CE 462 - Open Channel Hydraulics

HEC-RAS tutorial: How to build a simple model

This tutorial is written based on the section "Steps in Developing a Hydraulic Model with HEC-RAS" in the HEC-RAS user manual.

1 Introduction

This tutorial uses HEC-RAS to simulate backwater curve in a single open channel. You will learn the following typical HEC-RAS modeling steps:

1. Data input for open channel: river reaches, junctions, hydraulic structures, cross-section shapes, Manning's n, flow discharge, boundary conditions, etc.
2. Perform simulations and diagnosis.
3. Analysis and result examination with different formats available in HEC-RAS, e.g., charts, tables, figures.

The tutorial case is for a simple river reach (River Spring Creek, Main Reach) discharges into a downstream outlet with a known water depth. The peak discharge into the upstream inlet has been calculated as 100 cfs, using other methodology for input into HEC-RAS, such as HEC-HMS. The reach is 1000 ft long with a slope of $S = 0.005$. Six river stations have been defined as in the following figures.

2 Model building steps

Follow these steps to develop a HEC-RAS model:

1. Open HEC-RAS. Double click the "HEC-RAS" shortcut on the desktop, or go to Windows Start, Programs, HEC, and click on the HEC-RAS icon.

   We will work with English unit system, which is the default of HEC-RAS. If you want to change to SI, you can do so through menu "Options" and then "Unit System".

2. Enter Project Information. Select File, New Project.
   Give it a meaningful project title.

3. Begin building model starting with "Geometric Data". Click on the "Geometric Data" button.

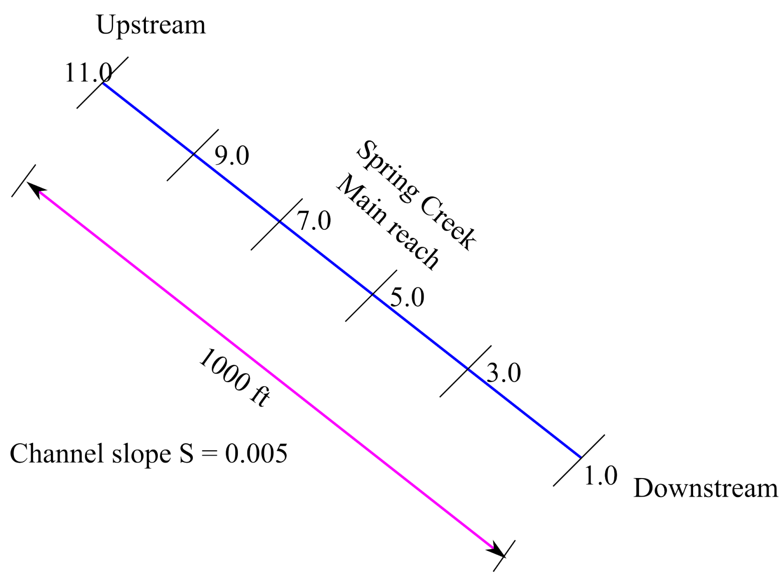

Figure 1: Layout of the Spring Creek and river stations

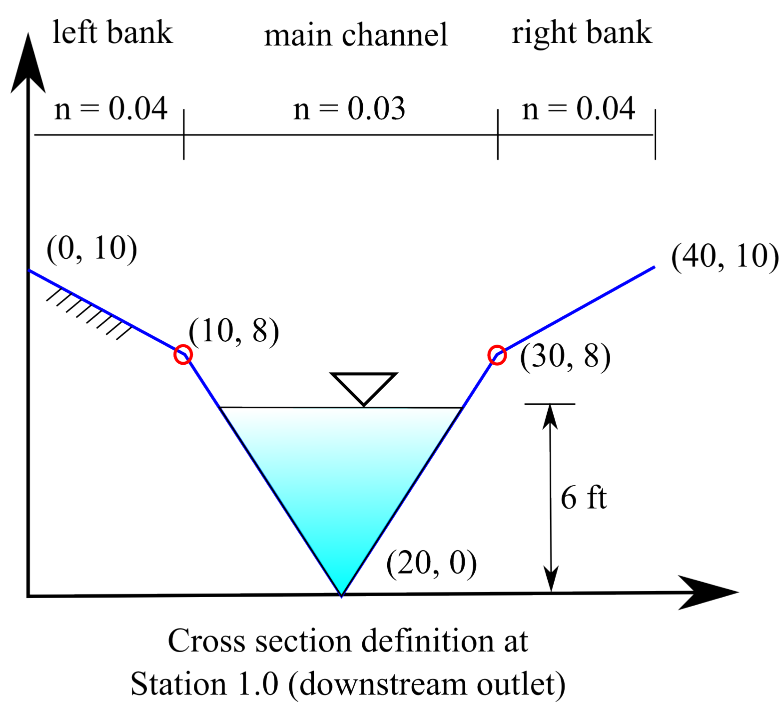

Figure 2: Cross section definition for downstream station 1.0. Other cross sections have the same shape but with different bottom elevation due to the river slope.

