Solutions Chapter 7

7.1. The Colorado River System Aqueduct has the cross section shown in Fig. P7.1. When the water in the aqueduct is 10.2 ft deep, flow is measured as 1600 cfs. If $n = 0.014$, what is S_0 in (a) ft/ft and (b) ft/mi?

Manning's equation for English units (Eq. 7.4) is:

$$V = \frac{1.49}{n} R^{2/3} \sqrt{S_0}$$

or

$$Q = \frac{1.49}{n} A R^{2/3} \sqrt{S_0}$$

Solving for S_0 gives:

$$S_0 = \left[\frac{nQ}{1.49} \frac{1}{AR^{2/3}} \right]^2$$

Referring to Fig. P7.1, we have:

y = 10.2 ft.

A = By + 2(1/2)(y)(1.5y)

= (20 ft)(10.2 ft) + (2)(1/2)(10.2 ft)(1.5)(10.2 ft)

A = 360 ft.^{2}

$$P = B + 2\left(\sqrt{y^2 + 1.5y^2}\right)$$

P = 57 ft

R = A/P

= 360 ft^2 / 57 ft

R = 6.32 ft

Then:

$$\text{a) } S_0 = \left[\frac{(0.014)(1600)}{1.49} \frac{1}{(360)(6.32)^{2/3}} \right]^2$$

S_0 = 0.00015 ft/ft

b) S_0 = (0.00015 ft/ft)(5280 ft/mi)

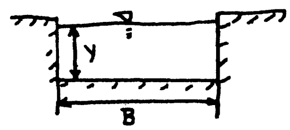
S_0=0.788ft/mi

7.2. A rectangular open channel that is 2 m wide has water flowing at a depth of 0.45 m. Using n = 0.014, find the rate of flow in the channel if S_0 is (a) 0.002 m/m, (b) 0.006 m/m, and (c) 0.012 m/m.

Manning's equation for metric units (Eq. 7.3) is

$$V = \frac{1}{n} R^{2/3} \sqrt{S_0}$$

or



$$Q = \frac{1}{n} A R^{2/3} \sqrt{S_0}$$

Referring to the figure:

A = By

= (2)(0.45m)

A = 0.9m^2

P = B + 2y

= 2m + 2(0.45m)

P = 2.9m

R = A/P

= 0.9m^2/2.9m

R = 0.31m

Then:

a) $Q = \frac{1}{0.014}(0.9)(0.31)^{2/3}(0.002)^{1/2}$

$Q = 1.32\, m^3/s$

b) $Q = \frac{1}{0.014}(0.9)(0.31)^{2/3}(0.006)^{1/2}$

$Q = 2.28\, m^3/s$

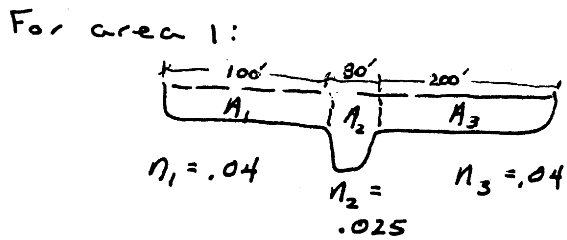
c) $Q = \frac{1}{0.014}(0.9)(0.31)^{2/3}(0.012)^{1/2}$

$Q = 3.23\, m^3/s$

7.3. A channel has the irregular shape shown in Fig. P7.3, with a bottom slope of 0.0016 ft/ft. The indicated Manning's n values apply to the corresponding areas only. Assuming that $Q = Q_1 + Q_2 + Q_3$, find the rate of flow in the channel if $y_1 = 2$ ft, $y_2 = 10$ ft, and $y_3 = 3$ ft.

The flow in each area is found using Manning's equation and summed to find the total flow. For area 1:

$$A_1 = B_1 y_1 = (100\,ft)(2\,ft) = 200\,ft^2$$



$$P_1 = B_1 + y_1 = (100\,ft) + (2\,ft) = 102\,ft$$

$$R_1 = A_1 / P_1 = (200\,ft^2)/(102\,ft) = 1.96\,ft$$

$$Q_1 = \frac{1.49}{0.04}(200)(1.96)^{2/3}(0.0016)^{1/2} = 467 cfs$$

For area 2:

$$A_2 = B_2 y_2 = (30\,ft)(10\,ft) = 300\,ft^2$$

$$P_2 = B_2 + (y_2 - y_1) + (y_2 - y_3) = (30\,ft) + (10-2) + (10-3) = 45\,ft$$

$$R_2 = A_2 / P_2 = (300\,ft^2)/(45\,ft) = 6.67\,ft$$

$$Q_2 = \frac{1.49}{0.025}(300)(6.67)^{2/3}(0.0016)^{1/2} = 2534 cfs$$

For area 3:

$$A_3 = B_3 y_3 = (200\,ft)(3\,ft) = 600\,ft^2$$

$$P_3 = B_3 + y_3 = 200\,ft + 3\,ft = 203\,ft$$

$$R_3 = A_3 / P_3 = (600\,ft^2)/(203\,ft) = 2.96\,ft$$

$$Q_3 = \frac{1.49}{0.04}(600)(2.96)^{2/3}(0.0016)^{1/2} = 1843 cfs$$

The total flow is:

$$Q_T = Q_1 + Q_2 + Q_3$$

$$= 467 + 2534 + 1843$$

$$Q_T = 4844 cfs$$

7.4. Water is flowing 2 m deep in a rectangular channel that is 2.5 m wide. The average velocity is 5.8 m/s and $C = 100$. What is the slope of the channel? (Use Chezy's formula.)

Chezy's formula (Eq. 7.1) is:

$$V = C\sqrt{Rs}$$

$$A = By = (2.5)(2) = 5.0m^2$$

$$P = B + 2y = 2.5 + 2(2) = 6.5m$$

$$R = A / P = 5.0m^2 / 6.5m = 0.77m$$

Solving for S yields:

$$S = V^2 / C^2 R$$

$$= (5.8)^2 / (100)^2 (0.77)$$

$$S = 0.0044 m / m$$

7.5. A triangular channel with side slopes at 45° to the horizontal has water flowing through it at a velocity of 10 ft/s. Find Chezy's roughness coefficient *C* if the bed slope is 0.03 ft/ft and the depth is 4 ft.

Solving Chezy's formula for C yields:

$$C = \frac{V}{\sqrt{Rs}}$$

We have

$$A = \tfrac{1}{2}(4)(8) = 16\,ft^2$$

$$P = 2\left(\sqrt{4^2 + 4^2}\right) = 11.31\,ft$$

$$R = 16\,ft^2 / 11.31\,ft = 1.41\,ft$$

Then

$$C = 10 / \sqrt{(1.41)(0.03)}$$

$$C = 48.5$$

7.6. Water is flowing at a rate of 900 cfs in a trapezoidal open channel. Given that $S_0 = 0.001$, $n = 0.015$, bottom width $b = 20$ ft, and the side slopes are 1:1.5, what is the normal depth y_n?

First we assume normal depth and find A and P:

$$A = By_n + 2\left(\tfrac{1}{2}\right)(y_n)(1.5y_n) = 20y_n + 1.5y_n^2 = y_n(20 + 1.5y_n)$$

$$P = B + 2\sqrt{y_n^2 + (1.5y_n)^2} = 20 + 3.61y_n$$

Next, we rearrange Manning's equation:

$$Q = \frac{1.49}{n} AR^{2/3}\sqrt{S_0}$$

$$= \frac{1.49}{n} A(A/P)^{2/3}\sqrt{S_0}$$

$$Q = \frac{1.49}{n}\frac{A^{5/3}}{P^{2/3}}\sqrt{S_0}$$

Substituting for A and P and rearranging yields:

$$\frac{y_n^{5/3}(20 + 1.5y_n)^{5/3}}{(20 + 3.61y_n)^{2/3}} = 286.52$$

A trial and error solution is used to solve for y_n:

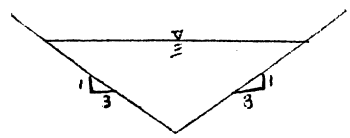
y_n	solution
4.00	217.3
4.50	268.0
5.00	323.8
4.75	295.2
4.60	278.7
4.65	284.2
4.67	286.4
4.68	287.5

So the normal depth is:

$$y_n = 4.67\,ft$$

7.7. Find the normal depth y_n for the triangular channel shown in Fig. P7.7 if $S_0 = 0.0005$ m/m, $Q = 40$ m^3/s, and $n = 0.030$.

