HEC-RAS Introduction

Shirley Clark
Penn State – Harrisburg

Robert Pitt
University of Alabama

April 26, 2004

Linear Routing: Floodrouting

- Two (2) types of floodrouting of a hydrograph
  - Linear – Muskingum
  - Reservoir – Storage-Indication / Modified Puls
- Hydrograph (Flow versus Time).
  - Floodrouting – input of the inflow hydrograph into a “Wedge” (Linear) or a “Pond” (Reservoir). The outflow hydrograph will be “dampened” such that the outflow hydrograph’s peak will be less and delayed.

Uniform Open Channel Flow

Manning’s Eqn for velocity or flow

$$v = \frac{1}{n} R^{2/3} \sqrt{S} \quad \text{S.I. units}$$

$$v = \frac{1.49}{n} R^{2/3} \sqrt{S} \quad \text{English units}$$

where

n **= Manning’s roughness coefficient**
R **= hydraulic radius =** ***A/P***
S **= channel slope**
Q **= flow rate (cfs) =** ***v A***

Uniform Open Channel Flow – Brays B.

Brays Bayou

Concrete Channel

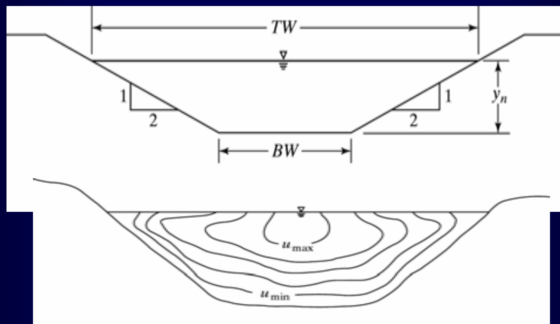


Figure 7.5

Typical velocity distribution in an open channel.

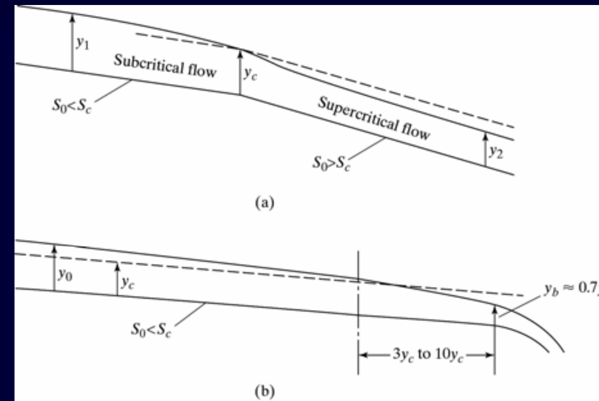


Figure 7.4

Occurrence of critical depth. (a) Change in flow from subcritical to supercritical at a break in slope. (b) Free outfall. Mild slope.

SHAPE	SECTION	OPTIMUM GEOMETRY	NORMAL DEPTH y_n	CROSS-SECTIONAL AREA A
Trapezoidal		$\alpha = 60°$ $b = \frac{2}{\sqrt{3}} y_n$	$0.968\left[\frac{Qn}{S_b^{1/2}}\right]^{3/8}$	$1.622\left[\frac{Qn}{S_b^{1/2}}\right]^{3/4}$
Rectangular		$b = 2y_n$	$0.917\left[\frac{Qn}{S_b^{1/2}}\right]^{3/8}$	$1.682\left[\frac{Qn}{S_b^{1/2}}\right]^{3/4}$
Triangular		$\alpha = 45°$	$1.297\left[\frac{Qn}{S_b^{1/2}}\right]^{3/8}$	$1.682\left[\frac{Qn}{S_b^{1/2}}\right]^{3/4}$
Wide flat		None	$1.00\left[\frac{(Q/b)n}{S_b^{1/2}}\right]^{3/8}$	—
Circular		$D = 2y_n$	$1.00\left[\frac{Qn}{S_b^{1/2}}\right]^{3/8}$	$1.583\left[\frac{Qn}{S_b^{1/2}}\right]^{3/4}$

Figure 7.2

Properties of optimum open channel sections.

Optimal Channels

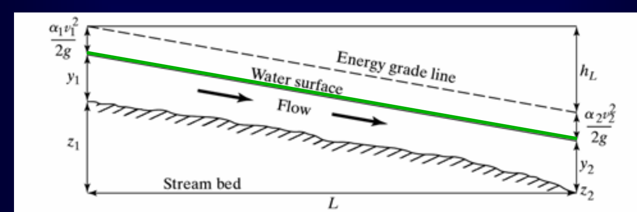


Figure 7.6

Nonuniform flow energy equation. For steady flow between two stations, 1 and 2, a distance L apart.

Non-uniform Flow

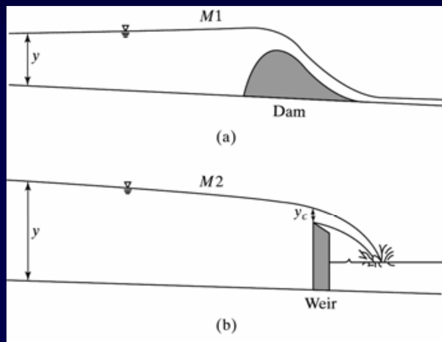


Figure 7.7

(a) Example of an *M*1 profile. (b) Example of an *M*2 profile.

White water rafting, Browns Canyon, Colorado

Non-Uniform Open Channel Flow

With natural or man-made channels, the shape, size, and slope may vary along the stream length, x. In addition, velocity and flow rate may also vary with x.

$$H = z + y + \left(\alpha v^2 / 2g\right)$$

Thus,

$$\frac{dH}{dx} = \frac{dz}{dx} + \frac{dy}{dx} + \frac{\alpha}{2g}\left(\frac{dv^2}{dx}\right)$$

Where *H* = total energy head
z = elevation head,
$\alpha v^2/2g$ = velocity head

Backwater Profiles - Compute Numerically

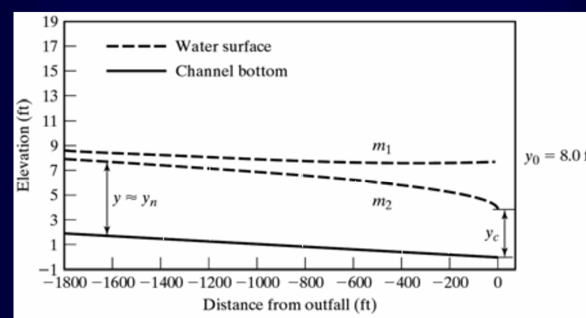


Figure E7.5(b)

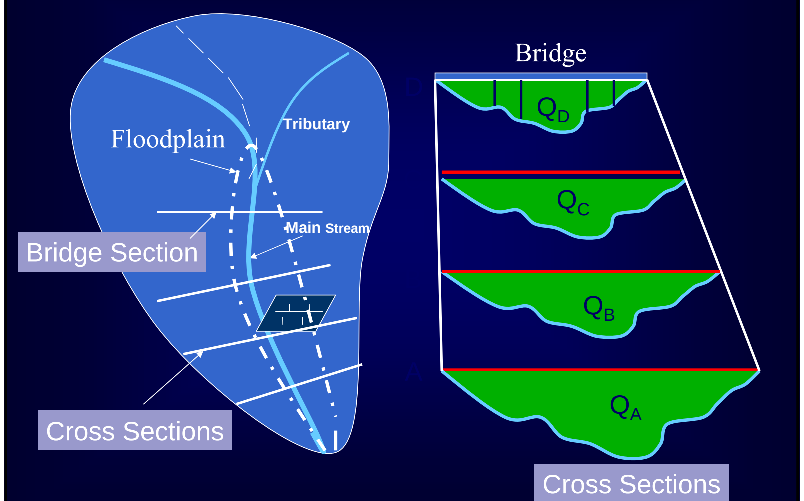
Routine Backwater Calculations

1. Select Y_1 (starting depth)
2. Calculate A_1 (cross sectional area)
3. Calculate P_1 (wetted perimeter)
4. Calculate $R_1 = A_1/P_1$
5. Calculate $V_1 = Q_1/A_1$
6. Select Y_2 (ending depth)
7. Calculate A_2
8. Calculate P_2
9. Calculate $R_2 = A_2/P_2$
10. Calculate $V_2 = Q_2/A_2$