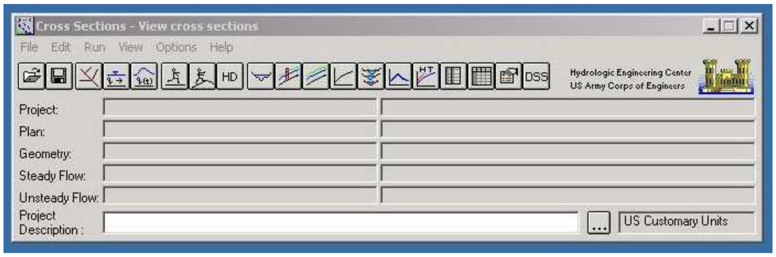

Figure 3: Main window of HEC-RAS

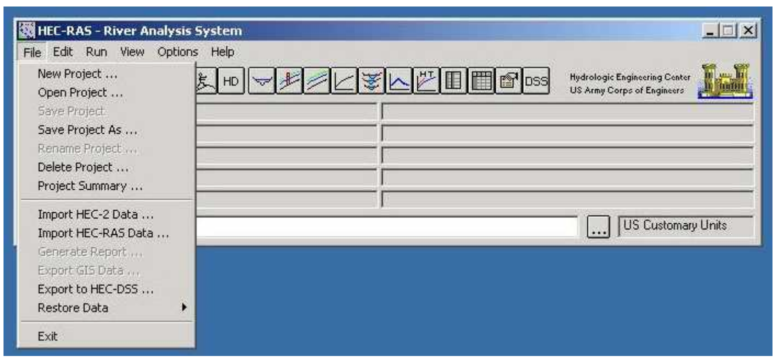

Figure 4: New project window of HEC-RAS

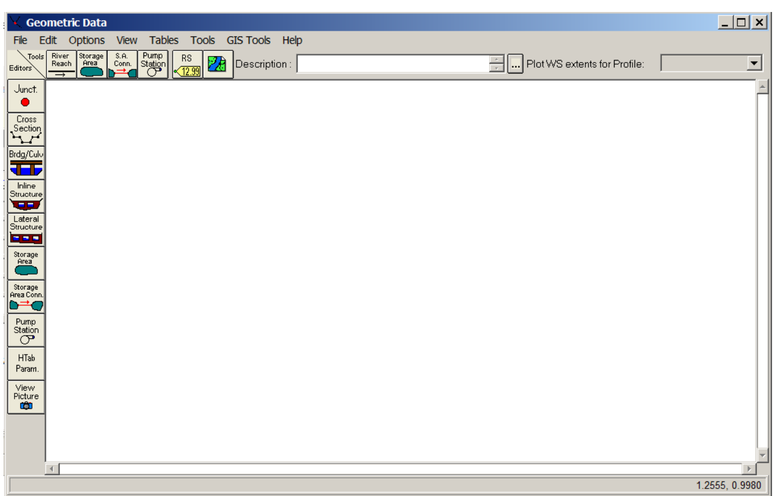

Figure 5: Geometric data window of HEC-RAS

4. Add Reaches and Cross Sections.
   Draw "Reach" by Selecting the Reach Button and then left click on the white space in the main window. Each click will add one point to the line which represents the river reach. The exact shape of the line does not matter since the HEC-RAS will not take into account the curvature of the river center line. However, the shape matters when you position the river in GIS if the coordinates are geo-referenced.

   In this simple case, we will just use two points to define a straight line. Click first point and move your cursor. Double click to add the second point and finish the line drawing. The order of the points you draw matters since HEC-RAS assume you draw from upstream to downstream. If you made mistake, delete the points that you don't want or just start over. "Deleting" and other editing operations can be accessed through menu "Edit".

   Notice the flow direction arrow after you input the "Reach" definition.