Again the normal depth is assumed.



$$A = \tfrac{1}{2}(y_n)(6y_n) = 3y_n^{\,2}$$

$$P = 2\left(\sqrt{y_n^{\,2} + (3y_n)^2}\right) = 6.32y_n$$

$$R = A/P = 3y_n/6.32y_n = 0.47y_n$$

Then

$$40 = \frac{1}{0.030}(3y_n^{\,2})(0.47y_n)^{2/3}\sqrt{0.0005}$$

$$y_n^{8/3} = 29.41$$

$$y_n = 3.55m$$

7.8. Determine the critical depth and the critical velocity for the Colorado River System Aqueduct (problem 7.1) if Q = 1500 cfs.

Referring to Fig. P7.1 and assuming critical depth, we have:

$$A = 20y_c + 1.5y_c^2$$

$$B = 20 + 2(1.5y_c) = 20 + 3y_c$$

where B = top width. Then,

$$\frac{Q^2}{S} = \frac{A^3}{B}$$

$$\frac{(y_c(20+1.5y_c))^3}{20+3y_c} = \frac{(1500)^2}{32.2}$$

Solving by trial and error yields:

$$y_c = 4.91 ft$$

7.9. Find the critical depth and critical velocity for the triangular channel of problem 7.7 if Q is (a) 10 m^3/s and (b) 50 cfs.

Referring to Fig. P7.7 and assuming critical depth, we have:

$$A = \tfrac{1}{2}(y_c)(6y_c) = 3y_c^{\,2}$$

$$B = 6y_c$$

Then:

a) $$\frac{Q^2}{g} = \frac{A^3}{B}$$

$$\frac{(10m^3/s)^2}{9.81m/s^2} = \frac{(3y_c^{\,2})^3}{6y_c}$$

$$y_c^{\,5} = 2.27m^5$$

$$y_c = 1.18m$$

$$A = 3y_c^{\,2} = 4.16m^2$$

$$V = Q/A$$

$$= (10m^3/s)/4.16m^2$$

$$V_c = 2.40m/s$$

b) $$\frac{Q^2}{g} = \frac{A^3}{B}$$

$$\frac{(50cfs)^2}{32.2ft/s^2} = \frac{(3y_c^{\,2})^3}{6y_c}$$

$$y_c^{\,5} = 17.25ft^5$$

$$y_c = 1.77ft$$

$$A = 3y_c^{\,2} = 9.37ft^2$$

$$V = Q/A$$

7.9. (cont) $= (50cfs)/(9.37ft^2)$

$V = 5.33 ft/s$

7.10. Determine the local change in water surface elevation caused by a 0.2-ft-high obstruction in the bottom of a 10-ft-wide rectangular channel on a slope of 0.0005 ft/ft. The rate of flow is 20 cfs and the unobstructed flow depth is 0.9 ft. See Fig. P7.10. Assume no head loss.

Referring to Fig. P7.10, we choose a section 1 where y = 0.9ft and section 2 at the centerline of the obstruction. Equation 7.15 gives

$$y_1 + \frac{V_1^2}{2g} + z_1 = y_2 + \frac{V_2^2}{2g} + z_2$$

or

$$y_1 + \frac{V_1^2}{2g} - \Delta z = y_2 + \frac{V_2^2}{2g}$$

But:

$$V_1 = Q / A_1 = 20cfs / \left[(10ft)(0.9ft)\right] = 2.22 ft/s$$

$$V_2 = Q / A_2 = 20cfs / (10ft)(y_2) = 2 / y_2$$

So

$$y_2 + \frac{(2/y_2)^2}{2(32.2)} = 0.9 + \frac{(2.22)^2}{2(32.2)} - 0.2$$

Solving by trial and error gives

$$y_2 = 0.61ft$$

Thus

$$d_y = y_1 - (\Delta z + y_2)$$

$$= 0.9 - (0.2 + 0.61)$$

$d_y = 0.09ft$ decrease in depth at section 2

7.11. A rectangular channel with $n = 0.012$ is 5 ft wide and is built on a slope of 0.0006 ft/ft. At point *a*, the flow rate is 60 cfs and $y_a = 3$ ft. Using one reach, find the distance to point *b* where $y_b = 2.5$ ft and determine whether this point is upstream or downstream of point *a*.

We assume that point b is downstream of point a. Equation 7.22 is used with $y_1 = y_a$ and $y_2 = y_b$:

$$L = \left[\left(y_1 + \frac{V_1^2}{2g}\right) - \left(y_2 + \frac{V_2^2}{2g}\right)\right] / (S - S_0)$$

where S is found using Eq. 7.17:

$$S = \left[nVm / 1.49Rm^{2/3}\right]^2$$

$$y_u = 3.16$$

$$y_c = 1.65$$

For any depth y, we have:

A = 5y

P = 5 + 2y

R = 5y/(5 + 2y)

Q = VA ⇒ V = Q/5y

The calculations may be tabulated as follows:

y (ft)	A (ft²)	P (ft)	R (ft)	V (ft/s)	Rm (ft)	Vm (ft)	S	$y+\frac{V^2}{2g}$ (ft)	Δx (ft)
3.0	15.0	11	1.36	4.00				3.25	
					1.31	4.40	0.000876		1413
2.5	12.5	10	1.25	4.80				2.86	

Since Δx is positive, our assumption that point b is downstream was correct. Pont b is 1413 ft downstream of point a.

7.12. If a channel with the same cross-sectional and flow properties as the channel of problem 7.11 is laid on a slope of 0.01 ft/ft, determine whether the flow is supercritical or subcritical. Find the depth of flow at a point 1000 ft downstream from the point where y = 1.5 ft. (A trial-and-error solution may be necessary.)

First, critical depth for this channel is found:

$$A_c = 5y_c \qquad B = 5\,ft \qquad \frac{Q^2}{g} = \frac{A^3}{B} \qquad \text{(Eq. 7.13)}$$

$$\frac{(60)^3}{32.2} = \frac{(5y_c)^3}{5}$$

$$y_c^3 = 4.47\,ft^3$$

$$y_c = 1.65\,ft$$

Next, the normal depth is found using Manning's equation:

$$Q = \frac{1.49}{n} AR^{2/3}\sqrt{S_0}$$

$$60 = \frac{1.49}{0.012}(5y_n)\left(\frac{5y_n}{5+2y_n}\right)^{2/3}\sqrt{.01}$$

Trial and Error solution gives: $y_n = 1.14\,ft$

Since $y_n > y_c$ flow is super critical.

To determine the depth at a point 1000ft downstream, Eq. 7.22 is used.

7.12. (cont) The results from Eq. 7.22:

y (L)	A (L^2)	P (L)	R=A/P (L)	V=Q/A (L/s)	Vm (L/s)	Rm (L)	S computed	y+ V^2/2g (L)	del x (L)	x (L)
1.50	7.50	8.00	0.94	8.00				2.49		0
					8.14	0.93	0.004748		4	
1.45	7.25	7.90	0.92	8.28				2.51		4
					8.42	0.91	0.005238		6	
1.40	7.00	7.80	0.90	8.57				2.54		9
					8.73	0.89	0.0058		9	
1.35	6.75	7.70	0.88	8.89				2.58		18
					9.06	0.87	0.00645		13	
1.30	6.50	7.60	0.86	9.23				2.62		31
					9.42	0.84	0.007206		21	
1.25	6.25	7.50	0.83	9.60				2.68		52
					9.80	0.82	0.008089		38	
1.20	6.00	7.40	0.81	10.00				2.75		89
					10.22	0.80	0.009129		101	
1.15	5.75	7.30	0.79	10.43				2.84		190
					10.48	0.79	0.009833		119	
1.14	5.70	7.28	0.78	10.53				2.86		309

The normal depth is reached before 1000 ft.

