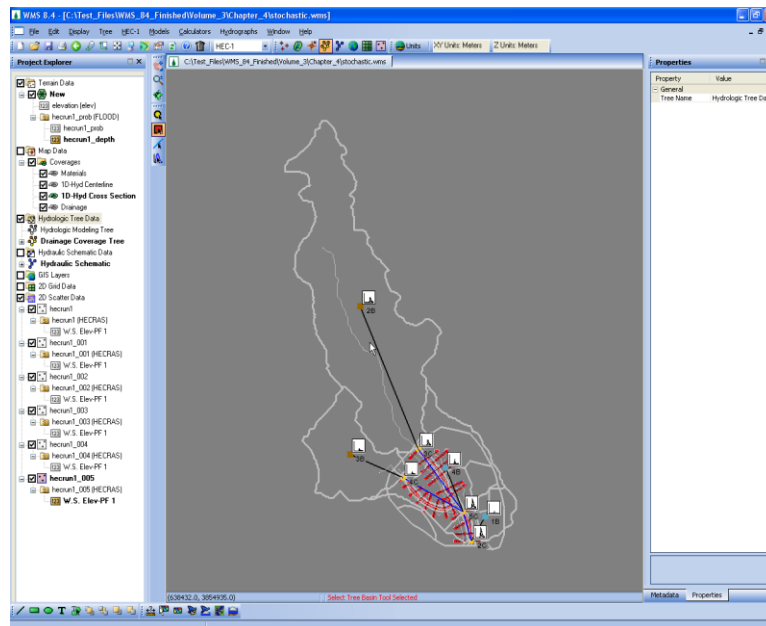*WMS 9.0 Tutorial*

Hydraulics and Floodplain Modeling – Stochastic Modeling Using HEC-1 and HEC-RAS

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

Objectives

This tutorial shows you how to setup and run a risk analysis that determines the probably of flooding at each point in your floodplain for a certain recurrence interval. This is called stochastic modeling, and you learn 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 your flood study area.

Prerequisite Tutorials
- Watershed Modeling – HEC-1 Interface
- Hydraulics and Floodplain Modeling – HEC-RAS Analysis
- Hydraulics and Floodplain Modeling – Floodplain Delineation
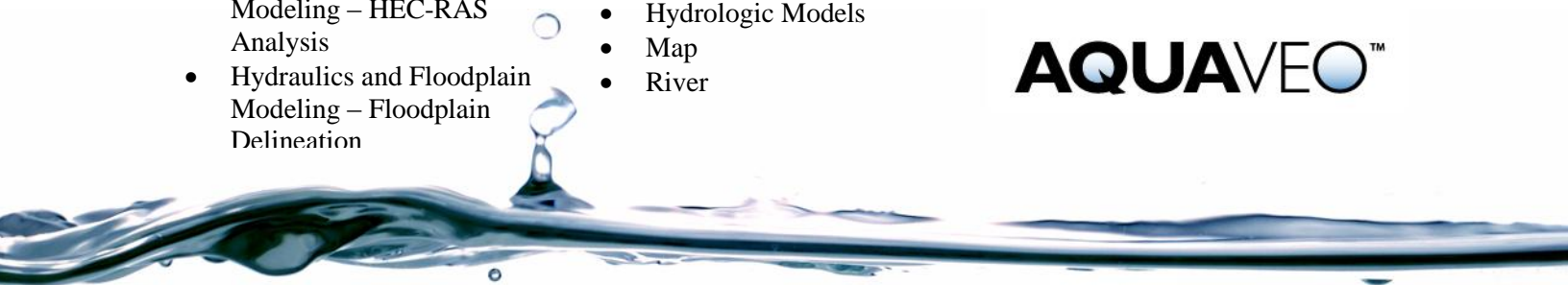
Required Components
- Data
- Drainage
- Hydrology
- Hydrologic Models
- Map
- River

Time
- 20-40 minutes

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1   Contents

2   Introduction

This exercise demonstrates how to run a stochastic model within WMS. 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. Users can specify a range of values to be used in the stochastic model.