5. Enter River Name (Spring Creek) and Reach Name (main).

6. Add Cross Sections to Reach.
   Select Cross Section Button in the "Geometric Data Window" and select "Options" menu in the popup window, then "Add a new Cross Section".
   In the pop out dialog window, enter the river station number "1.0". Station number must be numerical value and increases upstream. For example, in our case, the downstream (outlet) station number is "1.0". The upstream station numbers are "3.0", "5.0", "7.0", "9.0", and finally "11.0" at the upstream inlet.

   Next, enter the cross section data:
   HEC-RAS uses the convention of defining left and right banks by facing downstream. So cross sections are defined by points from left bank to right bank looking downstream. So you should enter the cross section station in the left column and the elevation data in the right column.

   In our case, it is a composite triangular channel cross section defined by the following (Station, Elevation) pairs:

Station	Elevation
0	10
10	8
20	0
30	8
40	10

River station 1.0 is our downstream cross section and there is no other section further downstream. As such, the downstream distance should all be left blank. What happens here should be specified through boundary conditions which we will discuss later. For all other cross-sections, downstream reach length should be defined. In our simple case, the six cross sections (with five segments) are evenly distributed over the 1000 ft reach. So the downstream distance for other river stations is 200 ft.

You can click the "Apply Data" button during the data input process to update the plot on the right hand side. This plot will help you visualize and check the data.

Input the Manning's n value for left bank, main channel and right bank as 0.04, 0.03, 0.04.

One last thing is to define where the main channel is by specifying the "Left Bank" and "Right Bank" stations. In our case, they are 10 and 30, respectively. After input the station numbers, you can click the "Apply Data" button to see that the two stations are marked as red so you can check where the main channel starts and ends.

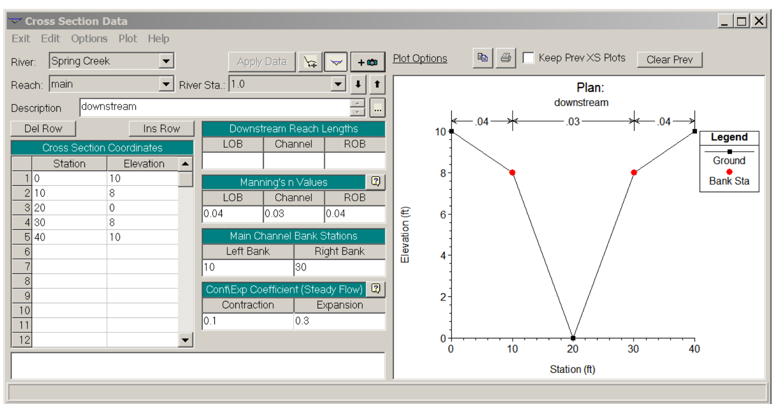

Figure 6: Definition of the downstream cross section at station 1.0

7. Repeat the previous step for other cross sections.
   You can add new or make a copy of existing ones. I found in this case, to make a copy is the easiest. To make a copy, click the "Options" menu and then "Copy Current Cross Section...". So make a copy and give it a numerical value (such as 3.0, 5.0, 7.0, etc.). Then you can adjust the elevation through "Options" and then "Adjust Elevations...". Each segment of the reach is 200 ft long. Given the slope $S = 0.005$, the elevation increases 1 ft each cross section upstream.

For each of the cross section, you also need to modify the downstream reach length as we have discussed (200 ft).

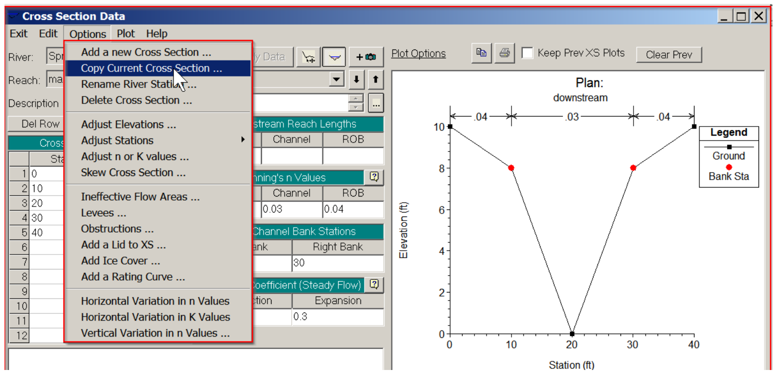

Figure 7: Items in the "Options" menu of the "Cross Section Data" window

8. When all cross sections have been defined, save you data through "File" and then "Save Geometric Data". In the popup window, give a meaningful name to the geometric data file, for example "backwater_geo". Then exit the "Geometric Data" window. You will find that in your project folder, there will be a new file named "backwater_geo.g01".

