CHAPTER 10

Performing a Floodplain Encroachment Analysis

The evaluation of the impact of floodplain encroachments on water surface profiles can be of substantial interest to planners, land developers, and engineers. Floodplain and floodway evaluations are the basis for floodplain management programs. Most of the studies are conducted under the National Flood Insurance Program and follow the procedures in the "Flood Insurance Study Guidelines and Specifications for Study Contractors," FEMA 37 (Federal Emergency Management Agency, 11085).

FEMA 37 defines a floodway "...as the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water-surface elevation by more than a designated height." Normally, the base flood is the one-percent chance event (100-year recurrence interval), and the designated height is one foot, unless the state has established a more stringent regulation for maximum rise. The floodway is usually determined by an encroachment analysis, using an equal loss of conveyance on opposite sides of the stream. For purposes of floodway analysis, the floodplain fringe removed by the encroachments is assumed to be completely blocked.

HEC-RAS contains five optional methods for specifying floodplain encroachments. For information on the computational details of each of the five encroachment methods, as well as special considerations for encroachments at bridges, culverts, and multiple openings, see Chapter 10 of the HEC-RAS hydraulics reference manual. This chapter describes how to enter floodplain encroachment data, how to perform the encroachment calculations, viewing the floodplain encroachment results, and how to perform a floodplain encroachment analysis within the unsteady flow computations module.

Contents

General

The HEC-RAS floodplain encroachment procedure is based on calculating a natural profile (existing conditions geometry) as the first profile in a multiple profile run. Other profiles, in a run, are calculated using various encroachment options, as desired. Before performing an encroachment analysis, the user should have developed a model of the existing river system. This model should be calibrated to the fullest extent that is possible. Verification that the model is adequately modeling the river system is an extremely important step before attempting to perform an encroachment analysis.

Currently, the HEC-RAS steady flow program has 5 methods to determine floodplain encroachments. These methods are:

Method 1 -	User enters right and left encroachment stations
Method 2 -	User enters fixed top width
Method 3 -	User specifies the percent reduction in conveyance
Method 4 -	User specifies a target water surface increase
Method 5 -	User specifies a target water surface increase and maximum change in energy

For unsteady flow analysis, only method one has been implemented so far in HEC-RAS. For a detailed discussion on each of these methods, the user is referred to Chapter 10 of the **Hydraulic Reference Manual**.

The goal of performing a floodplain encroachment analysis is to determine the limits of encroachment that will cause a specified change in water surface elevation. To determine the change in water surface elevation, the program must first determine a natural profile with no encroachments. This base profile is typically computed using the one percent chance discharge. The computed profile will define the floodplain, as shown in Figure 10.1. Then, by using one of the 5 encroachment methods, the floodplain will be divided into two zones: the floodway fringe and the floodway. The floodway fringe is the area blocked by the encroachment. The floodway is the remaining portion of the floodplain in which the one-percent chance event must flow without raising the water surface more than the target amount.