Backwater Calculations (cont'd)

1. Prepare a table of values
2. Calculate $V_m = (V_1 + V_2) / 2$
3. Calculate $R_m = (R_1 + R_2) / 2$
4. Calculate $S = \left(\frac{nV_m}{1.49R_m^{2/3}}\right)^2$ Manning's
5. Calculate $L = \Delta X$ from first equation $L = \frac{\left(y_1 + \frac{v_1^2}{2g}\right) - \left(y_2 + \frac{v_2^2}{2g}\right)}{S - S_0}$
6. $X = \sum \Delta X_i$ for each stream reach (SEE SPREADSHEET)

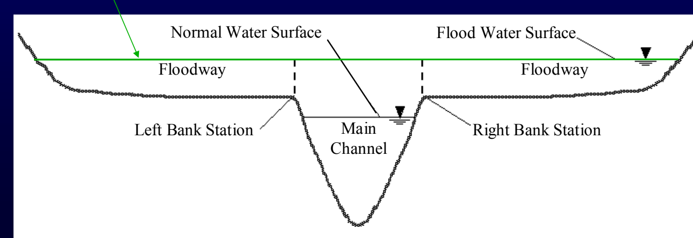
Watershed Hydraulics



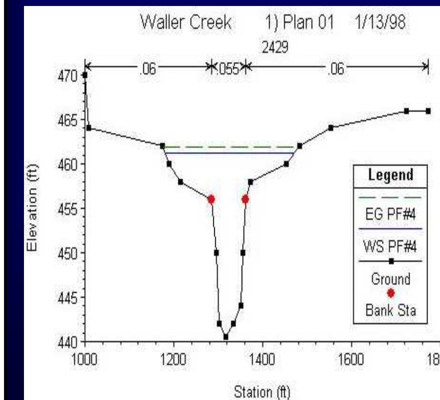
HEC-RAS: Background

- River Analysis System model of the U.S. Army Corps of Engineers
- Input = cross-section geometry and flow rates
- Output = flood water elevations

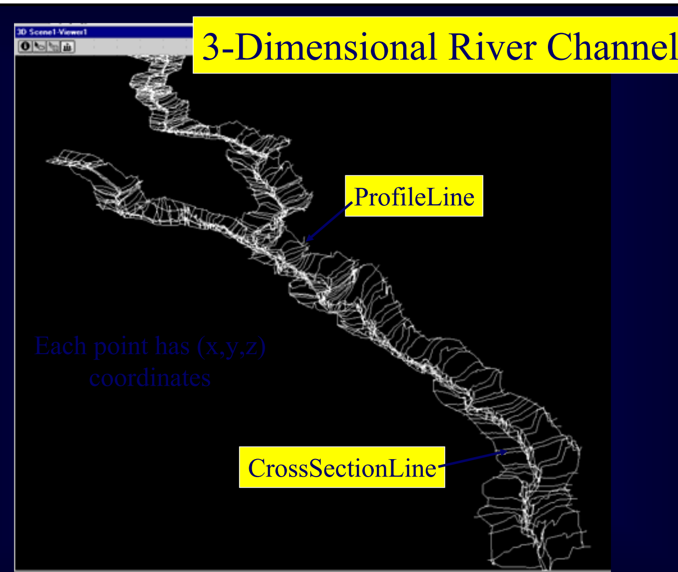
Cross-Section Schematic



HEC-RAS: Cross-Section Description



- Points describe channel and floodway geometry
- Bank station locations
- Water surface elevations and floodplain



Example

- Calculate the water surface profiles for two discharges in the channel described in the following tables.
  - Q_1 = 20000 cfs
  - Q_2 = 30000 cfs
- Assume a Manning's n of 0.24 for the two overbanks and a Manning's n of 0.04 for the channel.
- Assume the overbank distances between stations are the same as the distances between the stations in the channel.

Example

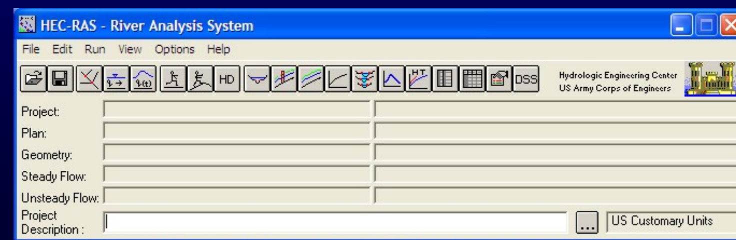
Section 1 Down L = 0 ft		Section 2 Down L = 1500 ft		Section 3 Down L = 2100 ft	
X	Y	X	Y	X	Y
0	40.5	0	43.6	0	46.1
40	36.3	60	19.7	40	45.1
95	19.7	120	18.8	140	12.5
140	9.8	195	16.2	240	1.7
200	5.3	210	7.1	275	15.1
299	1.7	245	4.1	290	15.3
360	21.8	345	20.5	305	15.9
421	42.9	450	25.7	310	19.9
		480	44.4	400	48.1

Example

Section 4 Down L = 2000 ft		Section 5 Down L = 3150 ft		Section 6 Down L = 1855 ft	
X	Y	X	Y	X	Y
0	48.2	0	61.1	0	64.4
100	19.1	50	51.2	19	57.0
113	15.1	101	14.3	49	29.1
230	17.3	201	1.1	149	19.0
340	5.9	259	19.6	207	14.4
395	6.4	289	21.1	217	13.1
461	41.4	356	60.9	293	18.8
503	48.4			361	36.1
				413	47.0
				471	63.3

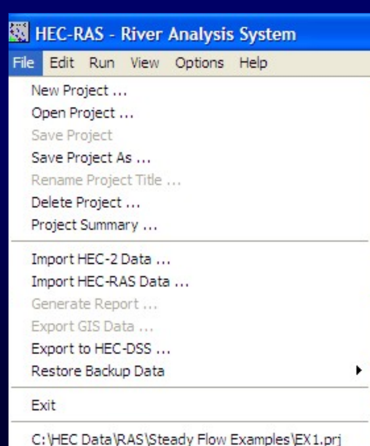
Running a Steady-State Flow Analysis on the Example

- Open HEC-RAS (River Analysis System) by double-clicking on the icon (after installing the program).
- The following screen should appear:



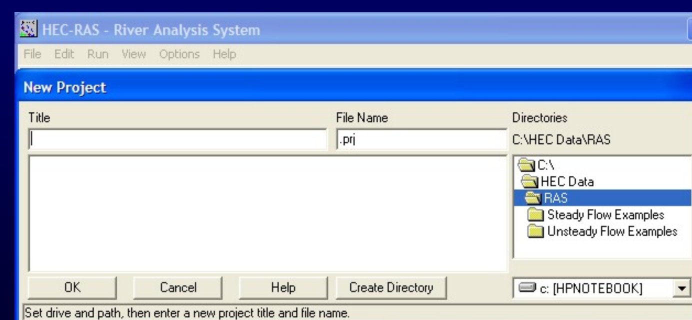
Running a Steady-State Flow Analysis on the Example

- Select **File|New Project**



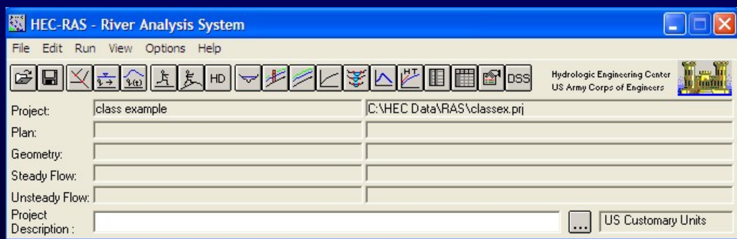
Running a Steady-State Flow Analysis on the Example

- This screen should appear. Fill in the needed data. Then click “OK.”