Therefore $y@1000ft = y_n = 1.14 ft$

7.13. Classify the water surface profiles according to Table 7.2 of (a) Problem 7.11 and (b) Problem 7.12.

a) Mild slope, subcritical flow and increasing depth downstream all mean the slope is on M2 slope.

b) S2 Supercritical flow on steep slope

7.14. Classify the bed slopes (mild, critical, steep) of the channels of the following problems: (a) problem 7.1, (b) problem 7.6, and (c) problem 7.7.

a) Critical depth for this section must be found.

$$\frac{Q^2}{g} = \frac{A^3}{B}$$

$$\frac{(1600cfs)^2}{32.2} = \frac{(20+1.5y_c)^3 y_c^3}{20+3y_c}$$

$$y_c = 5.1ft$$

$$y_n = 10.2ft \text{ (from Problem 7.1)}$$

Since $y_n > y_c$ the bed slope is mild.

b) Again, critical depth must be found.

$$\frac{Q^2}{g} = \frac{A^3}{B}$$

$$\frac{(900)^2}{32.2} = \frac{(20+1.5y_c)^3 y_c^3}{20+3y_c}$$

$$y_c = 3.61ft$$

$$y_n = 4.67ft \text{ (from Problem 7.6)}$$

Since $y_n > y_c$ the slope is again mild.

c) $$\frac{Q^2}{g} = \frac{A^3}{B}$$

$$\frac{(40)^2}{9.81} = \frac{(3y_c^2)^3}{6y_c}$$

$$y_c^5 = 36.24m^5$$

$$y_c = 2.05m \qquad y_n = 3.55m \text{ (Problem 7.7)}$$

Once again, we have a mild slope.

7.15. A stream bed has a rectangular cross section 5 m wide and a slope of 0.0002 m/m. The rate of flow in the stream is 8.75 m^3/s. A dam is built across the stream, causing the water surface to rise to 2.5 m just upstream of the dam. (See Fig. P7.15). Using the step method illustrated in Example 7.5, determine the water surface profile upstream of the dam to a point where $y = y_n \pm 0.1$ m. Assume $n = 0.015$. How far upstream does this point occur?

First we must find y_n. Assume n = 0.015.

$$A = 5y$$

$$P = 5 + 2y$$

$$Q = \frac{1}{n} A \left(\frac{A}{P}\right)^{2/3} \sqrt{S_0}$$

$$8.75 = \frac{1}{0.015} (5y)^{5/3} (0.0002)^{1/2} \Big/ (5+2y)^{2/3}$$

Solving by trial and error gives:

$$y_n = 1.8m$$

Using Eq. 7.22 and a change in y of 0.1m, we can solve for distance upstream.

7.15. (cont)

y (m)	A (m^2)	P (m)	R (m)	V (m/s)	Rm (m)	Vm (m/s)	S	$y+\frac{V^2}{2g}$ (m)	ΔX (m)	X (m)
2.5	12.50	10.00	1.25	0.70				2.526		0
					1.235	0.715	0.000087		-876	
2.4	12.00	9.80	1.22	0.73				2.427		-876
					1.210	0.745	0.000097		-951	
2.3	11.50	9.60	1.20	0.76				2.329		-1827
					1.185	0.780	0.000109		-1055	
2.2	11.00	9.40	1.17	0.80				2.233		-2882
					1.155	0.815	0.000123		-1273	
2.1	10.50	9.20	1.14	0.83				2.135		-4155
					1.125	0.855	0.000141		-1610	
2.0	10.00	9.00	1.11	0.88				2.040		-5765
					1.095	0.900	0.000161		-2487	
1.9	9.50	8.80	1.08	0.92				1.943		-8252

The negative values of Δx imply that we are moving upstream whereas the sign convention used in the equation assumes that we are moving downstream.

$y = y_n + 0.1m$ at about 8000 ft upstream

7.16. A rectangular concrete channel ($n = 0.020$) changes from a mild slope to a steep slope. The channel is 20 m wide throughout, and the rate of flow is 180 m^3/s. If the slope of the mild portion of the channel is 0.0006 m/m, determine the distance upstream from the slope change to the point where $y = 3.0$ m. (*Hint:* Use the same step method as in Example 7.5, with y intervals of 0.1 m.)

The water surface will pass through critical depth at the slope change so the computations will start at critical depth.

$$A = 20y_c$$

$$B = 20m$$

$$\frac{Q^2}{g} = \frac{A^3}{B}$$

$$\frac{\left(180\, m^3/s\right)^2}{9.81\, m/s^2} = \frac{[(20m)(y_c)]^3}{20m}$$

$$y_c^3 = 8.257m^3$$

$$y_c = 2.02m \qquad \text{(M}_2\text{ curve)}$$

7.16. (cont)

y (m)	A (m^2)	P (m)	R (m)	V (m/s)	Rm (m)	Vm (m/s)	S	$y+\frac{V^2}{2g}$ (m)	ΔX (m)	X (m)
2.02	40.4	24.04	1.681	4.455				3.032		0
					1.709	4.371	0.00374		-1.3	
2.10	42.0	24.2	1.736	4.286				3.036		-1.3
					1.770	4.189	0.00328		-6.3	
2.20	44.0	24.4	1.803	4.091				3.053		-7.6
					1.837	4.005	0.00285		-12.0	
2.30	46.0	24.6	1.870	3.913				3.080		-19.6
					1.903	3.832	0.00249		-19.6	
2.40	48.0	24.8	1.935	3.750				3.117		-39.2
					1.968	3.675	0.00219		-27.7	
2.50	50.0	25.0	2.000	3.600				3.161		-66.9
					2.032	3.531	0.00194		-37.3	
2.60	52.0	25.2	2.063	3.462				3.211		-104.2
					2.095	3.398	0.00172		-49.1	
2.70	54.0	25.4	2.126	3.333				3.266		-153.3
					2.157	3.274	0.00154		-63.8	
2.80	56.0	25.6	2.188	3.214				3.326		-217.1
					2.218	3.159	0.00138		-83.3	
2.90	58.0	25.8	2.248	3.103				3.391		-300.4
					2.278	3.052	0.00124		-106.4	
3.00	60.0	26.0	2.308	3.000				3.459		-406.8

y = 3m at 407m upstream

7.17. A rectangular channel 1.4 m wide on a slope of 0.0026 m/m has water flowing through it at a rate of 0.5 m^3/s and a depth of 0.6 m. A cross section of the channel is constricted to a width of 0.9 m. What is the change in water surface elevation at this point?

Choose Section 1 (upstream) and Section 2 (constricted)

$$y_1 + \frac{v_1^2}{2g} + z_1 = y_2 + \frac{v_2^2}{2g} + z_2 \qquad \text{Neglect } \Delta z$$

$$y_1 = 0.6m$$

$$A_1 = B_1 y_1 = (1.4)(0.6) = 0.84m^2$$

$$V_1 = Q/A_1 = \left(0.5\, m^3/s\right) 0.84m^2 = 0.595\, m/s$$

$$V_2 = Q/A_2 = \left(0.5\, m^3/s\right)(0.9y_2) = 0.556 / y_2$$

Then: $$y_1 + \frac{v_1^2}{2g} = y_2 + \frac{v_2^2}{2g} \qquad \text{Neglect } \Delta z$$

Substitute: $$0.6 + \frac{(0.595)^2}{(9.81)(2)} = y_2 + \frac{(0.556 / y_2)^2}{2(9.81)}$$

$$0.618 = y_2 + 0.016 / y_2^2$$

Solve by trial and error:

$$y_2 \cong 0.57m$$

Thus, change in water surface is

$$\Delta y = -(0.60 - 0.57)$$

$$\Delta y = -0.03 \text{ (drops from sections 1 to 2)}$$

Problems 7.18 through 7.20 refer to the watershed shown in Figs. P7.18(a) and (b).