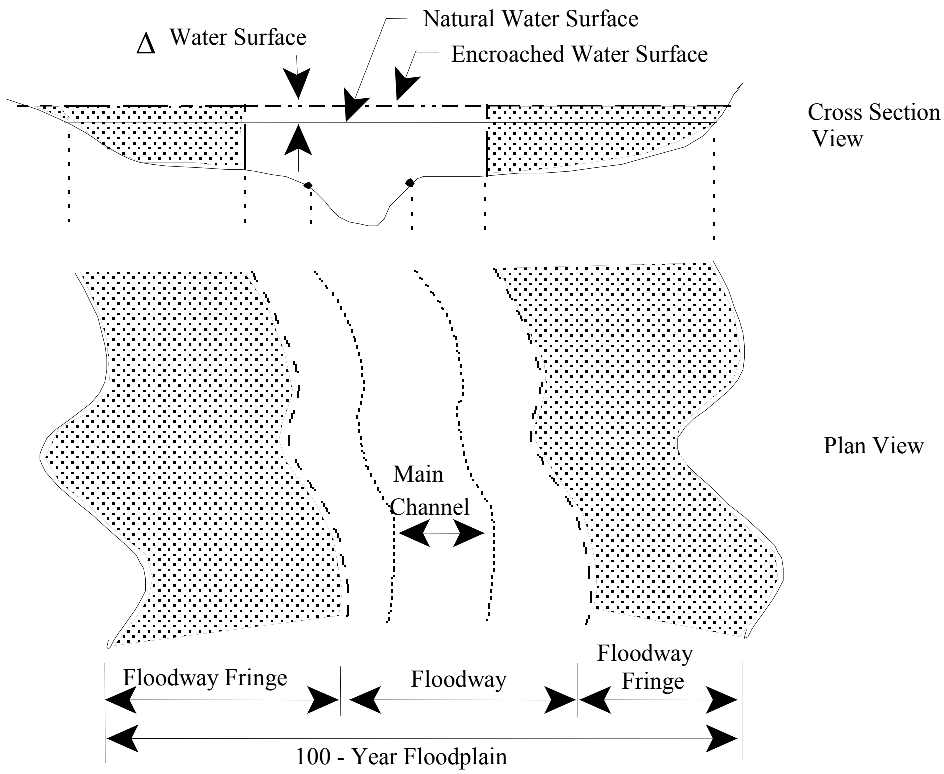

Figure 10.1 Floodway Definition Sketch

Entering Floodplain Encroachment Data

Within HEC-RAS, the data for performing a steady flow floodplain encroachment analysis are entered from the Steady Flow Analysis window. Encroachment information is not considered as permanent geometry or flow data, and is therefore not entered as such. The encroachment information is saved as part of the existing Plan data.

To bring up the floodplain encroachment data window, select the **Encroachments** option from the **Options** menu of the Steady Flow Analysis window. When this option is selected an Encroachment window will appear as shown in Figure 10.2 (except yours will be blank when you first open it).

As shown in Figure 10.2, there are several pieces of data that the user must supply for an encroachment analysis. The encroachment analysis can only be performed for profiles 2 through 15 (or what ever number has been set by the user in the flow data editor). Encroachments are not performed on profile one because most of the encroachment methods rely on having a base profile for comparison.

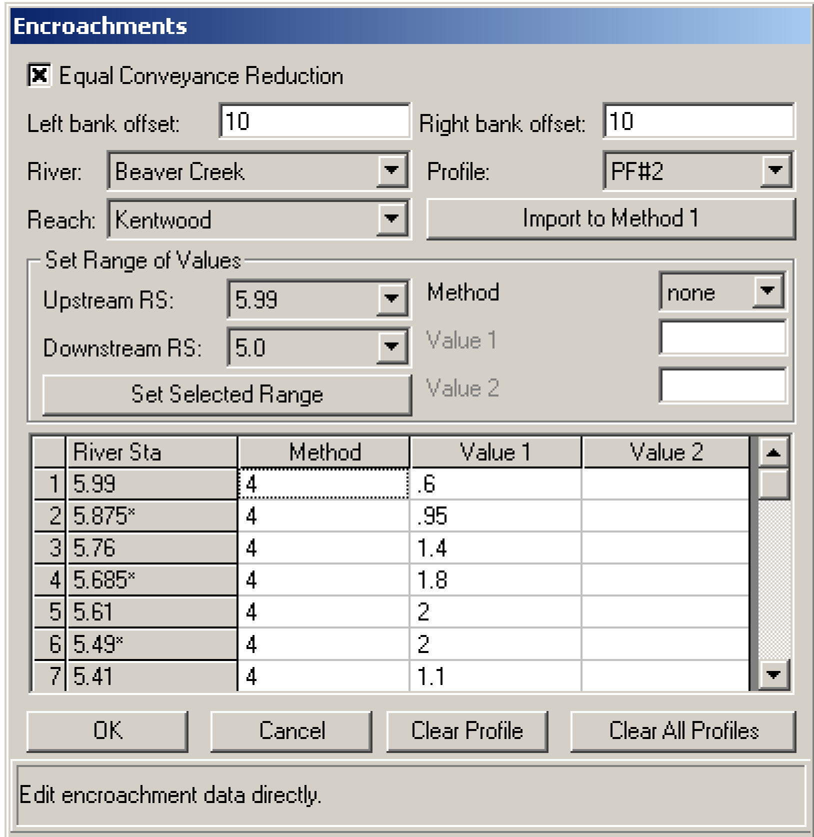

Figure 10.2 Floodplain Encroachment Data Editor

The data for an encroachment analysis should be entered in the following manner:

Global Information. Global information is data that will be applied at every cross section for every profile computed. The first piece of global information is the **Equal Conveyance Reduction** selection box at the top of the Encroachment data editor window. Equal conveyance reduction applies to encroachment methods 3, 4, and 5. When this is turned on, the program will attempt to encroach, such that an equal loss of conveyance is provided on both sides of the stream. If this option is turned off, the program will encroach by trying to maintain a loss in conveyance in proportion to the distribution of natural overbank conveyance. The default is to have equal conveyance reduction turned on.