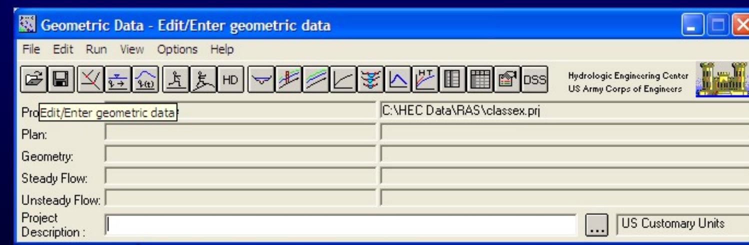
Running a Steady-State Flow Analysis on the Example

- The introductory screen should appear with the project name filled in.



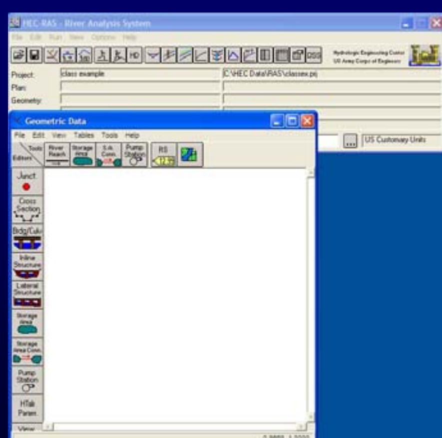
Running a Steady-State Flow Analysis on the Example

- Need to add geometric data (cross-section data). Click on Geometric Data button (tree).



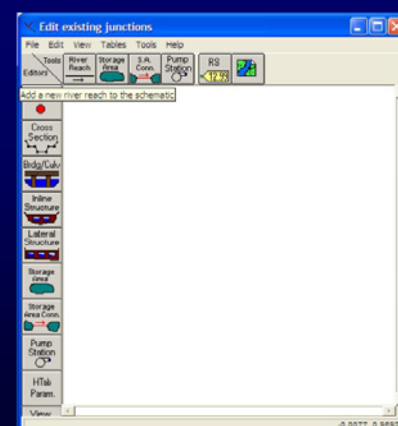
Running a Steady-State Flow Analysis on the Example

- Need to add geometric data (cross-section data). Click on Geometric Data button (tree).



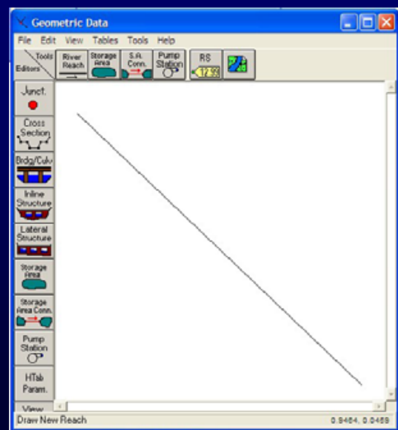
Running a Steady-State Flow Analysis on the Example

- Add River Reach by left-clicking on the River Reach button.



Running a Steady-State Flow Analysis on the Example

- In the tablet area, left-click where you want the reach to start and use the pencil to draw the reach. Double left-click when Reach is completed.

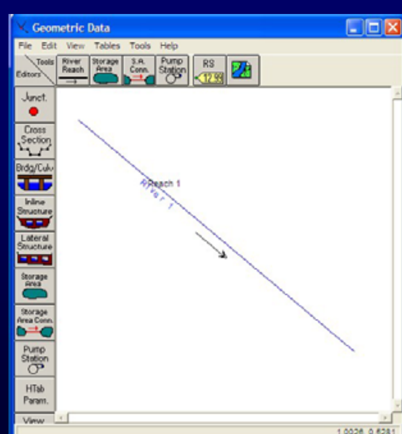


Running a Steady-State Flow Analysis on the Example

- Once the reach is drawn (ended by left double-click), a box will appear asking you to name the river and the reach.

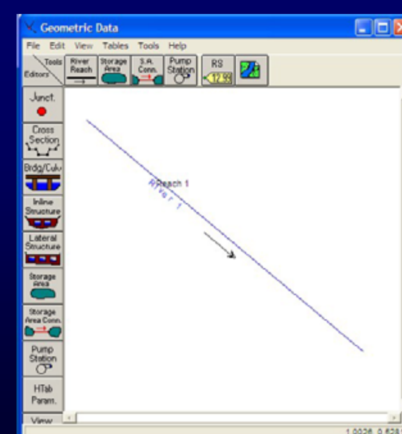
Running a Steady-State Flow Analysis on the Example

- The result will look like the screen to the right.
- Next will need to describe cross-sections in the reach. (or can add additional reaches that drain to same outlet).



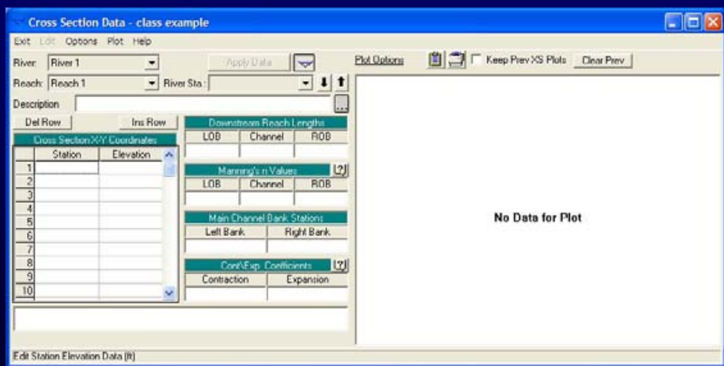
Running a Steady-State Flow Analysis on the Example

- Left-click on the cross-section button on the left.



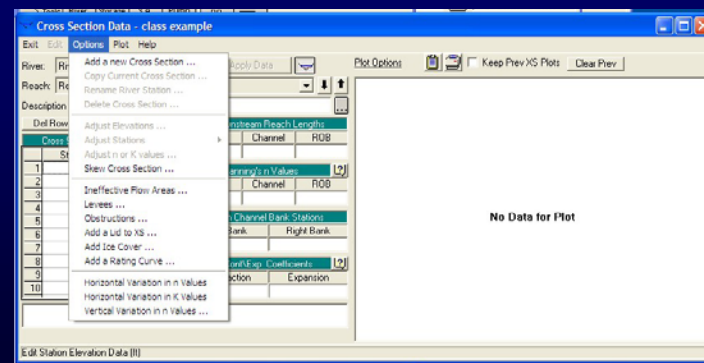
Running a Steady-State Flow Analysis on the Example

- The following table should appear.