Cypress Creek has a rectangular cross section with a bottom width of 200 ft, n = 0.03, and S_0 = 0.001 ft/ft. East Creek has the same characteristics except that the bottom width is 100 ft. The 100-yr storm hydrographs are shown for both creeks. The assumption is made that the flow in the creeks remains constant above point C and that the 100-yr hydrograph for Cypress Creek includes the inflow from East Creek at point C.

7.18. Determine the normal and critical depths for both creeks for the 100-yr peak flow.

For Cypress Creek, we have:

B = 200 ft

n = 0.03

S_0 = 0.001 ft/ft

Q_{100} = 13,729 cfs

$$A = By_n = 200y_n$$

$$P = B + 2y_n = 200 + 2y_n$$

$$R = 200y_n / (200 + 2y_n)$$

$$13,729 = \frac{1.49}{0.03}(200y_n)\left(\frac{200y_n}{200+2y_n}\right)^{2/3}\sqrt{0.001}$$

$$\frac{(200y_n)^{5/3}}{(200+2y_n)^{2/3}} = 8741$$

$$\boxed{y_n = 10.02\,ft}$$

$$A_c = 200y_c$$

$$\frac{Q^2}{g} = \frac{A^3}{B}$$

$$\frac{(13,729)^2}{32.2} = \frac{(200y_c)^3}{200}$$

7.18. (cont) $y_c^3 = 146\,ft^3$

$$\boxed{y_c = 5.27\,ft}$$

For East Creek, we have:

B = 100 ft

A = $100y_n$

P = $100 + 2y_n$

$$\frac{(100y_n)^{5/3}}{(100+2y_n)^{2/3}} = 2610$$

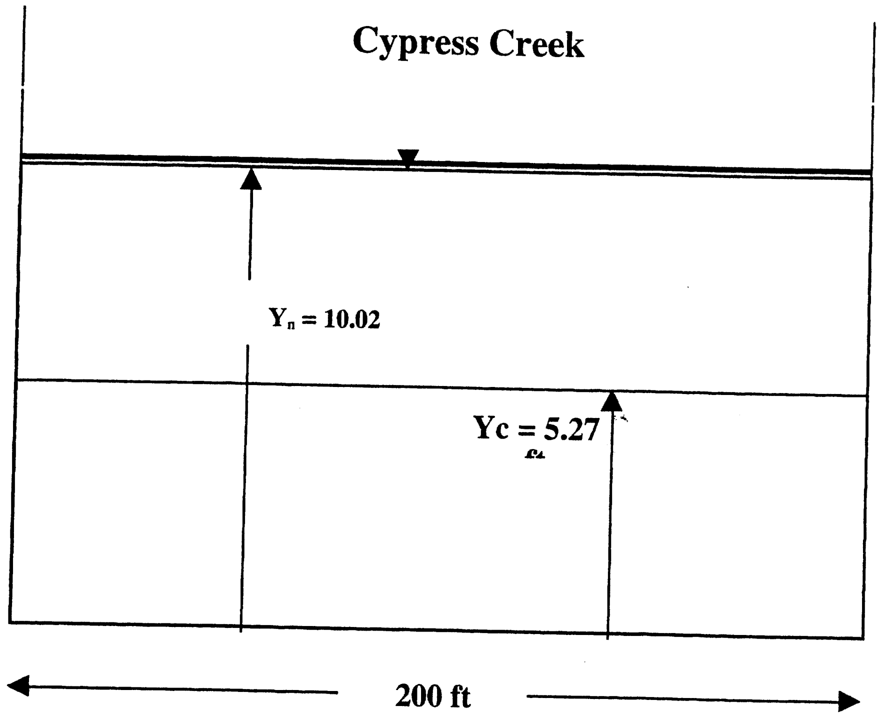
$$\boxed{y_n = 7.49\,ft}$$

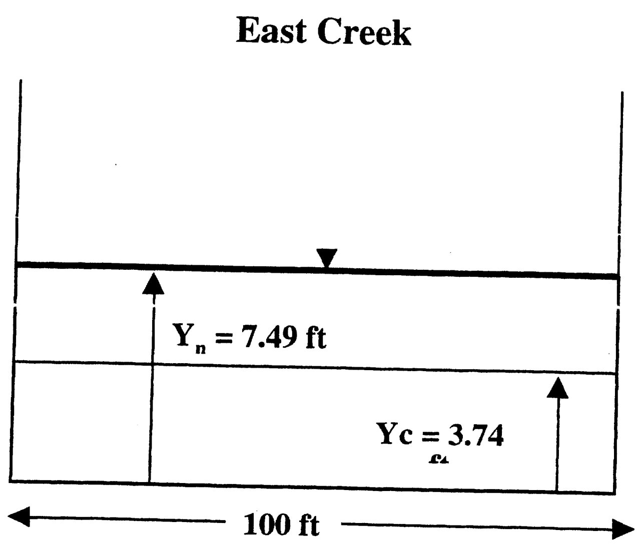
$$\frac{(4100)^2}{32.2} = \frac{(100y_c)^3}{100}$$

$$y_c^3 = 52.2\,ft^3$$

$$\boxed{y_c = 3.74\,ft}$$

7.18. (cont)


Cypress Creek
Yn = 10.02
Yc = 5.27
ft
200 ft


East Creek
Yn = 7.49 ft
Yc = 3.74
ft
100 ft

7.19. Assume that East Creek meets Cypress Creek as shown. Using a starting elevation at point *C* consistent with the 100-yr flow in Cypress Creek, develop the 100-yr water surface profile for East Creek. Use six points between the starting elevation and the elevation $y = 1.1\, y_n$.

The starting elevation will be the normal depth found in Problem 7.18 which was 10.02 ft. The elevation y = $1.1y_n$ is:

$$y = (1.1)(7.49\, ft)$$

$$y = 8.24\, ft$$

Using Eq. 7.22, we get:

y (m)	A (m^2)	P (m)	R (m)	V (m/s)	Rm (m)	Vm (m/s)	S	$y + \frac{V^2}{2g}$ (m)	ΔX (m)	X (m)
10.02	1002	120.04	8.374	4.092				10.28		0
					8.253	4.149	0.000418		-447	
9.75	975	119.50	8.159	4.205				10.02		-447
					7.983	4.319	0.000474		-875	
9.25	925	118.50	7.806	4.432				9.56		-1322
					7.627	4.559	0.000561		-1071	
8.75	875	117.50	7.447	4.686				9.09		-2393
					7.261	4.831	0.000673		-1437	
8.24	824	116.48	7.074	4.976				8.62		-3830

Thus, we can see that Cypress Creek has a backwater effect extending about 4000 ft. upstream on East Creek.

7.20. A developer proposes improvements to the East Creek subwatershed that will increase the peak flow of the 100-yr storm by 1000 cfs. The developer contends that there will be no change in the 100-yr elevations on the East Creek above point *C*. Determine the 100-yr water surface profile for East Creek. Use an interval of $\Delta y = 0.15$ ft. up to $y = 1.1\ y_n$. Discuss.