The second item under global information is the **Left bank offset** and the **Right bank offset**. The left and right offsets are used to establish a buffer zone around the main channel for further limiting the amount of the encroachments. For example, if a user established a right offset of 5 feet and a left offset of 10 feet, the model will limit all encroachments to 5 feet from the right bank station and 10 feet from the left bank station. The default is to have no right or left offset, this will allow the encroachments to go up to the main channel bank stations, if necessary.

River, Reach and River Station Selection Boxes. The next piece of data for the user to select is the river and reach in which to enter encroachment data. The user is limited to seeing one reach at a time on the encroachment data editor. Once a reach is selected, the user can then enter a **Starting and Ending River Station** to work on. By default, the program selects all the sections in the reach. The user can change this to any range of cross sections within the reach.

Profile. Next, the user should select a profile number to work on. Profiles are limited to 2 through the maximum number set in the currently opened flow data (e.g., 2 through 4, if the user has set 4 profiles in the flow data editor). The user can not set encroachments for profile 1.

Method and Target Values. The next step is to enter the desired encroachment method to be used for the currently selected profile. Once a method is selected, the data entry boxes that corresponds to that method will show up below the method selection box. Some of the methods require only one piece of data, while others require two. The user should then enter the required information that corresponds to the method that they have selected. For example, if the user selects encroachment method 4, only one piece of information is required, the target change in water surface elevation. The available encroachment methods in HEC-RAS are:

Method 1 - User enters right and left encroachment station
Method 2 - User enters a fixed top width
Method 3 - User specifies the percent reduction in conveyance
Method 4 - User specifies a target water surface increase
Method 5 - User specifies target water surface increase and maximum change in energy

Set Selected Range. Once the encroachment method is selected, and its corresponding data are entered, the user should press the **Set Selected Range** button. Pressing this button will fill in the table below with the selected range of river stations; the selected method; and the corresponding data for the method. Note that, if the selected method only has one data item, that method's data will go under the **Value 1** column of the table. If the selected method has two data items, the first goes into the **Value 1** column and the second goes into the **Value 2** column. Once the data is put into the table, the user can change the method and corresponding data values directly from the table.

At this point the user should repeat these tasks until all of the encroachment data are entered (i.e., for all the reaches and locations in the model, as well as all of the profiles for which the user wants to perform the encroachment analysis). Once all of the encroachment data are entered, the user presses the **OK** button and the data will be applied and the window will close. The user can return to the encroachment window and edit the data at any time. The encroachment data are not saved to the hard disk at this time, they are only saved in memory. To save the data to the hard disk, the user should either select **Save Project** from the File menu of the main HEC-RAS window, or select **Save Plan** from the File menu of the Steady Flow Analysis window.

The **Import Method 1** option, allows the user to transfer the computed encroachment stations from a previous run (output file) to the input data for a future run. For example, if the user performs a preliminary encroachment analysis using any of the methods 2 through 5, they may want to convert the results from one of the runs to a method 1 encroachment method. This will allow the user to further define the floodway, using method 1, without having to enter all of the encroachment stations. The import of encroachment stations, in this manner, is limited to the results of a single encroachment profile for each reach.

Performing The Floodplain Encroachment Analysis

The HEC-RAS floodway procedure is based on calculating a natural profile (no encroachments) as the first profile of a multiple profile run. Subsequent profiles are calculated with the various encroachment options available in the program.

In general, when performing a floodway analysis, encroachment methods 4 and 5 are normally used to get a first cut at the encroachment stations. Recognizing that the initial floodway computations may provide changes in water surface elevations greater, or less, than the "target" increase, initial computer runs are usually made with several "target" values. The initial computer results should then be analyzed for increases in water surface elevations, changes in velocities, changes in top width, and other parameters. Also, plotting the results with the X-Y-Z perspective plot, or onto a topo map, is recommended. From these initial results, new estimates can be made and tested.

