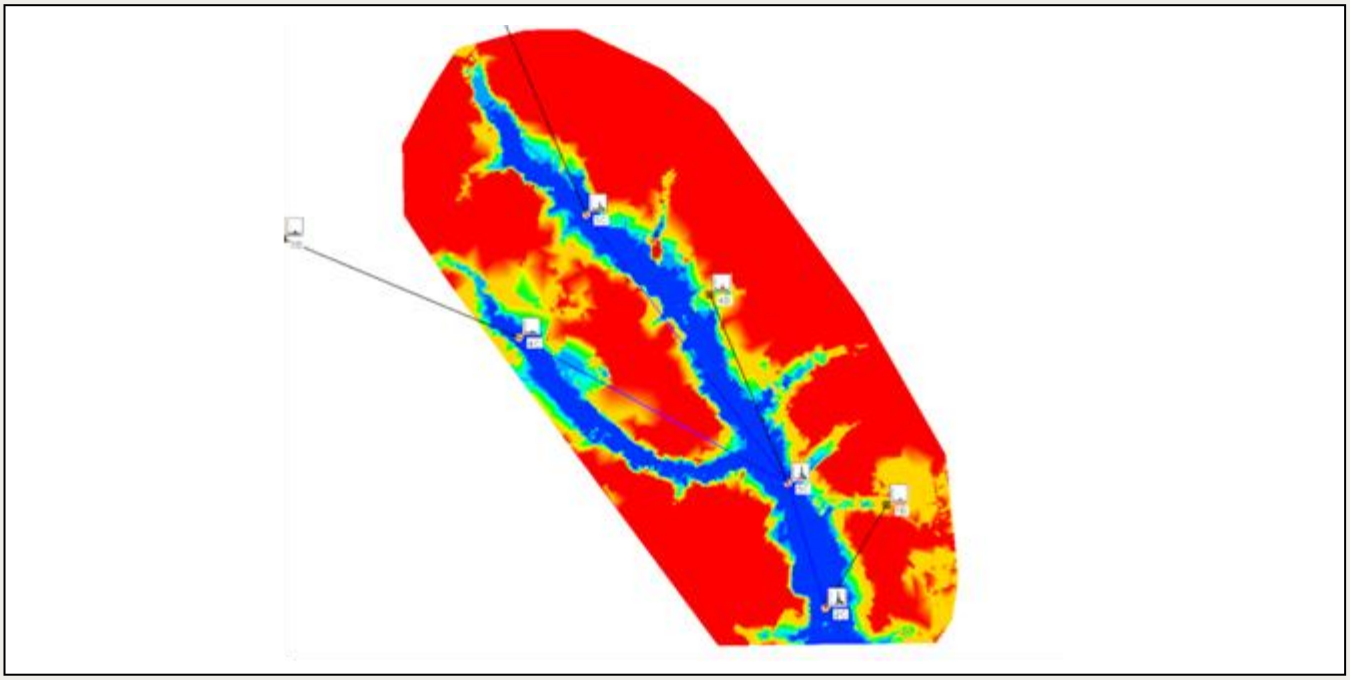
WMS 11.4 Tutorial

Stochastic Modeling Using HEC-1 and HEC-RAS

Learn how to set up and run a Monte-Carlo style risk analysis using the HEC-1 and HEC-RAS models



Objectives

This tutorial shows how to setup and run a risk analysis using stochastic modeling that determines the probably of flooding at each point in a floodplain for a certain recurrence interval.

Prerequisite Tutorials

- HEC-1 Interface
- HEC-RAS Analysis
- Floodplain Delineation

Required Components

- WMS Core
- HEC-1 Model
- HEC-RAS Model

Time

- 20–40 minutes

1 Introduction

This exercise demonstrates how to identify and set minimum, maximum, and mean values for hydrologic and hydraulic model parameters, and then to run a sequence of models and floodplain delineations to determine flood risks in a flood study area.

Since a certain degree of uncertainty usually exists in the selection of input parameters, running a stochastic model helps to explore multiple model solutions for differing input values. Specify a range of values to be used in the stochastic model.

This exercise shows the basics of setting up a stochastic model in WMS that will run the HEC-1, HEC-RAS, and Floodplain Delineation models simultaneously. It covers how to:

- Assign key values to parameters
- Define the Stochastic Model characteristics
- Run the Model
- View the solution means and probabilities

2 Opening the HEC-1 and HEC-RAS Models

Working HEC-1 and HEC-RAS models have been previously prepared for use in this exercise. Using the stochastic modeling features of WMS can create a probabilistic map of floodplain boundaries from these models.