The normal depth for East Creek will be different.

$$5100 = \frac{1.49}{0.03}(100y_n)\left(\frac{100y_n}{100+2y_n}\right)^{2/3}\sqrt{0.001}$$

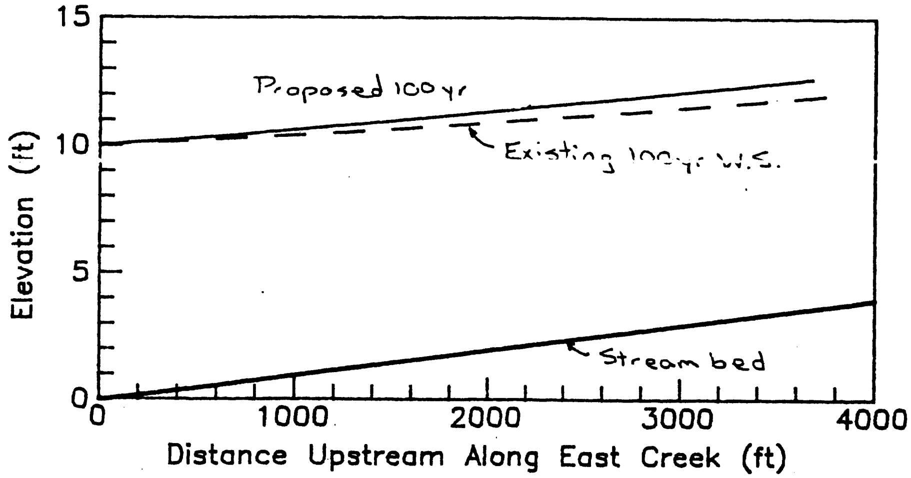
$$\frac{(100y_n)^{5/3}}{(100+2y_n)^{2/3}} = 3247$$

$$y_n = 8.60\,ft$$

$$1.1y_n = (1.1)(8.6) = 9.46\,ft$$

y (m)	A (m^2)	P (m)	R (m)	V (m/s)	Rm (m)	Vm (m/s)	S	$y+\frac{V^2}{2g}$ (m)	ΔX (m)	X (m)
10.02	1002	120.04	8.347	5.090				10.42		0
					8.288	5.134	0.000637		-416	
9.85	985	119.70	8.229	5.178				10.27		-413
					8.177	5.218	0.000670		-424	
9.70	970	119.40	8.124	5.258				10.13		-837
					8.071	5.299	0.000703		-471	
9.55	955	119.10	8.018	5.340				9.99		-1308
					7.986	5.366	0.00731		-297	
9.46	946	118.92	7.955	5.391				9.91		-1605
					7.791	5.529	0.000802		-2075	
9.00	900	118.0	7.627	5.667				9.50		-3680

7.20. (cont)



15
10
5
0
Elevation (ft)
Proposed 100 yr
Existing 100 yr W.S.
Stream bed
0
1000
2000
3000
4000
Distance Upstream Along East Creek (ft)

7.21. Lost Creek has a rectangular channel 2 mi in length (10,560 ft) with a wooden bridge in the middle of this reach (x = 5280 ft.) (see Fig. P7.21). The channel is dredged earth (n = 0.025) with a bottom width of 200 ft and a bed slope of 0.001. The computed 100-yr peak flow is 10,000 cfs for the entire 2-mi reach.

a) Compute the normal depth.

b) Compute the critical depth.

a) From Equation 7.4, $$V = \frac{1.49}{n} R^{2/3} \sqrt{S}$$

Knowing Q = VA, $$Q = \frac{1.49}{n} A R^{2/3} \sqrt{S}$$

Q = 10,000cfs

n = 0.025

S_0 = 0.001 ft/ft

b = 200 ft

$$R = A/P$$

$$A = y_n b = 200 y_n$$

$$P = 2y_n + b = 200 + 2y_n$$

$$R = \frac{200 y_n}{(200 + 2y_n)}$$

$$Q = \left(\frac{1.49}{0.025}\right)(200 y_n)\left(\frac{200 y_n}{200 + 2y_n}\right)^{2/3} \sqrt{0.001}$$

For Q = 10,000 cfs, $y_n = 7.35 ft$

b) From Equation 7.13, $$\frac{Q^2}{g} = \frac{A^3}{B}$$

Q = 10,000cfs

A = By_c

B = 200ft

7.21. (cont)

$$\frac{(10,000)^2}{32.2} = \frac{(200y_c)^3}{200}$$

$$y_c^3 = 77.64$$

$$\underline{y_c = 4.27\,ft}$$

7.22. For the channel in problem 7.21, the initial downstream water elevation is 10 ft. A house is to be built at a distance of $x = 2640$ ft upstream of the bridge.

a) At what elevation should the house foundation be built to ensure 100-yr flood protection (neglect effects of the bridge)? Note the water velocity just downstream of the bridge.

b) Compute the head loss through the bridge according to the Yarnell equation (Eq. 7.37) using $K = 0.95$, $a = 1/10$, and the velocity just downstream of the bridge as computed in part (a).

c) Determine slab elevation of the house for flood safety, taking into account the effects of the bridge. Compare the slab elevation in part (a) to that computed in part (b). What effect (if any) does the bridge have on the slab elevation?

a) To find total elevation of the slab, compute the water surface elevation usig the backwater program, and add this to the channel elevation due to bed slope.

According to the following table:

$\text{Elev.}_{BW} = 7.44$ ft

$\text{Elev.}_{BS} = 7920\,ft \cdot 0.001\, {}^{ft}\!/_{ft} = 7.92\,ft$

TOTAL ELEVATION = 7.44 + 7.92 = 15.36 ft

7.22. (cont)

y (L)	A rect (L^2)	P rect (L)	R=A/P (L)	V=Q/A (L/s)	Vm (L/s)	Rm (L)	S computed	y+ V^2/2g (L)	Δ x (L)	x (L)
10.00	2000	220.00	9.09	5.00				10.39		0
					5.06	8.99	0.04%		-375	
9.75	1950	219.50	8.88	5.13				10.16		-375
					5.20	8.78	0.04%		-393	
9.50	1900	219.00	8.68	5.26				9.93		-768
					5.33	8.57	0.05%		-417	
9.25	1850	218.50	8.47	5.41				9.70		-1185
					5.48	8.36	0.05%		-447	
9.00	1800	218.00	8.26	5.56				9.48		-1632
					5.63	8.15	0.05%		-488	
8.75	1750	217.50	8.05	5.71				9.26		-2120
					5.80	7.94	0.06%		-546	
8.50	1700	217.00	7.83	5.88				9.04		-2666
					5.97	7.73	0.07%		-633	
8.25	1650	216.50	7.62	6.06				8.82		-3299
					6.16	7.51	0.07%		-777	
8.00	1600	216.00	7.41	6.25				8.61		-4075
					6.36	7.29	0.08%		-1204	
7.72	1544	215.45	7.17	6.47	(LOCATION OF BRIDGE)			8.37		-5280
					6.53	7.12	0.09%		-818	
↑h3 7.60	1520	215.20	7.06	V3↗ 6.58				8.27		-6098
					6.65	7.00	0.09%		-1822	
7.44	1489	214.89	6.93	6.72	(LOCATION OF HOUSE)			8.14		-7920

b) Yarnell Equation, EQ. 7.37 = $H3 = 2K(K+10w-0.6)(a+15a^4)\left(\frac{V3^2}{2g}\right)$

H3 = Change in water surface elevation through bridge

K = 0.95 = Pier shape coefficient

a = 1/10 = Ratio (obstructed area/unobstructed area)

V3 = 6.47 ft/s = Velocity downstream from bridge

h3 = 7.72 ft = depth downstream from bridge

w = 0.084 = ratio (velocity head/depth) downstream from bridge = $\frac{V3^2/2g}{h3}$

$$H3 = 2(0.95)(0.95+10\cdot 0.084-0.6)\left(\frac{1}{10}+15\left(\frac{1}{10}\right)^4\right)\left(\frac{6.47^2}{2(32.2)}\right)$$

$$H3 = (1.9)(1.19)(0.1015)(0.65) = 0.15\,ft$$

7.22. (cont)

c)

y (L)	A rect (L^2)	P rect (L)	R=A/P (L)	V=Q/A (L/s)	Vm (L/s)	Rm (L)	S computed	y+ V^2/2g (L)	Δ x (L)	x (L)
7.87	1574	215.74	7.30	6.35	(LOCATION OF BRIDGE)			8.50		-5280
					6.40	7.24	0.08%		-566	
7.75	1550	215.50	7.19	6.45				8.40		-5846
					6.49	7.15	0.09%		-601	
7.65	1530	215.30	7.11	6.54				8.31		-6447
					6.58	7.06	0.09%		-817	
7.55	1510	215.10	7.02	6.62				8.23		-7264
					6.65	7.00	0.09%		-657	
7.494	1499	214.99	6.97	6.67	(LOCATION OF HOUSE)			8.18		-7920