3   Objectives

In this exercise, you will learn the basics of setting up a stochastic model that will run the HEC-1, HEC-RAS, and Floodplain Delineation models simultaneously. You will:

1. Assign key values to parameters

2. Define the Stochastic Model characteristics

3. Run the Model

4. View the solution means and probabilities

4   Opening the HEC-1 and HEC-RAS Models

Working HEC-1 and HEC-RAS models have been previously prepared for use in this exercise. We will use the stochastic modeling features of WMS to create a probabilistic map of floodplain boundaries. You may choose to review the development of these models in their separate exercises.

There is generally a high degree of uncertainty associated with hydrologic modeling parameters such as the SCS Curve Number and rainfall depth. Using WMS you 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. Close all instances of WMS

2. Open WMS

3. Select *File | Open* 📂

4. Locate the *stochastic* folder in your tutorial files. If you have used default installation settings in WMS, the tutorial files will be located in *\My documents\WMS 9.0\Tutorials\.*

5. Open *"run1.wms"*

This file is a WMS project file that references all of 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.

4.1   Preparing the HEC-RAS Model

To begin, we will zoom in on the HEC-RAS model domain.

⊞ ☐ 📁 Hydrologic Tree Data

1. Hide all basins and outlets by un-checking the box next to the Hydrologic Tree Data folder in the Project Explorer

2. Hide the coverage named Drainage by un-checking its visibility box in the Project Explorer

3. Select the *Frame* macro ⊹

4. Activate the 1D-Hyd Centerline coverage by single-clicking on its name in the Project Explorer

5. Select *River Tools* from the model list at the top of the screen

6. Select *River Tools | Map -> 1D Schematic*. This step initializes the HEC-RAS river scheme in preparation for reading in the HEC-RAS solution.

7. Switch to the *River* module 🪀

8. Select *HEC-RAS | Read Solution*

9. Open *"hecrun1.prj"*

When we read in a HEC-RAS project file 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, we need to interpolate more scatter points along both the center-line and cross section arcs.

10. Make sure the 1D-Hyd-Centerline coverage is active in the Project Explorer

11. Select *River Tools | Interpolate Water Surface Elevations*

12. Set the Create a data point field to *At a specified spacing*

13. Enter 60 for the Data point spacing

14. Select *OK*

15. Activate the 1D-Hyd Cross Section coverage from the Project Explorer

16. Select *River Tools | Interpolate Water Surface Elevations*

17. Select *OK*

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.

4.2   Preparing the HEC-1 Model

1. Show the Drainage coverage by checking its box in the Project Explorer

2. Show the contents of the Hydrologic Tree Data folder by toggling on its check box

3. Select the *Frame* macro

We will now assign key values to the parameters that we wish to randomly vary during the Stochastic run. Key values are negative integers that we assign 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. Choose the *Select Basin* tool

6. Multi-select the basins labeled 2B and 3B by holding the SHIFT key as you single-click on each basin icon

7. Select *HEC-1 | Edit Parameters*

8. Select the *Precipitation* button

9. Enter a value of -1 in the Average precipitation field

10. Select *OK*

11. Select the *Loss Method* button

12. Enter a value of -2 in the CRVNBR field

13. Select *OK*

14. Select *Done*

15. Multi-select the basins labeled 4B and 1B. You may need to hide the River Hydraulic Schematic in the River Data display options in order to see the basin icons.

16. Use the method shown in the previous steps to assign an Average precipitation value of -1 and a CRVNBR value of -3 to these basins

5   Running the Stochastic Model

For this exercise, we have assigned key values only to HEC-1 parameters, 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.