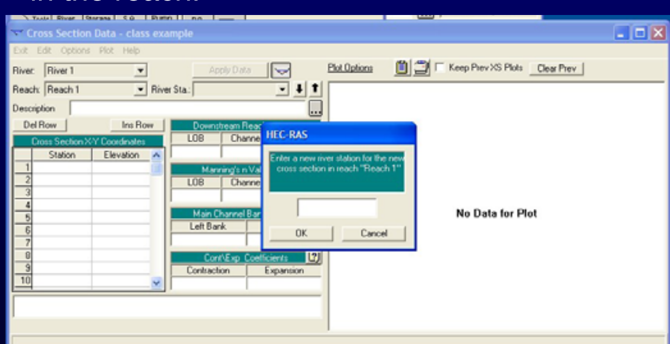
Running a Steady-State Flow Analysis on the Example

- Under Options, select Add New Cross-Section.



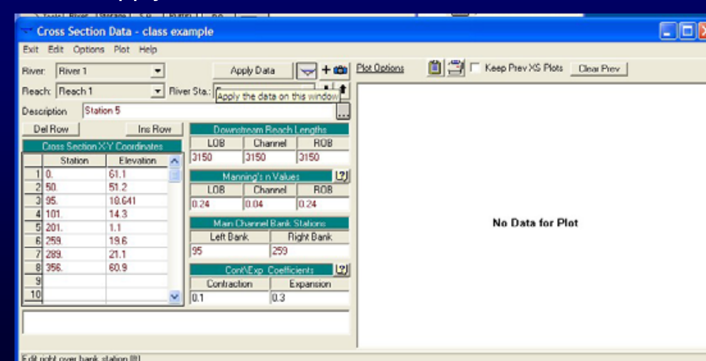
Running a Steady-State Flow Analysis on the Example

- When the box appears, enter the station number in the reach.



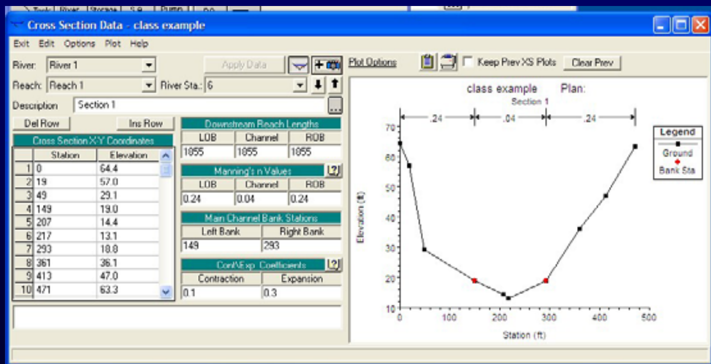
Running a Steady-State Flow Analysis on the Example

- Enter the data as required in each of the boxes and then click “Apply Data”.



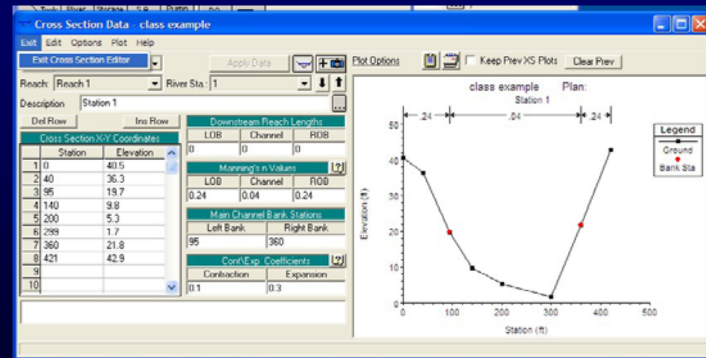
Running a Steady-State Flow Analysis on the Example

- After clicking on "Apply Data", the plot should appear.



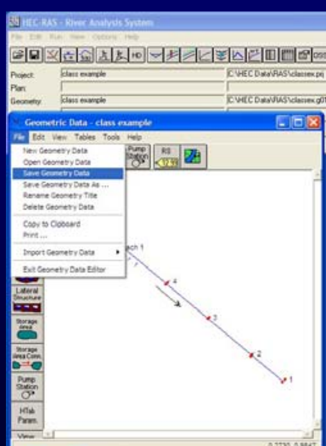
Running a Steady-State Flow Analysis on the Example

- When all cross-sections are entered and the data applied, select "Exit Cross-Section Editor".



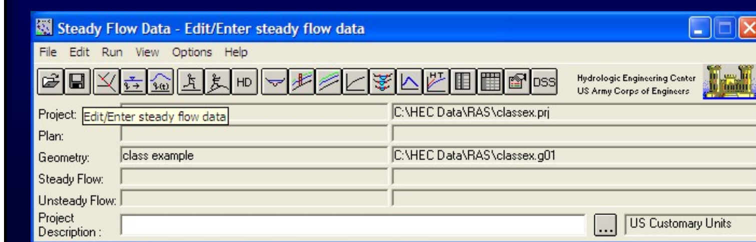
Running a Steady-State Flow Analysis on the Example

- This will return the active screen to the Geometric Data screen. Need to save the geometric data.



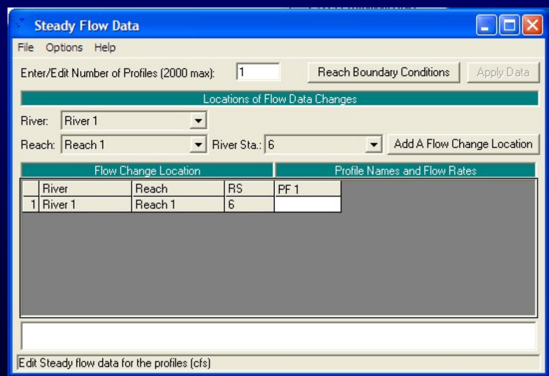
Running a Steady-State Flow Analysis on the Example

- This will return the introductory (project organization) screen.
- Want to enter the conditions necessary to perform the steady-state flow example. Click on steady-state flow button.



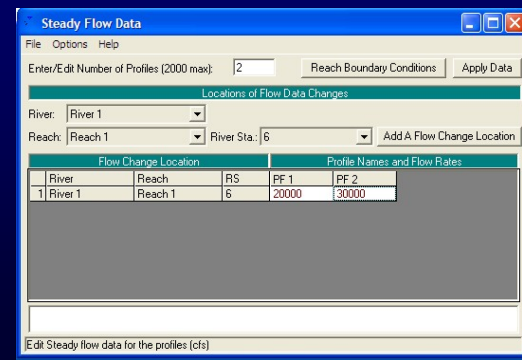
Running a Steady-State Flow Analysis on the Example

- The Steady-Flow Data screen will appear.



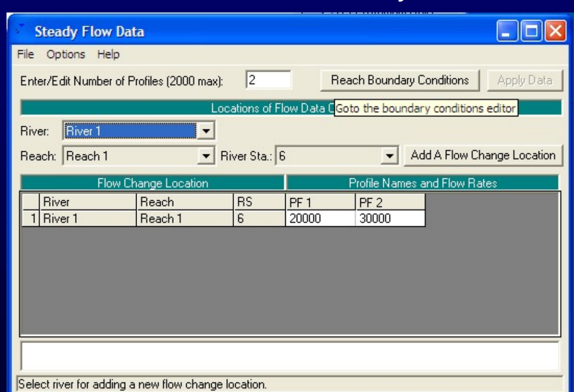
Running a Steady-State Flow Analysis on the Example

- Enter the data (enter number of profiles and the Q values).