Again, we apply the backwater calculation. At the upstream edge of the bridge, we find the water surface elevation by adding the losses calculated in Part b.) to the downstream bridge elevation in a).

$$Elev._{upstream} = 0.15 \text{ ft} + 7.72 \text{ ft} = 7.87 \text{ ft}$$

The slab elevation now becomes:

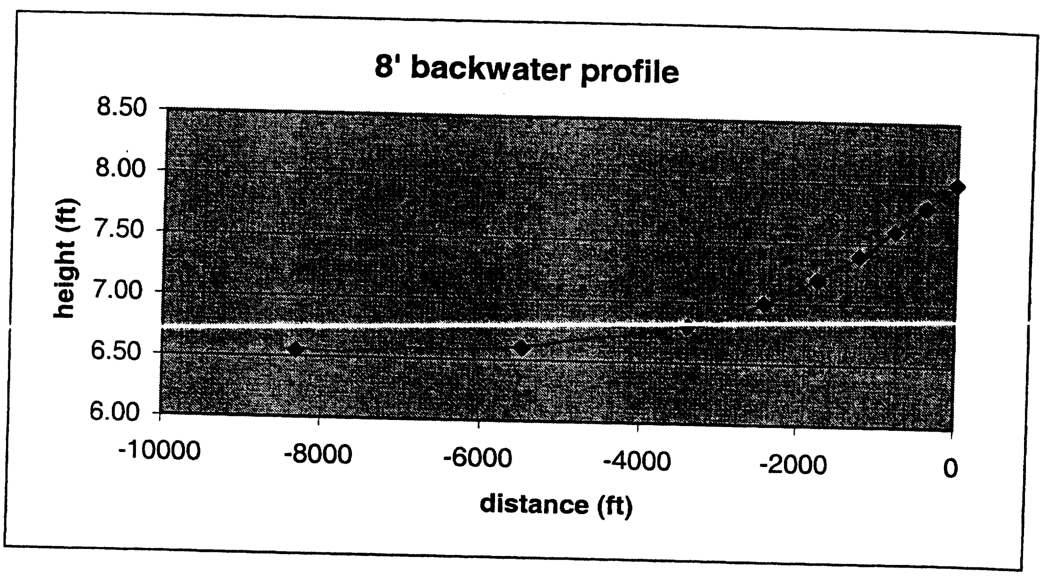
Total Elevation = 7.494 ft + 7.92 ft = <u>15.414 ft.</u>

This is roughly 0.05 ft greater than the slab elevation in part a), which is not a significant effect due to the bridge.

7.23. Derive the backwater curve for Example 7.5 with a starting downstream elevation of 8.0 ft. Repeat the calculation for 9.0 ft. All other parameters remain the same.

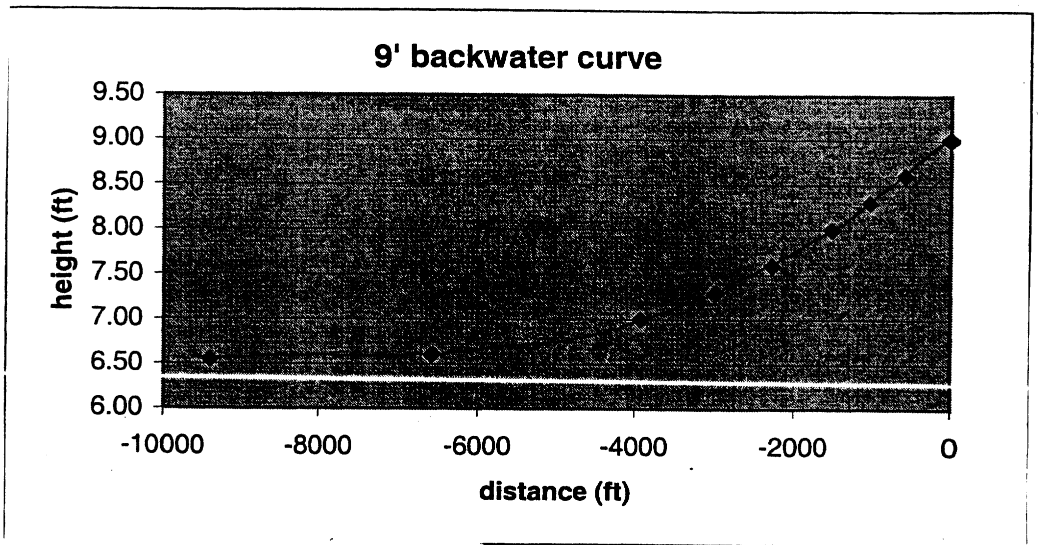
Starting downstream elevation of 8.0 ft:

y (L)	A (L^2)	P (L)	R=A/P (L)	V=Q/A (L/s)	Vm (L/s)	Rm (L)	S computed	y+ V^2/2g (L)	del x (L)	x (L)
8.00	256.00	48.84	5.24	3.91				8.24		0
7.80	247.26	48.12	5.14	4.04	3.98	5.19	0.000495	8.05	-362	-362
7.60	238.64	47.40	5.03	4.19	4.12	5.09	0.000546	7.87	-399	-761
7.40	230.14	46.68	4.93	4.35	4.27	4.98	0.000603	7.69	-452	-1213
7.20	221.76	45.96	4.83	4.51	4.43	4.88	0.000667	7.52	-533	-1746
7.00	213.50	45.24	4.72	4.68	4.60	4.77	0.00074	7.34	-674	-2420
6.80	205.36	44.52	4.61	4.87	4.78	4.67	0.000824	7.17	-979	-3399
6.60	197.34	43.80	4.51	5.07	4.97	4.56	0.000919	7.00	-2097	-5496
6.55	195.35	43.62	4.48	5.12	5.09	4.49	0.000985	6.96	-2824	-8319