9. Next step is to specify the steady flow simulation data.
   Click "Edit" menu and then "Steady Flow Data".

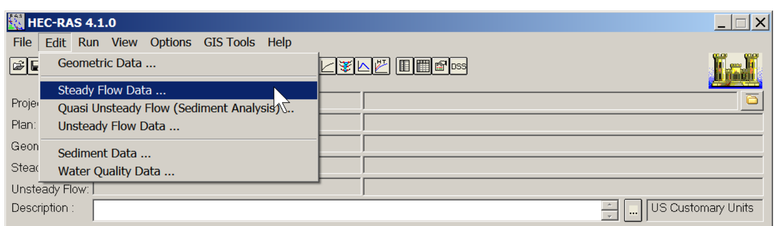

Figure 8: Steady state simulation menu

In the popup window, change the inflow at upstream river station 11.0 to 100 as shown in the figure below.

In the same window, click the "Reach Boundary Conditions" button. In the popup window, first click the "Downstream" cell in the table to make the cursor focused on it. Then click "Known W.S." button. You should be able to specify the known water surface elevation as 6 ft.

In HEC-RAS (as well as open channel hydraulics in general), most downstream boundary conditions are

- Known water surface elevation.

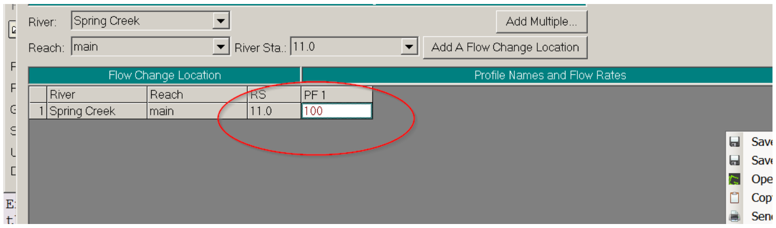

Figure 9: Specification of in flow discharge $Q = 100$ cfs at upstream river station 11.0

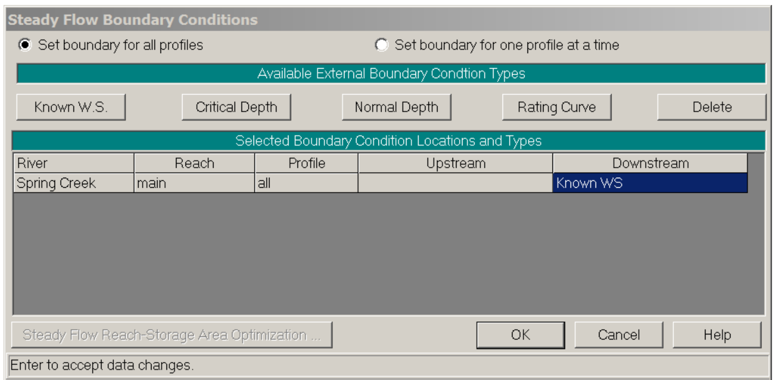

Figure 10: Specification of known water surface elevation at downstream river station 1.0

- Critical depth, determined by size of channel. This happens if the downstream is a free overfall.
- Normal depth defined by channel shape, slope, Manning's n and flow. This can be used if the downstream is far from any disturbance.
- Rating curve (user defined).

10. Save the flow data by clicking menu "File", then "Save Flow Data". Give the flow data file a meaningful name. Then exit the "Steady Flow Data" window. There will be a new file with an extension "f01". It is a good habit to save your data often.
11. Now we can simulate the case. Click menu "Run" and then "Steady Flow Analysis ...". We know the flow is in the subcritical flow regime (how? by estimating the Froude number) so just leave it as the default. click "Compute". If the run is successful, HEC-RAS will report so. Otherwise, read the error message it provides.
12. Exit the steady flow analysis window.
13. Now we have the results and it is time to see them. HEC-RAS provides multiple ways to inspect the results, both graphically and in text/table.

    Graphically, you can examine the result on cross sections, generate water surface profiles, even plot the result in 3D. However, remember HEC-RAS is a 1D hydraulics modeling program. The 3D perspective view of the result is constructed using cross section shapes. The graphical representation of the result can be accessed through the corresponding buttons in the main window. The following are some examples. If you want to write a report and include these nice figures, you can use menu "File" and then "Copy plot to clipboard". Or simply do a screen capture through Windows (Print Screen key).

Look at the water surface profile plot. This should be a M1 curve as we expected. You can check this with the knowledge you learned from this course. Remember we did a similar homework on backwater curve calculations. That was for a simple wide rectangular channel. Here we have a slightly complicated cross section shape.