5.1   Setting up the Model

1. Select *HEC-1 | Stochastic Modeling*

Users can choose either a Monte Carlo or Latin Hypercube approach to generating values for the stochastic model. We will use the Monte Carlo approach for this exercise. When using the Monte Carlo method, we must specify the number of simulations that we want to run. With the Latin Hypercube approach, instead of specifying a number of simulations, we 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 we have 3 variables, with 3 segments each, then a Latin Hypercube model will run 27 times. Users also specify maximum, minimum, and starting values for each stochastic variable.

2. Select the *Monte Carlo* option for the Simulation type

3. Enter 5 for the Number of simulations

We 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. Choose *HEC-1* from the Selected model list box

5. Toggle on the *Define stochastic model* check box

6. Under the Filename parameters section, select the Base filename *Browse* button

7. Browse to the folder in which the HEC-RAS project file (*hecrun1.prj*) is located and enter "hecrun1" as the File name

8. Select *Save*

9. Select the *Add variable* button 3 times to add 3 variables to the table

10. Refer to Figure 5-1 and enter the values shown for each stochastic variable

	Used	Name	Key	Type	Sta...	Min ...	Ma...	Stand...	Distribution	Log
1	☑	HEC1_1	-1	Precipitat... ▼	6.0	3.0	9.0	2.5	Normal ▼	☐
2	☑	HEC1_2	-2	Curve Nu... ▼	68.0	62.0	72.0	4.0	Normal ▼	☐
3	☑	HEC1_3	-3	Curve Nu... ▼	76.0	70.0	80.0	4.0	Normal ▼	☐

Figure 5-1: Values for the Stochastic Variables table

Now, we will turn on stochastic modeling for the HEC-RAS and Floodplain models:

11. Change the Selected model list box to *HEC-RAS*

12. Toggle on the *Define stochastic model* check box

13. Select the Base filename *Browse* button and browse to the same path as *hecrun1.prj*

14. Enter "hecrun1" as the File name and select *Save*

15. Change the Selected model list box to *Floodplain*

16. Toggle on the *Define stochastic model* check box

17. Select the *Base filename* button and browse to the same path as *hecrun1.prj*

18. Enter hecrun1 as the File name and select *Save*

19. Select *OK* to exit the Stochastic Run Parameters dialog

20. Select *File | Save* 🖫 to save your changes

5.2   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**

2. Choose *2B Basin Hydrograph* from the Select a hydrograph combo box

3. Choose *Leith River* from the Select a river combo box

4. Choose *Upper Branch* from the Select a reach combo box

5. Choose *2648.529* from the Select a cross section list box

6. Select the *Assign Peak Flow BC* button

7. Repeat the previous steps to link the hydrographs and cross sections shown in Table 5-1:

Table 5-1: Assigning additional hydrographs to cross sections

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 we use the Stochastic Model to run Floodplain Delineation over and over again, we need to change some of the delineation options. To set these options:

8. Select the *Floodplain Delineation Options* button

9. Change the Max search radius to 1500

10. Make sure the *Quadrants* check box is toggled on

11. Enter 3 for the Number of stages in a quadrant

12. Select *OK*

13. Select *OK* to run the Stochastic simulations

Progress for the simulations will be displayed in the Stochastic dialog. You will be able to see the values selected for the CN and precipitation for each run as well as the

diagnostic information for the models. It is possible to abort prematurely by selecting the *Abort* button.

6   Viewing the Results

All solutions (HEC-1 hydrographs, HEC-RAS river stages, and Floodplain delineations) are 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 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.   Select *Close* to exit the Stochastic HEC-1 wrapper

2.   Switch to the *Terrain Data* module

3.   Right-click on *New* under *Terrain Data* and select ***Display Options***

4.   Select *TIN Data* and toggle on the *TIN Contours* check box

5.   Select *OK*

6.   Select the dataset named *hecrun1_prob* in the Terrain Data folder of the Project Explorer

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

7.   Now, select the dataset named *hecrun1_depth*

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