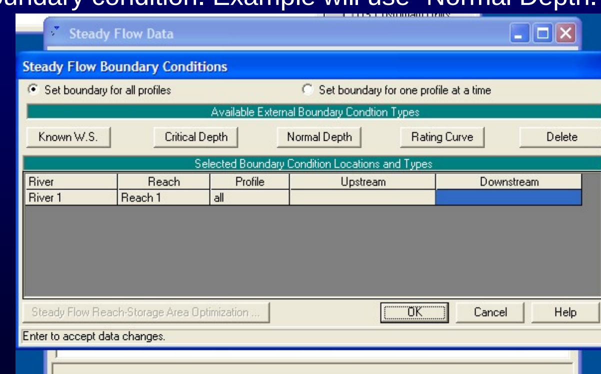
Running a Steady-State Flow Analysis on the Example

- Select the button “Reach Boundary Conditions.”



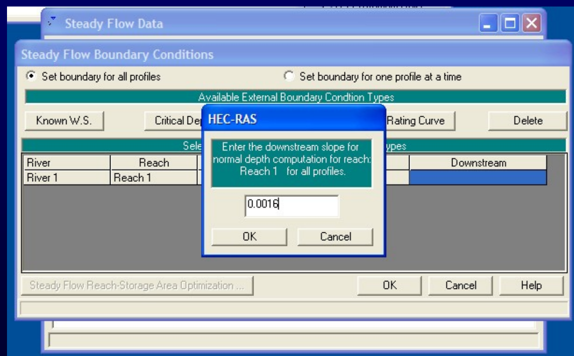
Running a Steady-State Flow Analysis on the Example

- The following screen will appear. Click on desired boundary condition. Example will use “Normal Depth.”



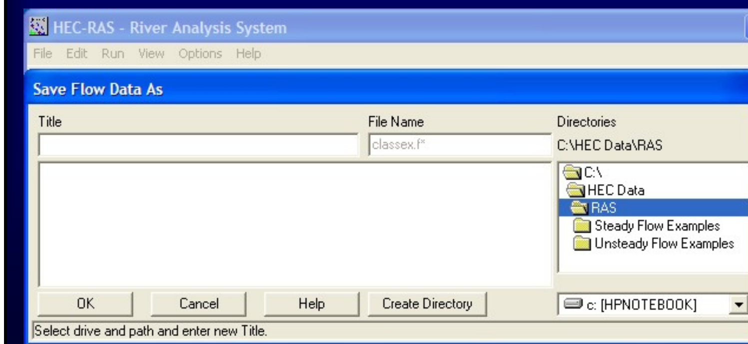
Running a Steady-State Flow Analysis on the Example

- “Normal Depth” requires entry of downstream slope at outlet. Use same slope as channel from Stations 2 to 1.



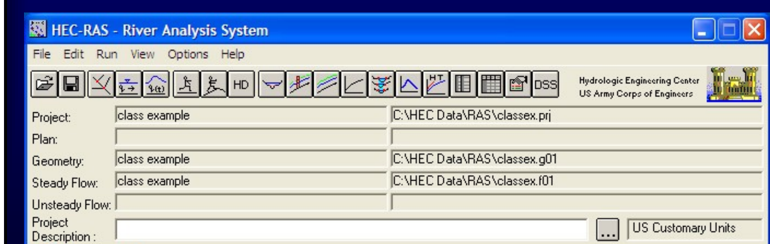
Running a Steady-State Flow Analysis on the Example

- Once boundary conditions have been entered, save the flow data and click OK.



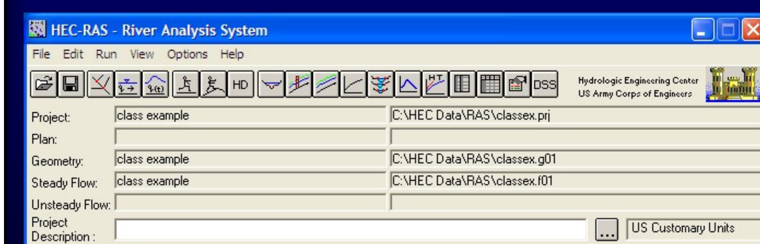
Running a Steady-State Flow Analysis on the Example

- After saving, return to the introductory screen. The names of the data files for the Project, Geometry and Steady Flow should be showing.



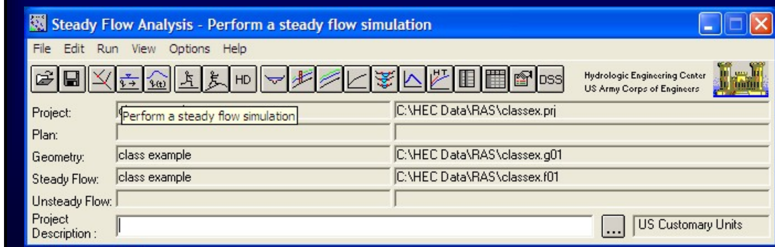
Running a Steady-State Flow Analysis on the Example

- After saving, return to the introductory screen. The names of the data files for the Project, Geometry and Steady Flow should be showing.



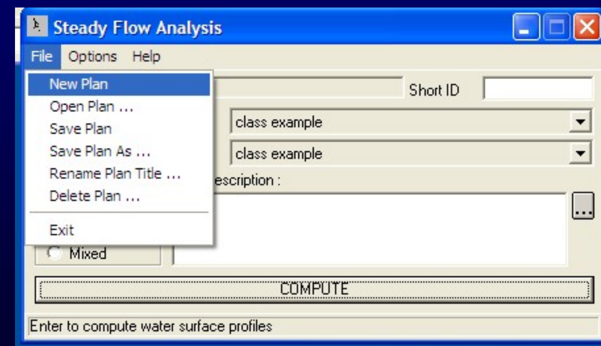
Running a Steady-State Flow Analysis on the Example

- Click on the Perform a Steady Flow Simulation button.



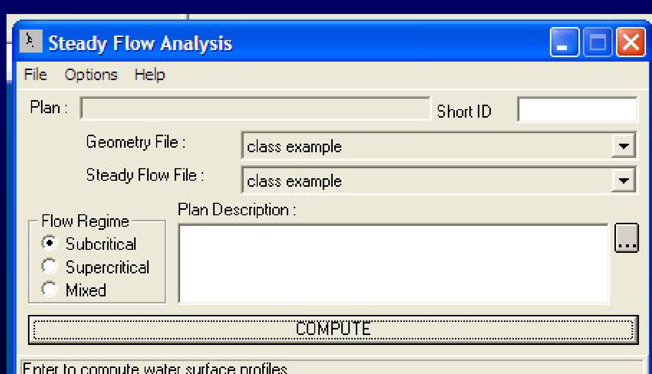
Running a Steady-State Flow Analysis on the Example

- Select New Plan.



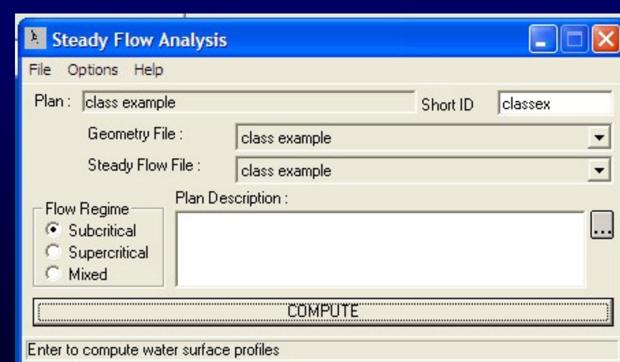
Running a Steady-State Flow Analysis on the Example

- Fill in the Plan Name and Short ID.