After a few initial runs, the encroachment stations should become more defined. Because portions of several computed profiles may be used, the final computer runs are usually made with encroachment Method 1 defining the specific encroachment stations at each cross section. Additional runs are often made with Method 1, allowing the user to adjust encroachment stations at specific cross sections to further define the floodway.

While the floodway analysis generally focuses on the change in water surface elevation, it is important to remember that the floodway must be consistent with local development plans and provide reasonable hydraulic transitions through the study reach. Sometimes the computed floodway solution, that provides computed water surfaces at or near the target maximum, may be unreasonable when transferred to the map of the actual study reach. If this occurs, the user may need to change some of the encroachment stations, based on the visual inspection of the topo map. The floodway computations should be re-run with the new encroachment stations to ensure that the target maximum is not exceeded.

Viewing the Floodplain Encroachment Results

Floodplain encroachment results can be viewed in both graphical and tabular modes. Graphically, the encroachment results show up on the cross section plots as well as the X-Y-Z Perspective plot. An example cross-section plot is shown in Figure 10.3.

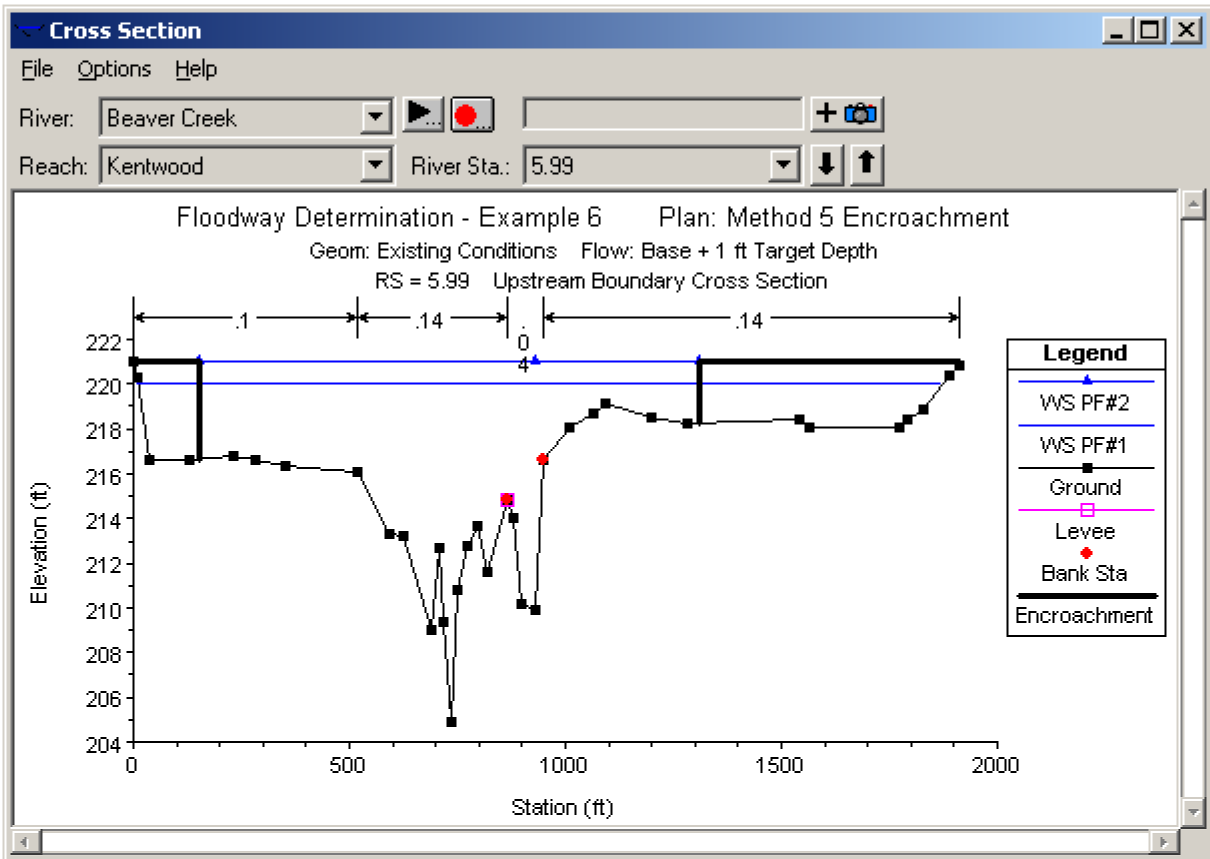

Figure 10.3 Example Cross Section Plot With Encroachments

As shown in Figure 10.3, the encroachments are plotted as outlined blocks. In this example, the water surface profile for the base run (first profile) is plotted along with one of the encroached profiles. The user can plot as many profiles as they wish, but it may become a little confusing with several sets of encroachments plotted at they same time.

