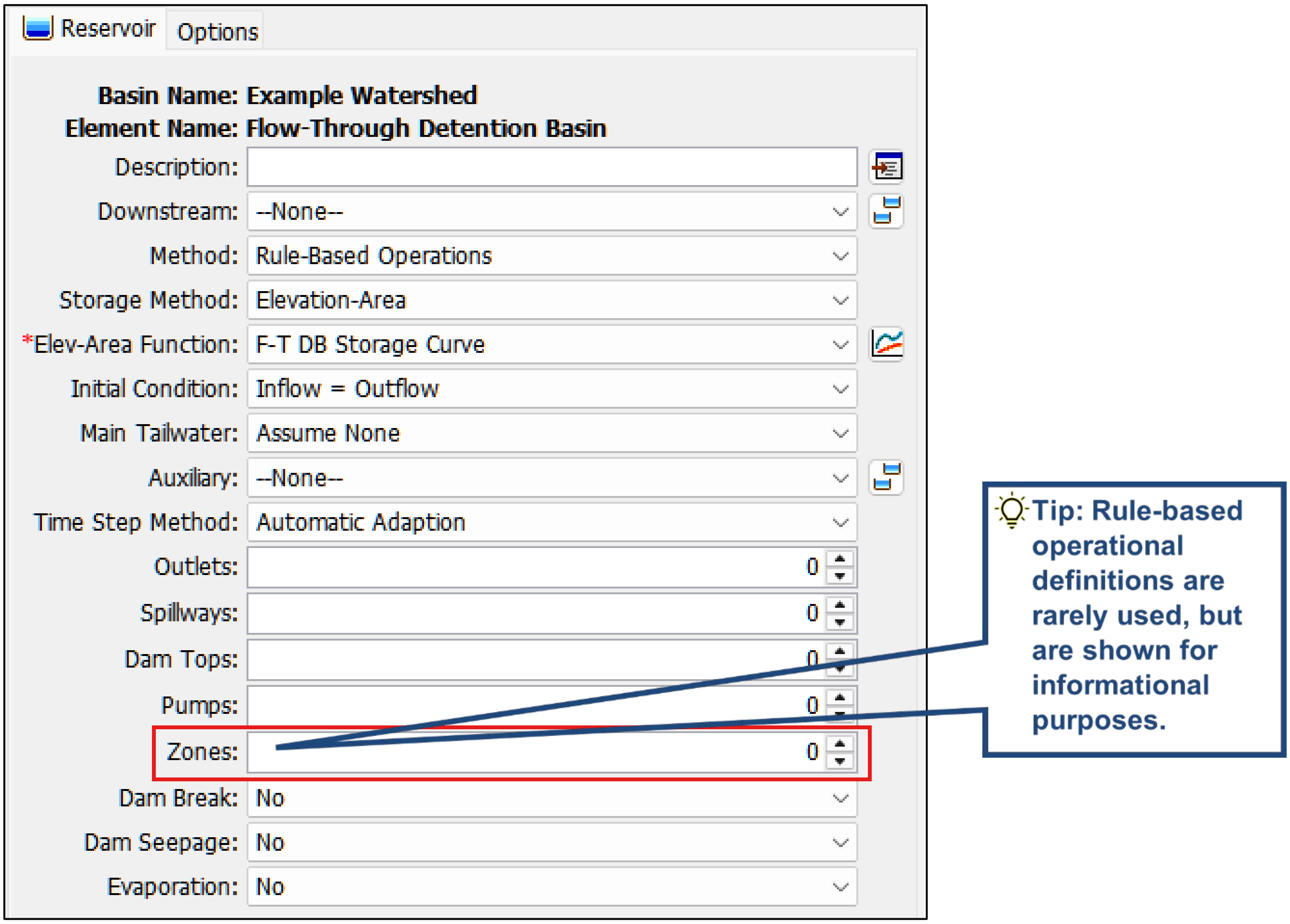


Figure 29. Basin Model Manager→Reservoir Editor – Rule-Based Operations Method

In this example, the Outflow Structures Method was selected. The user must enter the number outlets, spillways, and other components (see

Figure 28) to open the associated editor screen as shown in **Figure 30**. Here a culvert outlet was specified:

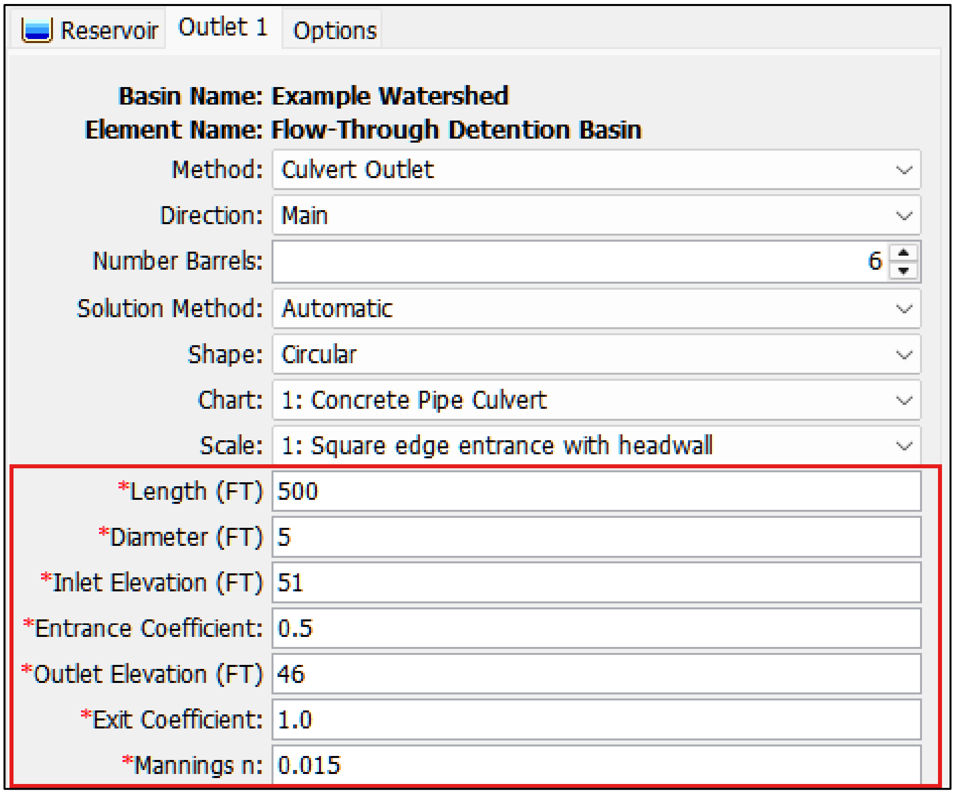


Figure 30. Basin Model Manager→Reservoir Editor – Culvert Outlet

The flow-through detention basin routing results can be viewed within the reservoir results tab or using USACE HEC-DSSVue software. The detention basin storage, elevation, inflow, and outflow results are shown in **Figure 31.**

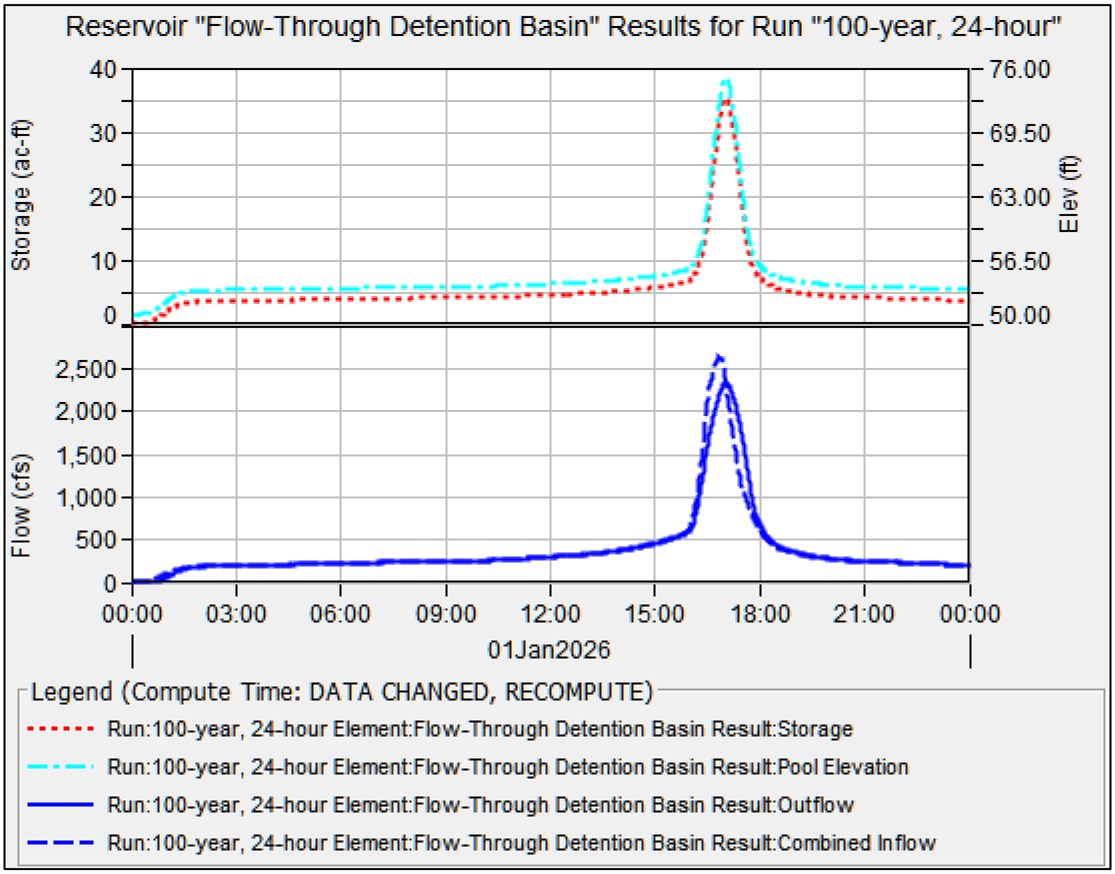


Figure 31. Flow-Through Detention Basin Results

The following list provides general detention basin analysis review items to aid the user:

- **Confirm hydrologic balance:** Ensure runoff volume from the UH equals the rainfall excess; detention outflow plus storage change equals inflow (i.e., mass conservation).
- **Review results:** Check the reservoir stage, storage, inflow, and outflow time series. Verify the peak flow attenuation (i.e., reduced peak and delayed timing) meets design and regulatory criteria.
- **Iterate design:** Adjust basin size, outlet structure type→ sizes, and→or crest elevations to achieve target release rates or water surface elevations.
- **Refine model:** Re-run until peak flow, volume, and drawdown meet standards.
- **Ensure stability:** Verify numerical model stability (e.g., appropriate timesteps and smooth rating-curve inflections).
- **Export results:** Save time-series plots and summary tables (e.g., peak flow, time to peak, storage maximum, and routing parameters). Document all inputs for reproducibility.
- **Consult additional resources:** See USACE HEC-HMS Tutorials and Guides for method-specific workflows; videos→ third-party tutorials offer practical examples and tips.

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