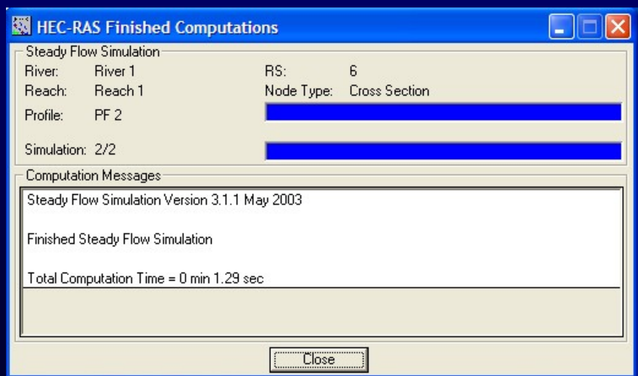
Running a Steady-State Flow Analysis on the Example

- The screen now should look like this. Click on COMPUTE to run the simulation.



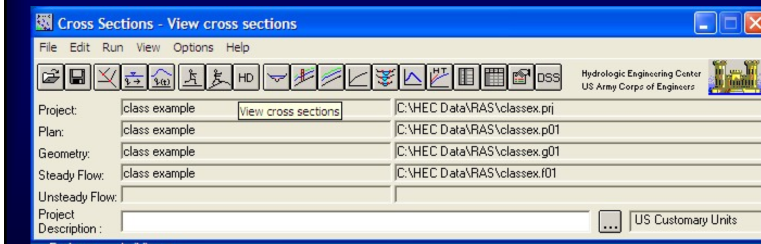
Running a Steady-State Flow Analysis on the Example

- This screen will appear when the simulation is complete.

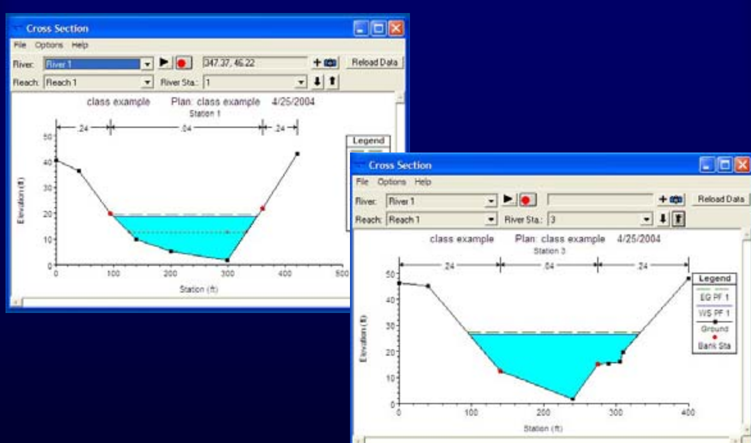


Running a Steady-State Flow Analysis on the Example

- Select "View Cross-Sections."

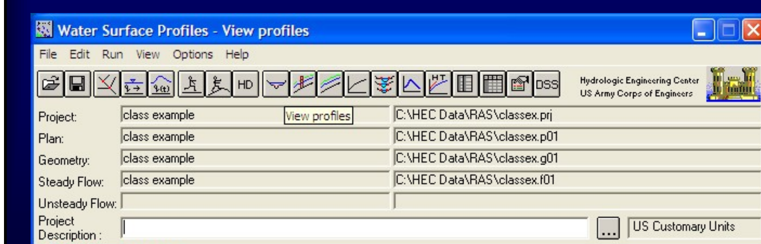


Running a Steady-State Flow Analysis on the Example

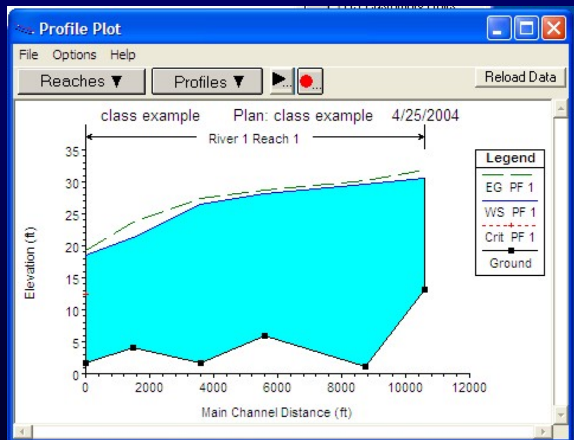


Running a Steady-State Flow Analysis on the Example

- Select "View Profiles."

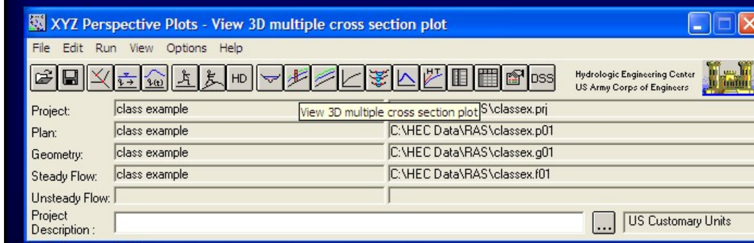


Running a Steady-State Flow Analysis on the Example

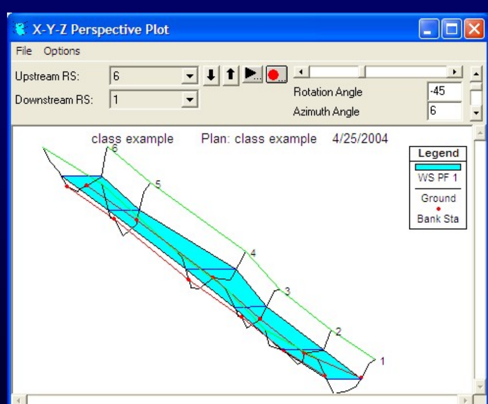


Running a Steady-State Flow Analysis on the Example

- Select "View 3D Multiple Cross-Section Plot."

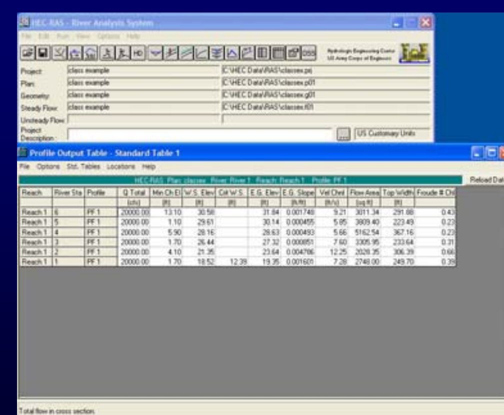


Running a Steady-State Flow Analysis on the Example



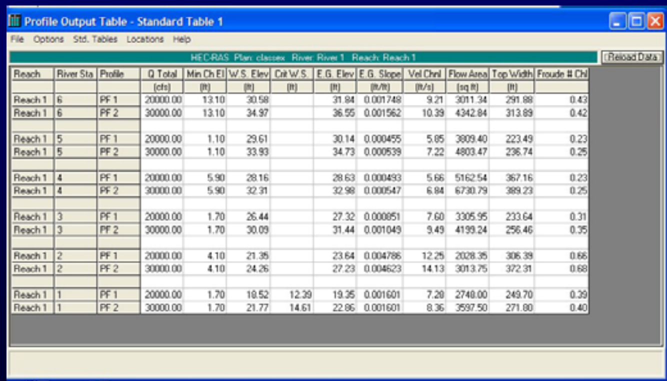
Running a Steady-State Flow Analysis on the Example

- Select "Profile Table Output" button.