Another type of graphic that can be used to view the encroachments is the X-Y-Z perspective plot, an example is shown in Figure 10.4. In this example, the base profile (profile 1) as well as one of the encroached profiles is plotted at the same time over a range of cross sections. This type of plot allows the user to get a reach view of the floodplain encroachment. The user can quickly see if the encroachments transition smoothly or if they are erratic. In general, the final encroachments should have a consistent and smooth transition from one cross section to the next. With the assistance of this type of plot, the user may want to further refine the final encroachment stations and re-run the model.

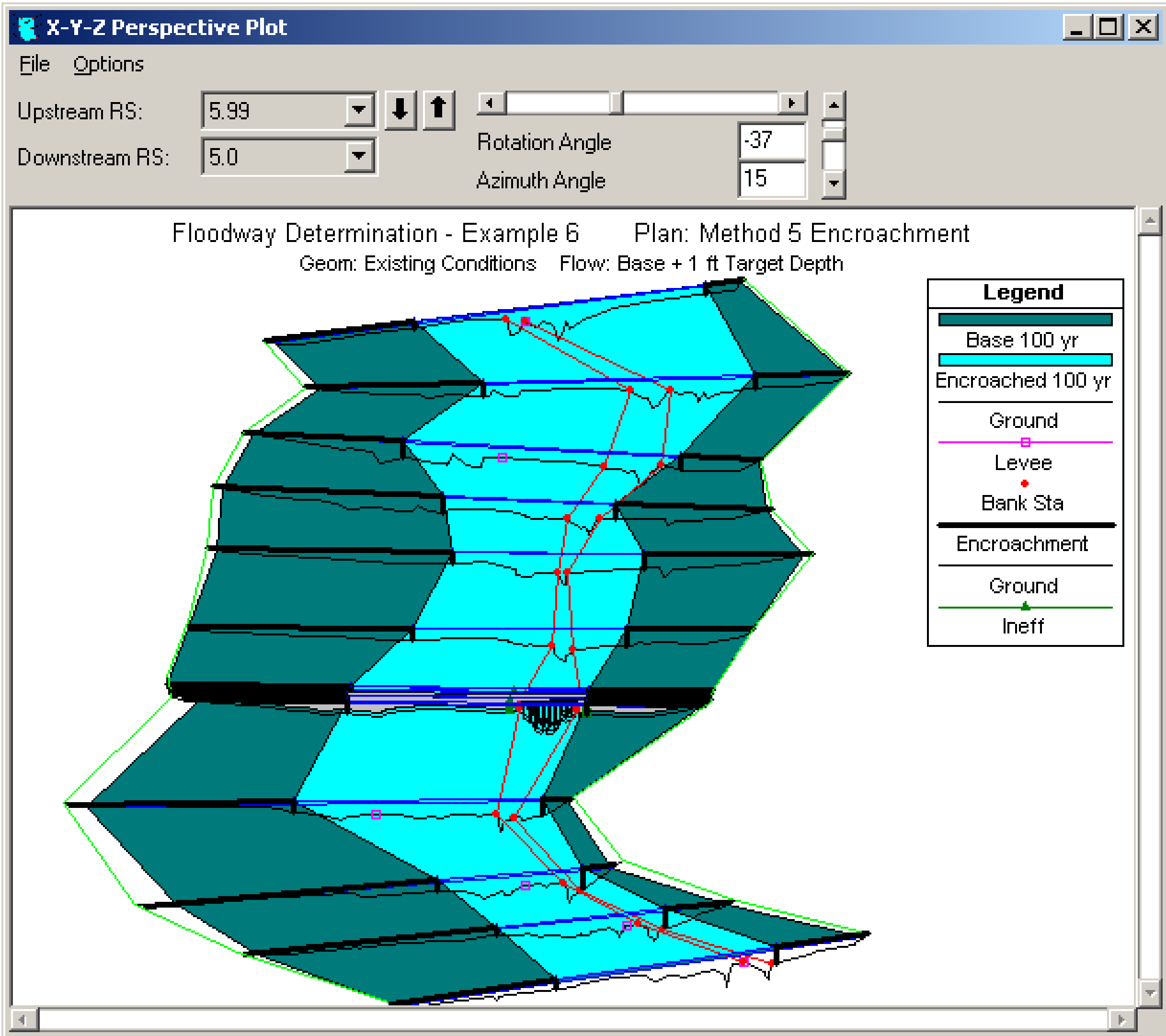

Figure 10.4 Example X-Y-Z Perspective Plot with Base and Encroached Profiles

Encroachment results can also be viewed in a tabular mode from the Profile Output Tables. Select **Profile Table** from the **View** menu of the main HEC-RAS window. When the table comes up, the user can select from three different pre-defined encroachment tables. To bring up one of the encroachment tables, select **Encroachment 1** from the **Std. Tables** menu on the Profile table window. An example of Encroachment 1 table is shown in Figure 10.5. The table shows the basic encroachment results of: computed water surface elevation; change in water surface from the base profile; the computed energy; top width of the active flow area; the flow in the left overbank, main channel, and right overbank; the left encroachment station; the station of the left bank of the main channel; the station of the right bank of the main channel; and the right encroachment station.

Profile Output Table - Encroachment 1

File Options Std. Tables Help

HEC-RAS Plan: M5 River: Beaver Creek Reach: Kentwood | Reload Data

Reach	River Sta	W.S. Elev	Prof Delta WS	E.G. Elev	Top Wdth Act	Q Left	Q Channel	Q Right	Enc Sta L	Ch Sta L	Ch Sta R
		(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)