There is generally a high degree of uncertainty associated with hydrologic modeling parameters such as the SCS Curve Number and rainfall depth. WMS can vary these parameters stochastically in order to analyze a more complete parameter space and then use the results to reflect the known uncertainty in a floodplain delineation. The stochastic simulation will run a specified number of simulations using randomly generated values of basin curve numbers and basin precipitation for each simulation. Results from the HEC-1 run are then passed to a developed HEC-RAS simulation, and finally the results from HEC-RAS are used to compute a series of flood plain boundaries from which a probability of flooding, based on model parameter uncertainty, can be computed.

1. Open WMS. If WMS is already open, select *File* | **New**.
2. Click **Don’t Save** if asked to save changes.
3. Select *File* | **Open** to access the *Open* dialog.
4. Locate the “stochastic” folder in the files for this tutorial.
5. Open “Run1.wms”.

This file is a WMS project file that references all the prepared input data for the HEC-1 and HEC-RAS models. Each simulation has been previously tested to ensure that they can be run successfully.

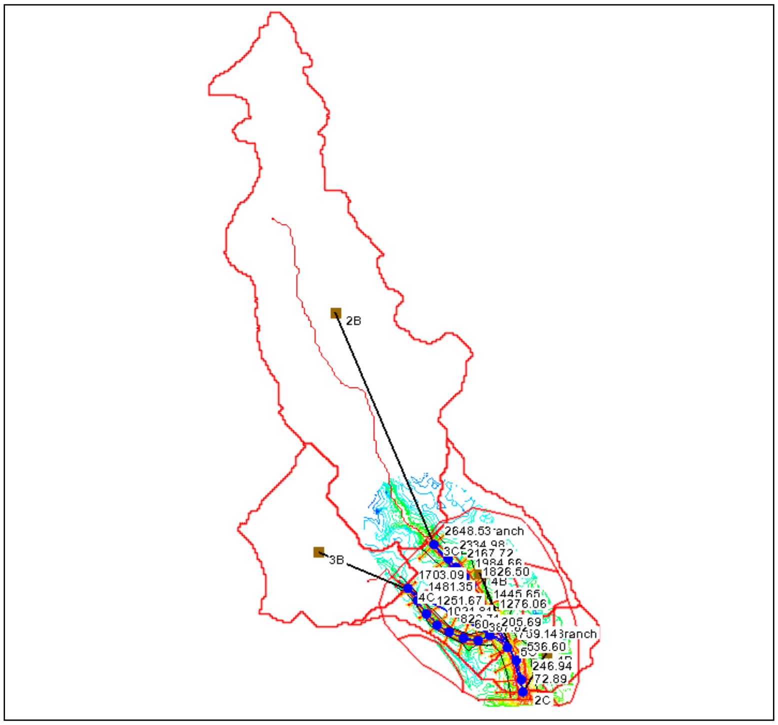


Figure 1 Initial project

2.1 Preparing the HEC-RAS Model

To begin, **Zoom** in on the HEC-RAS model domain.

1. In the Project Explorer, un-check the box next to the “ Hydrologic Tree Data” folder to hide all basins and outlets.
2. Uncheck the box next to “ Drainage” coverage.
3. Click on the **Frame** macro.
4. In the Project Explorer, click on “ 1D-Hyd Centerline” to make it active.
5. Select “River Tools” from the *Model* drop-down box at the top of the screen.
6. Select *River Tools* | **Map** → **1D Schematic**.

This initializes the HEC-RAS river scheme in preparation for reading in the HEC-RAS solution.

7. Switch to the **Hydraulic Modeling Module** .
8. Select *HEC-RAS* | **Read Solution…** to bring up the *Open* dialog.
9. Navigate to the *stochastic\stochastic* directory and select the file “hecrun1.prj”.
10. Click **Open** to import the solution.

When a HEC-RAS project file is imported, in which the water surface profiles have been calculated, a scatter point is placed at the thalweg location of each cross section. Each scatter point contains the value of the water surface elevation at that point in the river reach. To create additional scatter points for interpolation purposes, interpolate more scatter points along both the centerline and cross section arcs.