Running a Steady-State Flow Analysis on the Example

- Use Options to show both profiles.



Profile Output Table - Standard Table 1

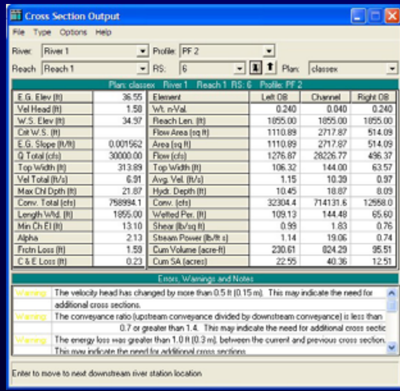
File Options Std. Tables Locations Help

HEC-RAS Plan: classex River: River 1 Reach: Reach 1

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Reach 1	6	PF 1	20000.00	13.10	30.58		31.84	0.001748	9.21	3011.34	291.88	0.43
Reach 1	6	PF 2	30000.00	13.10	34.97		36.55	0.001562	10.39	4342.84	313.89	0.42
Reach 1	5	PF 1	20000.00	1.10	29.61		30.14	0.000455	5.85	3809.40	223.49	0.23
Reach 1	5	PF 2	30000.00	1.10	33.93		34.73	0.000539	7.22	4803.47	236.74	0.25
Reach 1	4	PF 1	20000.00	5.90	28.16		28.63	0.000493	5.66	5162.54	367.16	0.23
Reach 1	4	PF 2	30000.00	5.90	32.31		32.98	0.000547	6.84	6730.79	389.23	0.25
Reach 1	3	PF 1	20000.00	1.70	26.44		27.32	0.000851	7.60	3305.95	233.64	0.31
Reach 1	3	PF 2	30000.00	1.70	30.09		31.44	0.001049	9.49	4199.24	256.46	0.35
Reach 1	2	PF 1	20000.00	4.10	21.35		23.64	0.004786	12.25	2028.35	306.39	0.66
Reach 1	2	PF 2	30000.00	4.10	24.26		27.23	0.004623	14.13	3013.75	372.31	0.68
Reach 1	1	PF 1	20000.00	1.70	18.52	12.39	19.35	0.001601	7.20	2740.00	249.70	0.39
Reach 1	1	PF 2	30000.00	1.70	21.77	14.61	22.86	0.001601	8.36	3597.50	271.80	0.40

Running a Steady-State Flow Analysis on the Example

- Use Options to show detailed cross-section output.



Cross Section Output

File Type Options Help

River: River 1 Profile: PF 2

Reach: Reach 1 RS: 6 Plan: classex

Plan: classex River 1 Reach 1 RS: 6 Profile: PF 2

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	36.55	Wt. n-Val.	0.240	0.040	0.240
Vel Head (ft)	1.58	Reach Len. (ft)	1855.00	1855.00	1855.00
W.S. Elev (ft)	34.97	Flow Area (sq ft)	1110.89	2717.87	514.09
Crit W.S. (ft)		Area (sq ft)	1110.89	2717.87	514.09
E.G. Slope (ft/ft)	0.001562	Flow (cfs)	1276.87	28226.77	496.37
Q Total (cfs)	30000.00	Top Width (ft)	106.32	144.00	63.57
Top Width (ft)	313.89	Avg. Vel. (ft/s)	1.15	10.39	0.97
Vel Total (ft/s)	6.91	Hydr. Depth (ft)	10.45	18.87	8.09
Max Chl Dpth (ft)	21.87	Conv. (cfs)	32304.4	714131.6	12558.0
Conv. Total (cfs)	758994.1	Wetted Per. (ft)	109.13	144.48	65.60
Length Wtd. (ft)	1855.00	Shear (lb/sq ft)	0.99	1.83	0.76
Min Ch El (ft)	13.10	Stream Power (lb/ft s)	1.14	19.06	0.74
Alpha	2.13	Cum Volume (acre-ft)	230.61	824.29	95.51
Frctn Loss (ft)	1.59	Cum SA (acres)	22.55	40.36	12.51
C & E Loss (ft)	0.23				

Errors, Warnings and Notes

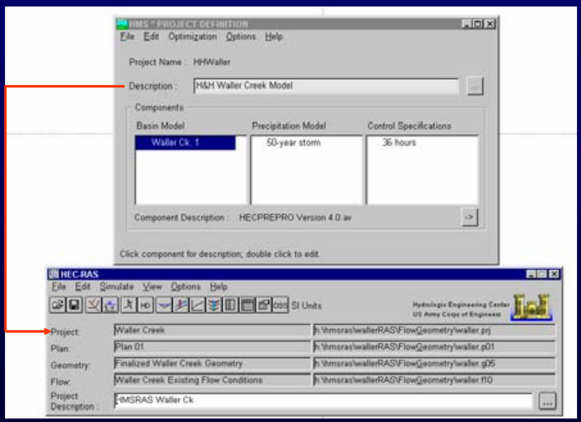
Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sectic

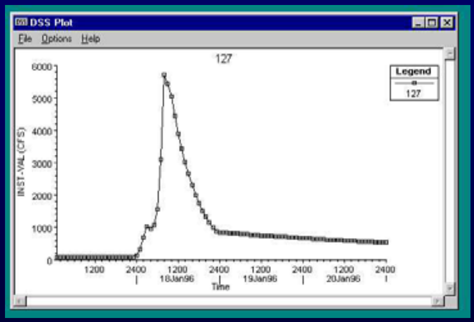
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section.

Enter to move to next downstream river station location

Connecting HMS and RAS



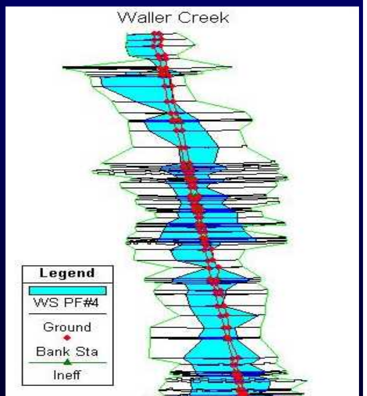
Discharge at a Particular Cross-Section

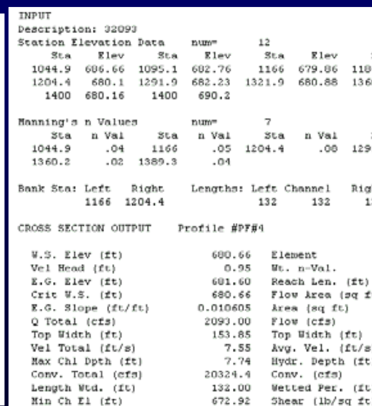


HEC-RAS: Output

Graphical

Text File





```
INPUT
Description: 32093
Station Elevation Data     num=      12
      Sta     Elev      Sta     Elev      Sta     Elev      S
   1044.9   686.66   1095.1   682.76     1166   679.86   118
   1204.4    680.1   1291.9   682.23   1321.9   680.88   136
     1400   680.16     1400    690.2

Manning's n Values         num=       7
      Sta    n Val      Sta    n Val      Sta    n Val      S
   1044.9      .04     1166      .05   1204.4      .08   129
   1360.2      .02   1389.3      .04

Bank Sta: Left    Right     Lengths: Left Channel    Righ
            1166   1204.4                132      132      13

CROSS SECTION OUTPUT    Profile #PF#4

  W.S. Elev (ft)                  680.66   Element
  Vel Head (ft)                     0.95   Wt. n-Val.
  E.G. Elev (ft)                  681.60   Reach Len. (ft)
  Crit W.S. (ft)                  680.66   Flow Area (sq ft
  E.G. Slope (ft/ft)            0.010605   Area (sq ft)
  Q Total (cfs)                  2093.00   Flow (cfs)
  Top Width (ft)                  153.85   Top Width (ft)
  Vel Total (ft/s)                  7.55   Avg. Vel. (ft/s)
  Max Chl Dpth (ft)                 7.74   Hydr. Depth (ft)
  Conv. Total (cfs)              20324.4   Conv. (cfs)
  Length Wtd. (ft)                132.00   Wetted Per. (ft)
  Min Ch El (ft)                  672.92   Shear (lb/sq ft)
```