Kentwood	5.4 BR U	217.44		217.68	1847.04	849.46	10817.92	2376.36		450.00	647.00
Kentwood	5.4 BR U	217.39	-0.04	217.79	807.60	65.95	12136.13	1797.88	420.85	450.00	647.00
Kentwood	5.4 BR D	217.44		217.68	1824.00	858.86	10867.73	2317.15		450.00	647.00
Kentwood	5.4 BR D	217.39	-0.04	217.79	807.60	67.29	12148.29	1784.38	420.85	450.00	647.00
Kentwood	5.39	215.61		216.04	1702.76	1073.43	10253.83	2672.74		450.00	647.00
Kentwood	5.39	216.35	0.73	216.86	807.60	113.48	11602.49	2284.04	420.85	450.00	647.00
Kentwood	5.24*	214.63		214.77	1633.15	2336.07	2507.27	9156.67		200.30	257.00
Kentwood	5.24*	215.63	0.99	215.75	845.19	1922.36	2527.11	9550.53	101.99	200.30	257.00
Kentwood	5.13	213.33		213.76	1425.37	1102.78	4954.85	7942.37		155.00	213.00
Kentwood	5.13	214.34	1.01	214.92	535.14	212.93	5788.66	7998.41	145.00	155.00	213.00
Kentwood	5.065*	212.55		212.89	1782.32	1624.48	5352.58	7022.95		274.50	365.50
Kentwood	5.065*	213.54	0.99	214.03	642.15	167.70	6493.35	7338.95	264.50	274.50	365.50
Kentwood	5.0	211.80		212.05	1925.36	2217.73	5187.01	6595.27		394.00	518.00
Kentwood	5.0	212.80	1.00	213.18	912.57	127.69	6544.90	7327.41	384.00	394.00	518.00

Difference in WS between current profile and WS for first profile.

Figure 10.5 Example of the Encroachment 1 Standard Table

Encroachment 2 table provides some additional information that is often used when plotting the encroachments onto a map. This table includes: the change in water surface elevations from the first profile; the top width of the active flow area; the percentage of conveyance reduction in the left overbank; the left encroachment station; the distance from the center of the main channel to the left encroachment station; the station of the center of the main channel; the distance from the center of the main channel to the right encroachment station; the right encroachment station; and the percentage of conveyance reduction in the right overbank. An example of the Encroachment 2 standard table is shown in Figure 10.6.