11. Make sure the " 1D-Hyd-Centerline" coverage is active in the Project Explorer.
12. Select *River Tools* | **Interpolate Water Surface Elevations…** to open the *Interpolate Stages* dialog.
13. Set the *Create a data point* field to "At a specified spacing".
14. For the *Data point spacing,* enter "60".
15. Click **OK** to close the *Interpolate Stages* dialog.
16. Activate the " 1D-Hyd Cross Section" coverage from the Project Explorer.
17. Select *River Tools* | **Interpolate Water Surface Elevations…** to open the *Interpolate Stages* dialog.
18. Accept the current settings and select **OK** to close the *Interpolate Stages* dialog.

This same data point spacing (60) will be used to interpolate each HEC-RAS solution along the reach and the cross sections when running the stochastic simulations.

2.2 Preparing the HEC-1 Model

1. In the Project Explorer, turn on the " Drainage" coverage.
2. Turn on the contents of the " Hydrologic Tree Data" folder in the Project Explorer.
3. Select the **Frame** macro.

Now to assign key values to the parameters that will randomly vary during the stochastic run. Key values are negative integers assigned to a parameter in lieu of the actual value. By entering a negative value for precipitation, for example, WMS replaces the precipitation value with a feasible precipitation value at run time. This precipitation value changes for each new run. Each generated value is based on a normal distribution and can be controlled by specifying minimum and maximum allowable values.

4. Select the " Hydrologic Tree Data" folder in the Project Explorer.
5. Using the **Select basin** tool, multi-select the basins labeled 2B and 3B by holding the *Shift* key while single-clicking on each basin icon.
6. Select *HEC-1* | **Edit Parameters…** to open the *Edit HEC-1 Parameters* dialog.
7. Select **Precipitation…** to open the *HEC-1 Precipitation* dialog.
8. In the *Average precipitation* field, enter a value of "-1".
9. Click **OK** to close the *HEC-1 Precipitation* dialog.
10. Select **Loss Method…** to open the *HEC-1 Loss Methods* dialog.
11. In the *CRVNBR* field, enter a value of "-2".
12. Click **OK** to close the *HEC-1 Loss Methods* dialog.
13. Click **Done** to close the *Edit HEC-1 Parameters* dialog.
14. Click anywhere to deselect basins 2B and 3B.

15. Multi-select the basins labeled 4B and 1B.
    - If needed in order to see the basin icons, use **Display Options** to turn off the *River Hydraulic Schematic* option in the *River Data* tab.
16. Repeat steps 6–13 to assign an *Average precipitation* value of "-1" and a *CRVNBR* value of "-3" for basins 4B and 1B.

3 Running the Stochastic Model

For this exercise, only HEC-1 parameters have assigned key values, namely precipitation and curve number. However, WMS also allows key values to be assigned to Manning's n values for the HEC-RAS model, and search radius for the Floodplain Delineation model.

3.1 Setting up the Model

1. Select *HEC-1* **| Stochastic Modeling…** to open the *Stochastic Run Parameters* dialog.

Either a Monte Carlo or Latin Hypercube approach can be selected to generating values for the stochastic model. This exercise will use the Monte Carlo approach. When using the Monte Carlo method, specify the number of simulations to run. With the Latin Hypercube approach, instead of specifying a number of simulations, enter a number of segments for each variable. The total number of simulations for a Latin Hypercube run is equal to the product of the number of segments for each variable. If there are three variables, with three segments each, then a Latin hypercube model will run 27 times. Also specify maximum, minimum, and starting values for each stochastic variable.

2. For the *Simulation type,* select the *Monte Carlo* option.
3. Set *Number of simulations* to "5".

Only specify five simulations for this exercise in the interest of time. Remember, though, that statistical studies indicate that in order for the generated values to resemble a normal distribution, one should run at least 30 simulations.

4. For *Selected model,* choose "HEC-1" from the drop-down list.
5. Turn on the *Define stochastic model* check box.
6. Under the *Filename parameters* section, select the **Browse** button next to *Base filename* to open the *Select the stochastic run base filename* dialog.
7. Browse to the same folder "hecrun1.prj" is located and enter "hecrun1" as the *File name*.
8. Select **Save** to close the *Select the stochastic run base filename* dialog.
9. If three variables are not already shown, select the **Add variable** button 3 times to add 3 variables to the table.
10. Refer to the table below and enter the values shown for each stochastic variable.