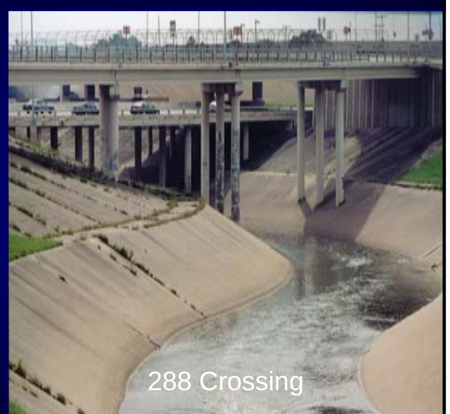
HEC-RAS: Data Translation

Station No	Location	L Flood X	L Bank X	Channel	R Bank X	R Flood X	Flood Elevati
28514		238.0	36.6	3579.0	13.4	179.1	651.5
28490	55 1/2 Street o		36.6	3628.0	13.4		
28465		246.4	36.6		13.4	184.8	651.7
28428		137.7	23.0	3665.0	12.0	175.6	651.1
28308		95.7	23.0	3785.0	12.0	148.5	649.2
28118		216.9	32.9	3975.0	27.8	118.3	648.2
28092		236.3	30.9	4001.0	29.8	140.5	648.3
28066	55th Street on		30.9	4052.0	29.8		
28041		227.9	30.9		29.8	133.1	648.2
28001		201.0	11.0	4092.0	25.0	113.0	647.6
27901		182.2	11.0	4192.0	25.0	108.0	646.5
27798		245.3	28.5	4295.0	21.5	134.4	646.9
27775		237.3	22.9	4318.0	27.1	138.6	646.9
27752	Nelray Street o		22.9	4364.0	27.1		
27729		253.3	22.9		27.1	149.1	647.1
27699		285.1	11.8	4394.0	12.3	155.5	646.9
27569		272.4	11.8	4524.0	12.3	146.0	645.4
27427		263.2	6.0	4666.0	23.5	240.9	644.9
27404		370.7	5.5	4689.0	24.0	354.4	645.1
27381	Franklin Street		5.5	4734.0	24.0		
27359		372.7	5.5		24.0	353.1	645.2
27337		294.6	17.5	4756.0	20.0	268.9	644.8

- Data translation from HEC-RAS text file to dbase table
- Bank and floodplain boundaries measured from stream centerline

Brays Bayou-Typical Urban System

- Bridges cause unique problems in hydraulics
- Piers, low chords, and top of road is considered
- Expansion/contraction can cause hydraulic losses
- Several cross sections are needed for a bridge
- Critical in urban settings



The Floodplain

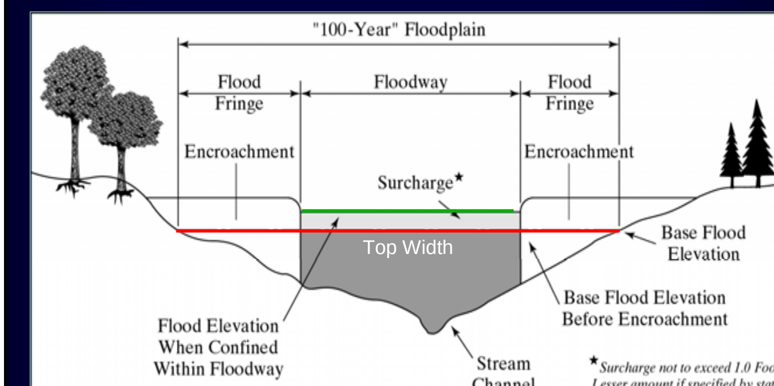


Figure 12.2

A 100-year floodplain and floodway schematic. Source: National Wildlife Federation, (1998). Higher Ground.

Floodplain Determination

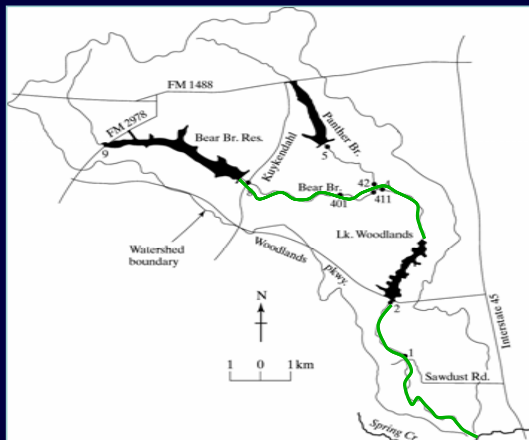


Figure 9.6

Watershed map—Panther Branch at The Woodlands. (From Bedient et al., 1985.)

The Woodlands

- The Woodlands planners wanted to design the community to withstand a 100-year storm.
- In doing this, they would attempt to minimize any changes to the existing, undeveloped floodplain as development proceeded through time.

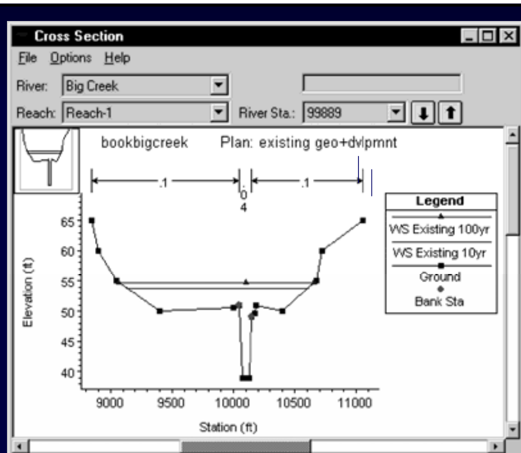
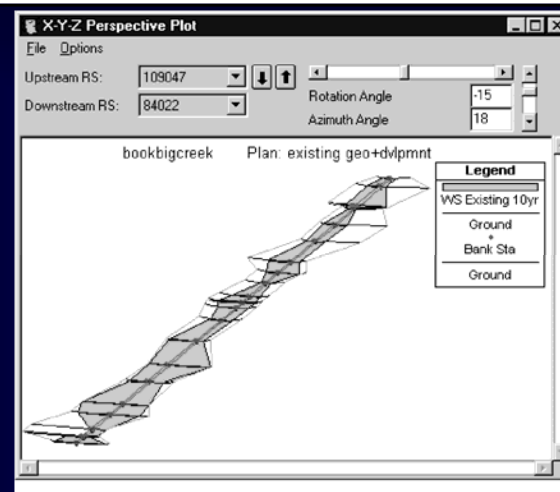


Figure 7.17

Cross-section with water surface profiles.

HEC RAS Cross Section



3-D Floodplain