Profile Output Table - Encroachment 2

File Options Std. Tables Help

HEC-RAS Plan: Method 1 River: Beaver Creek Reach: Kentwood | Reload Data

Reach	River Sta	Prof Delta WS (ft)	Top Wdth Act (ft)	K Perc L	Enc Sta L (ft)	Dist Center L (ft)	Center Station (ft)	Dist Center R (ft)	Enc Sta R (ft)	K Perc R	Encr WD (ft)
Kentwood	5.99		1862.66				907.00				
Kentwood	5.99	1.00	885.42	8.96	233.00	674.00	907.00	211.42	1118.42	10.01	885.42
Kentwood	5.875*		1797.64				678.25				
Kentwood	5.875*	0.98	928.58	12.53	327.07	351.18	678.25	577.40	1255.65	12.56	928.58
Kentwood	5.76		1765.50				449.50				
Kentwood	5.76	0.86	847.98	13.62	341.00	108.50	449.50	739.48	1188.98	14.84	847.98
Kentwood	5.685*		1873.52				647.25				
Kentwood	5.685*	0.72	789.38	17.40	464.82	182.43	647.25	606.95	1254.20	16.00	789.38
Kentwood	5.61		1989.05				845.00				
Kentwood	5.61	0.62	707.62	20.61	609.60	235.40	845.00	472.22	1317.22	16.20	707.62
Kentwood	5.49*		1910.09				647.00				
Kentwood	5.49*	0.43	752.77	20.64	477.33	169.67	647.00	583.10	1230.10	15.40	752.77
Kentwood	5.41		1847.04				548.50				
Kentwood	5.41	0.11	617.70		440.00	108.50	548.50	509.20	1057.70		617.70
Kentwood	5.4 BR U		1847.04				548.50				
Kentwood	5.4 BR U	0.11	617.70		440.00	108.50	548.50	509.20	1057.70		617.70

Figure 10.6 Example of the Encroachment 2 Standard Table

The last encroachment table, Encroachment 3, provides the minimum floodway data for reporting. This table includes: the active flow top width; the flow area (including any ineffective flow area); the average velocity of the entire cross section; the computed water surface elevation; the base water surface elevation (profile 1); and the change in water surface from the first profile. An example of this table is shown in Figure 10.7

Profile Output Table - Encroachment 3

File Options Std. Tables Help

HEC-RAS Plan: Method 1 River: Beaver Creek Reach: Kentwood Reload Data

Reach	River Sta	Top Wdth Act (ft)	Area (sq ft)	Vel Total (ft/s)	W.S. Elev (ft)	Base WS (ft)	Prof Delta WS (ft)
Kentwood	5.99	1862.66	6609.02	2.12	220.00	220.00	
Kentwood	5.99	885.42	5564.08	2.52	221.00	220.00	1.00
Kentwood	5.875*	1797.64	7068.82	1.98	218.99	218.99	
Kentwood	5.875*	928.58	5276.75	2.65	219.97	218.99	0.98
Kentwood	5.76	1765.50	9092.73	1.54	218.46	218.46	
Kentwood	5.76	847.98	5913.15	2.37	219.32	218.46	0.86
Kentwood	5.685*	1873.52	9248.86	1.51	218.23	218.23	
Kentwood	5.685*	789.38	5530.05	2.53	218.95	218.23	0.72
Kentwood	5.61	1989.05	9499.42	1.47	218.09	218.09	
Kentwood	5.61	707.62	5352.12	2.62	218.71	218.09	0.62
Kentwood	5.49*	1910.09	9447.83	1.48	217.91	217.91	
Kentwood	5.49*	752.77	5179.35	2.70	218.34	217.91	0.43
Kentwood	5.41	1847.04	8985.57	1.56	217.44	217.44	
Kentwood	5.41	617.70	4043.15	3.46	217.54	217.44	0.11
Kentwood	5.4 BR U	1847.04	2533.60	5.53	217.44	217.44	
Kentwood	5.4 BR U	617.70	1979.08	7.07	217.54	217.44	0.11
Kentwood	5.4 BR D	1824.00	2522.19	5.55	217.44	217.44	
Kentwood	5.4 BR D	617.70	1979.08	7.07	217.54	217.44	0.11

Top width of the wetted cross section, not including ineffective flow.

Figure 10.7 Example of the Encroachment 3 Standard Table

Floodway Encroachments With Unsteady Flow

Encroachment analyses can also be performed with the unsteady flow computations module within HEC-RAS. However, only method one (user placed encroachments) has been added to the unsteady flow computations. A suggested methodology for performing an encroachment analysis with an unsteady flow model is the following:

1. First, develop the unsteady flow model of the river system and calibrate it to the extent possible.

2. Develop an unsteady flow plan of the 100 yr event in order to establish the base floodplain.

3. Develop a steady flow plan that incorporates the peak flows from the unsteady flow run as the 100 yr event for the model. Set up the model for two profiles with the same flows.