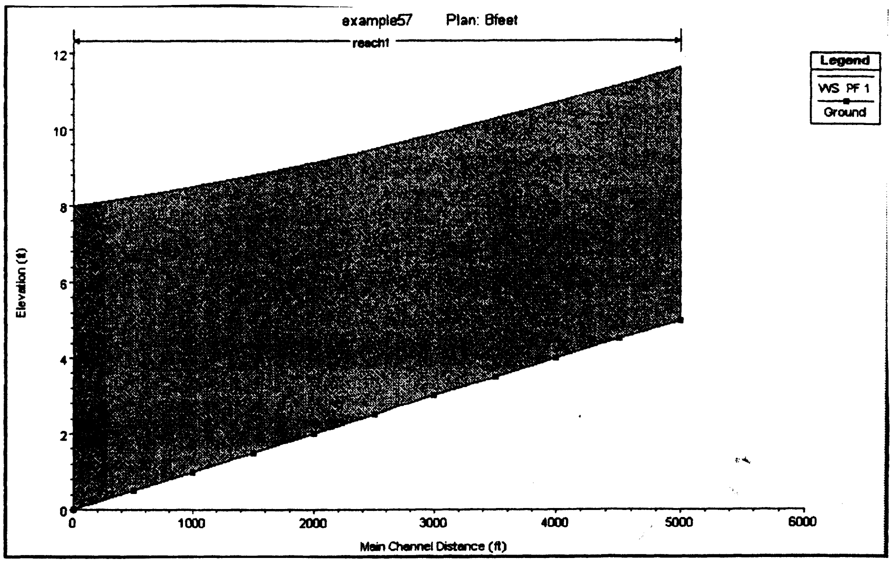


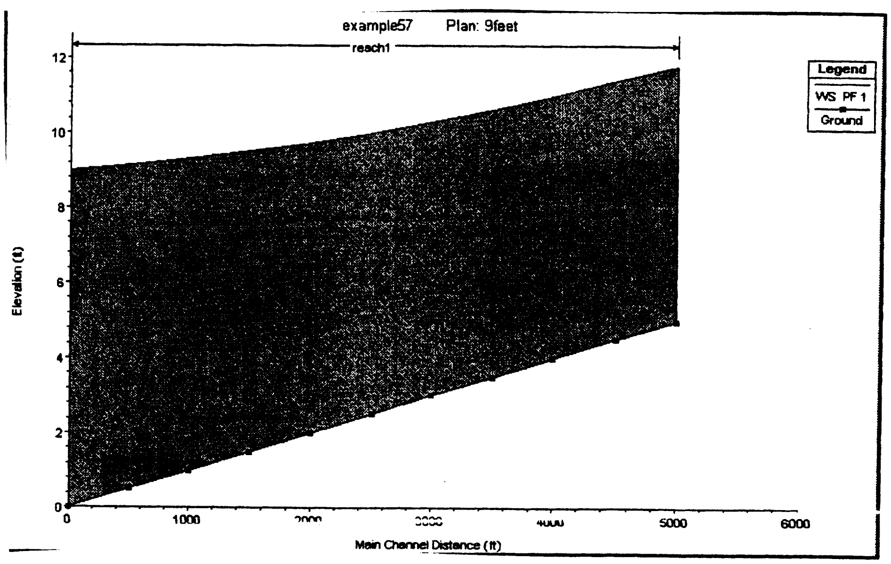
7.23. (cont) Starting downstream elevation of 9.0 ft:

y (L)	A (L^2)	P (L)	R=A/P (L)	V=Q/A (L/s)	Vm (L/s)	Rm (L)	S computed	y+ V^2/2g (L)	del x (L)	x (L)
9.00	301.50	52.45	5.75	3.32				9.17		0
					3.43	5.65	0.000328		-561	
8.60	282.94	51.01	5.55	3.53				8.79		-561
					3.62	5.47	0.000383		-454	
8.30	269.33	49.93	5.39	3.71				8.51		-1015
					3.81	5.32	0.00044		-495	
8.00	256.00	48.84	5.24	3.91				8.24		-1510
					4.05	5.14	0.00052		-760	
7.60	238.64	47.40	5.03	4.19				7.87		-2270
					4.31	4.96	0.000618		-704	
7.30	225.93	46.32	4.88	4.43				7.60		-2973
					4.55	4.80	0.000722		-947	
7.00	213.50	45.24	4.72	4.68				7.34		-3920
					4.88	4.61	0.000872		-2662	
6.60	197.34	43.80	4.51	5.07				7.00		-6583
					5.09	4.49	0.000985		-2824	
6.55	195.35	43.62	4.48	5.12				6.96		-9406



7.24. Set up the input data structure to run Example 7.5 using HEC-RAS, with a starting downstream elevation of (a) 8.0 and (b) 9.0 ft.