Used	Name	Key	Type	Start Value	Min Value	Max Value	Standard Deviation	Distribution
On	HEC1_1	-1	Precipitation	6.0	3.0	9.0	2.5	Normal
On	HEC1_2	-2	Curve Number	68.0	62.0	72.0	4.0	Normal
On	HEC1_3	-3	Curve Number	76.0	70.0	80.0	4.0	Normal

Now to turn on stochastic modeling for the HEC-RAS and Floodplain models:

11. Change the *Selected model* list box to “HEC-RAS”.
12. Turn on the *Define stochastic model* check box.
13. Select the **Browse** button next to *Base filename* to open the *Select the stochastic run base filename* dialog.
14. Browse to the folder in which the HEC-RAS project file (“hecrun1.prj”) is located and enter “hecrun1” as the *File name*.
15. Click **Save** to close the *Select the stochastic run base filename* dialog.
16. Change the *Selected model* list box to “Floodplain”.
17. Turn on the *Define stochastic model* check box.
18. Select the **Browse** button next to *Base filename* to open the *Select the stochastic run base filename* dialog.
19. Browse to the folder in which the HEC-RAS project file (“hecrun1.prj”) is located and enter “hecrun1” as the *File name*.
20. Select **Save** to close the *Select the stochastic run base filename* dialog.
21. Select **OK** to exit the *Stochastic Run Parameters* dialog.
22. Select *File* | **Save** to save the changes.

3.2 Running the Model

The last step in setting up the stochastic simulation is linking the output hydrographs (in this case it is a steady state simulation and so only the peak flow is used) from the HEC-1 model to the HEC-RAS input boundary condition for the appropriate rivers and reaches.

1. Select *HEC-1* | **Run Stochastic Model…** to open the *Model Steering* dialog.
2. For *Select a hydrograph,* select “2B Basin Hydrograph” from the drop-down.
3. For *Select a river*, choose “Leith River” from the drop-down.
4. For *Select a reach,* choose “Upper Branch” from the drop-down.
5. For *Select a cross section*, choose “2648.529” from the list.
6. Select the **Assign Peak Flow BC** button
7. Repeat steps 2–6 to link the hydrographs and cross sections shown in the table below:

Hydrograph	River	Reach	Cross section
3B	Left Fork	Branch	1703.086
5C	Leith River	Lower Branch	759.138
2C	Leith River	Lower Branch	72.889

Before using the stochastic model to run floodplain delineation over and over again, change some of the delineation options. To set these options:

8. At the bottom of *Model Steering,* select the **Floodplain Delineation Options…** button to open the *Floodplain Delineation* dialog.
9. Change the *Max search radius* to “1500”.
10. Make sure the *Quadrants* check box is turned on.

11. Enter “3” for the *Number of stages in a quadrant*.
12. Select **OK** to close the *Floodplain Delineation* dialog.
13. Select **OK** in the *Model Steering* dialog to open the *Stochastic HEC-1* dialog and run the stochastic simulations.

Progress for the simulations will be displayed in the *Stochastic HEC-1* dialog. The values selected for the CN and precipitation are shown for each run as well as the diagnostic information for the models. It is possible to abort prematurely by selecting the **Abort** button.

14. When the run has finished, click **Close** to exit the *Stochastic HEC-1* dialog.

4 Viewing the Results

All solutions (HEC-1 hydrographs, HEC-RAS river stages, and floodplain delineations) will read into WMS. Furthermore, at the completion of the stochastic run, WMS computes a dataset containing the probabilities that flooding will occur at various locations within the original TIN. This is computed by assigning to each vertex in the TIN a value whether it was flooded or not. At the completion of all runs, contours showing 0-100 percent probability of flooding can be viewed. 100% probability would mean that flooding occurred for the entire model, 50% probability would be flooding for half of the simulations, etc. To view the results:

1. Switch to the **Terrain Data Module** .
2. In the Project Explorer, under “ Terrain Data, right-click on “ New” and select **Display Options…** to open the *Display Options* dialog.
3. Select *TIN Data* and turn on the *TIN Contours* check box.
4. Select **OK** to close the *Display Options* dialog.
5. In the Project Explorer, select “ hecrun1_prob” in the “Terrain Data”.

By contouring this dataset, notice the probabilities of the floodplain arriving at different locations.

6. Now, select the dataset named “ hecrun1_depth”.

This dataset contains the average depths from all of the stochastic simulations.

5 Conclusion

This exercise demonstrates how to run a stochastic model within WMS. It showed the basics of setting up a stochastic model that will run the HEC-1, HEC-RAS, and Floodplain Delineation models simultaneously. This objective reviewed how to:

- Assign key values to parameters
- Define the Stochastic Model characteristics
- Run the Model
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