HEC-RAS also provides tables and text output for the simulation result. You should explore those too.

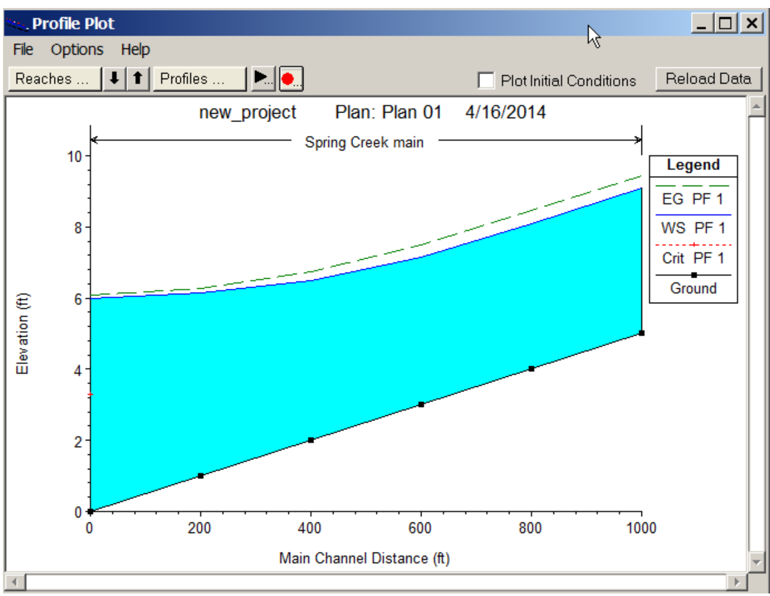

Figure 11: Water surface profile in the reach

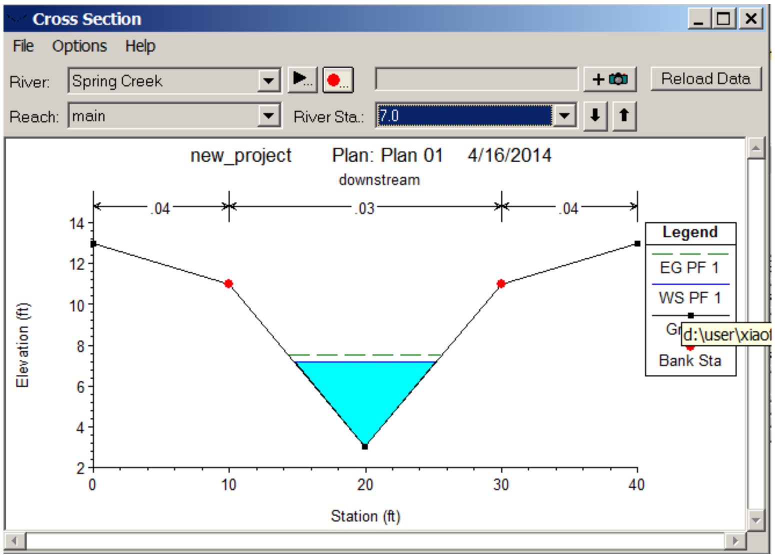

Figure 12: Result for each cross section

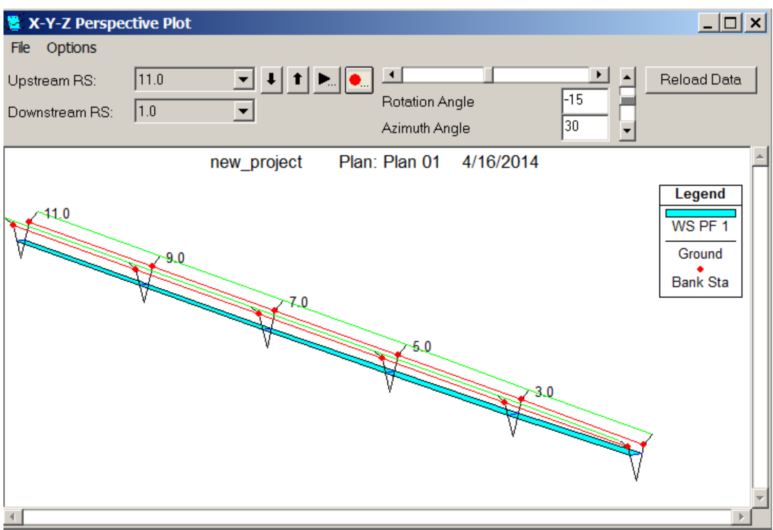

Figure 13: 3D result for the reach