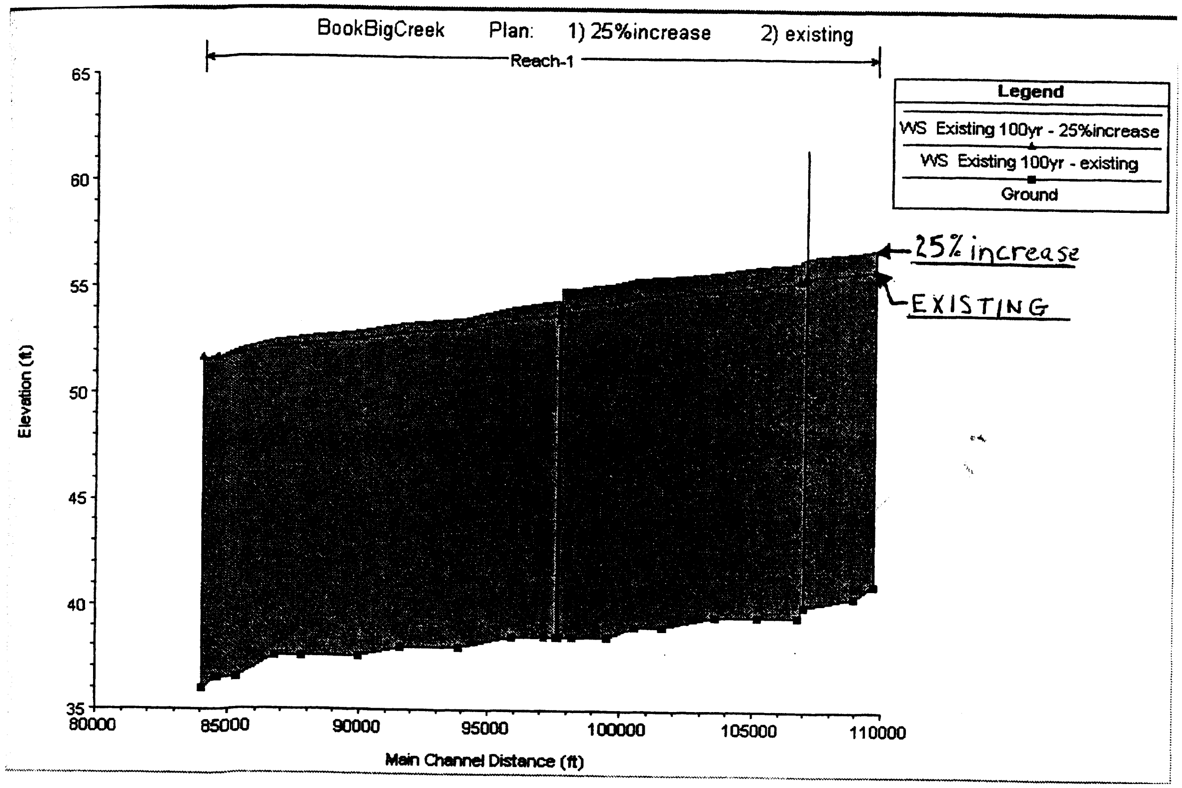


7.25. Refer to the HEC-RAS user's manua as needed. Run the sample river dataset provided in the tutorial.

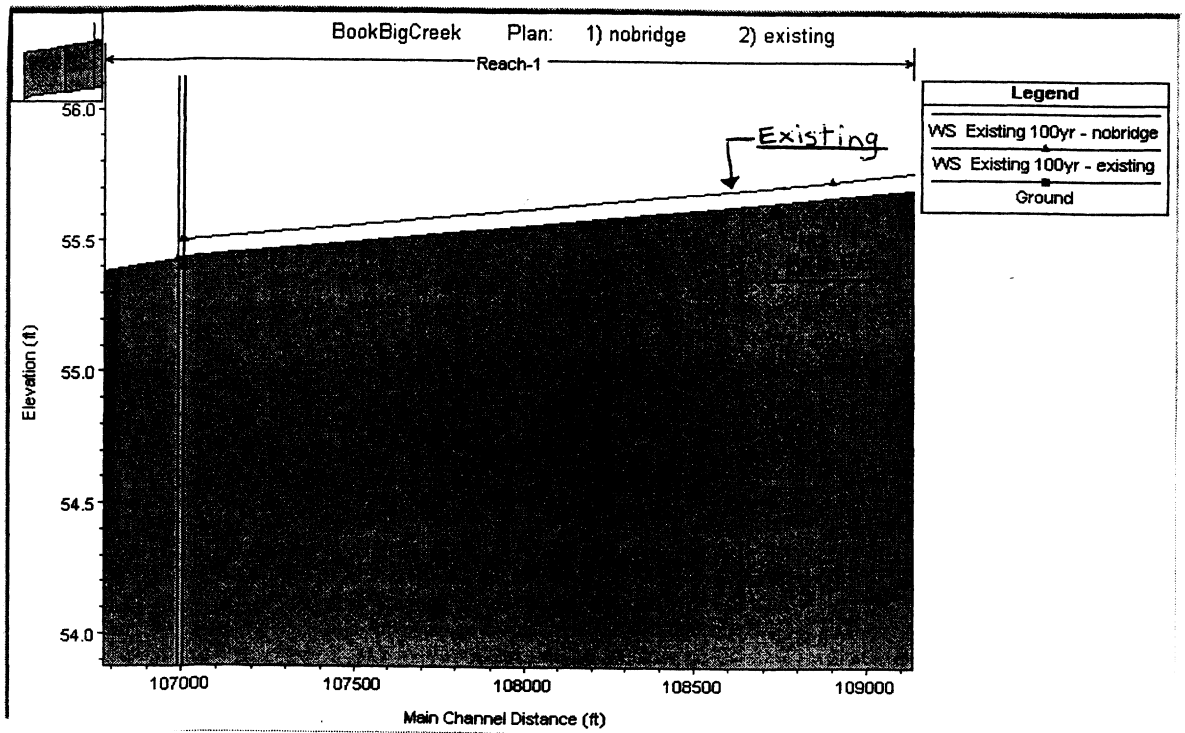
Please contact Dr. Philip Bedient at bedient@rice.edu for solution.

For problems 7.26–7.30, set up the Big Creek data for Example 7.7, available from the Prentice Hall Web site (see Appendix E).

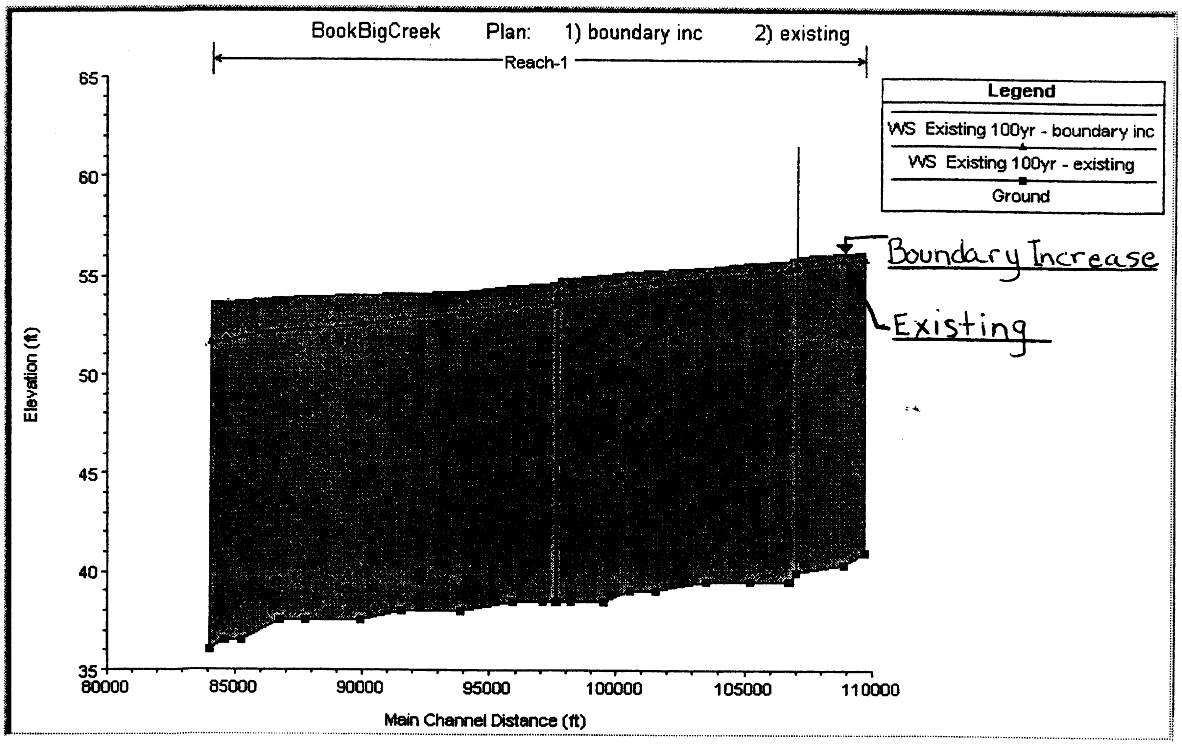
7.26. Run the existing condition 100-year floodplain and plot the profile output with HEC-RAS. Rerun the model with a 25% increase in flow rate and compare.



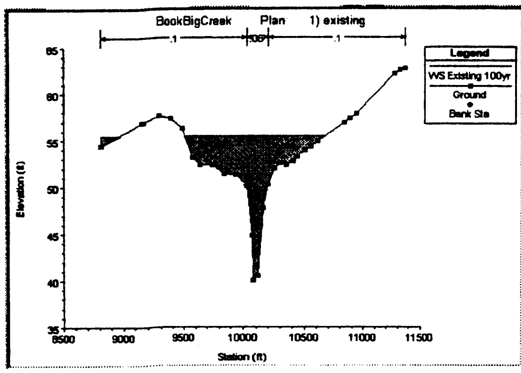
7.27. Evaluate the effect of removing the upstream bridge at section 106365 on the backwater profile in HEC-RAS.

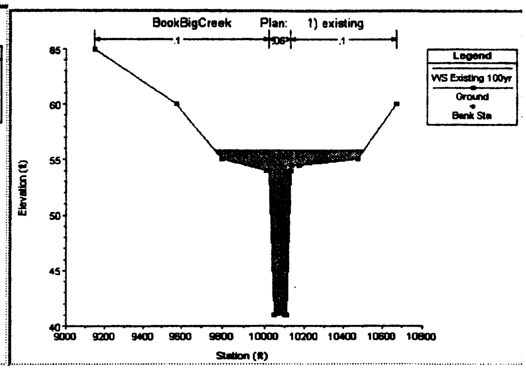


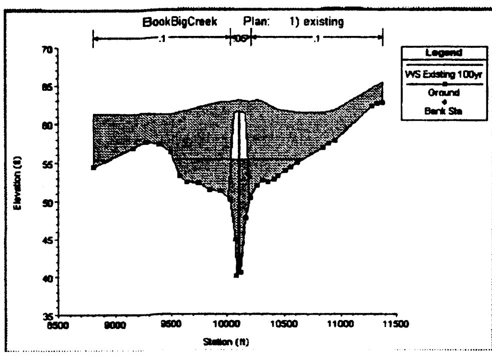
7.28. Evaluate the effect of increasing the downstream boundary condition water elevation by 2.0 ft in HEC-RAS.

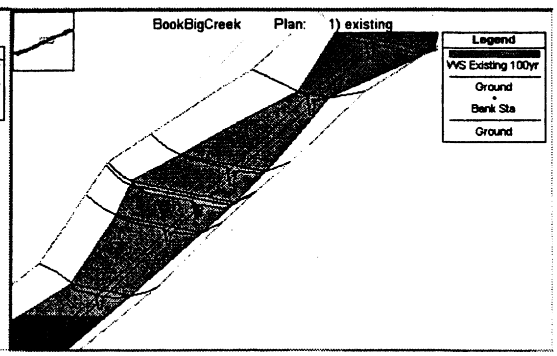


7.29. Run the existing condition 100-year floodplain and plot three cross sections as well as the X-Y-Z perspective plot with HEC-RAS.









7.30. Set up the Big Creek data for Example 7.7, available from the Prentice Hall Web site (see Appendix E). Investigate the effects of changing Manning's n values for the channel from 0.04 to 0.06 and from 0.08 to 0.10 for out of bank areas in HEC-RAS.