4. Perform a steady flow encroachment analysis using the available steady flow encroachment methods to calculate an approximate floodway.

5. Copy the unsteady flow plan to a new plan (using the Save As option), and give it a name that represents the encroached plan.

6. Adjust the boundary conditions file to reflect an increased water surface elevation at the downstream boundary for the range of possible flows. If using a rating curve, you will need to develop a new rating to reflect the encroached condition at the downstream boundary. If you are using normal depth or critical depth, no change is necessary, since the program will calculate a new water surface with the encroachments.

7. Go to the **Options** menu of the unsteady flow analysis window and select **Unsteady Encroachments**. This will bring up the Unsteady flow Encroachment editor shown in Figure 10.8.

8. Import the final encroachments from the steady flow encroachment run in to the unsteady flow encroachment editor. This is accomplished by pressing the button labeled "**Get Encroachments From Steady Flow Plan**", and then selecting the appropriate plan and profile number from the steady flow encroachment analysis.

9. Run the unsteady flow model with the encroachments and compare the output of the encroached unsteady flow plan with the output from the base unsteady flow plan.

10. Adjust the encroachments as necessary to stay within the limits for increased water surface elevations. Re-run the unsteady flow model. Repeat this process until a final floodway is achieved.

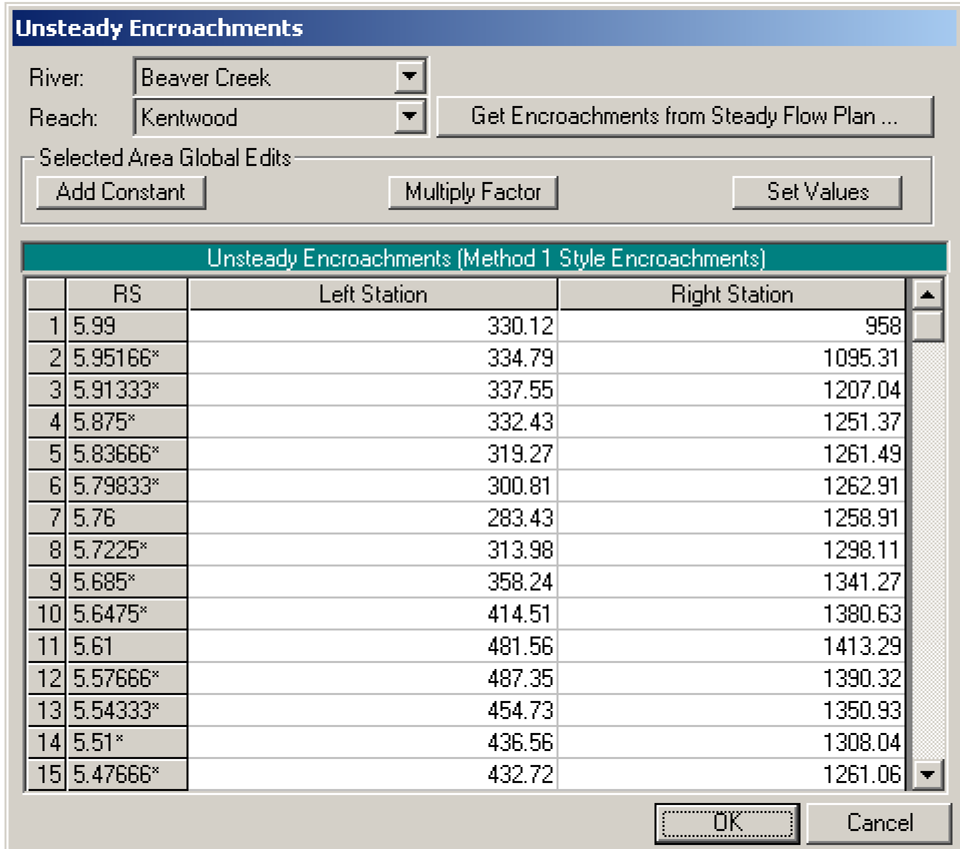

Figure 10.8 Unsteady Flow Encroachment Editor.