6.5.3

From Eq'n 6.20: $\Delta E = (y_2 - y_1)^3/(4y_1y_2)$

$\mathbf{\Delta E} = (3.00 - 0.66)^3/(4 \cdot 0.66 \cdot 3.00) = \mathbf{1.62\ ft;}$

From Eq'n 6.18: $N_{F1} = V_1/(gy_1)^{1/2}$; where $V_1 = q/y_1$

Now using Eq'n 6.16: $q^2/g = y_1 \cdot y_2[(y_1 + y_2)/2]$;

$q^2/(32.2) = 0.66 \cdot 3.0[(0.66 + 3.0)/2]$; $q = 10.8\ ft^3/sec\text{-}ft$

Now, $V_1 = q/y_1 = 10.8/0.66 = 16.4$ ft/s

$\mathbf{N_{F1}} = V_1/(gy_1)^{1/2} = 16.4/(32.2 \cdot 0.66)^{1/2} = \mathbf{3.56}$
(supercritical)

Alternate solution to determine the Froude number:

$y_2/y_1 = ½[(1 + 8N_{F1}^2)^{1/2} - 1]$;

$3.0/0.66 = ½[(1 + 8N_{F1}^2)^{1/2} - 1]$;

$\mathbf{N_{F1} = 3.55}$ **(supercritical)**

6.5.6

$y_c = [(Q^2/(gb^2)]^{1/3} = [(15^2/(9.81 \cdot 10^2)]^{1/3} = \mathbf{0.612\ m}$

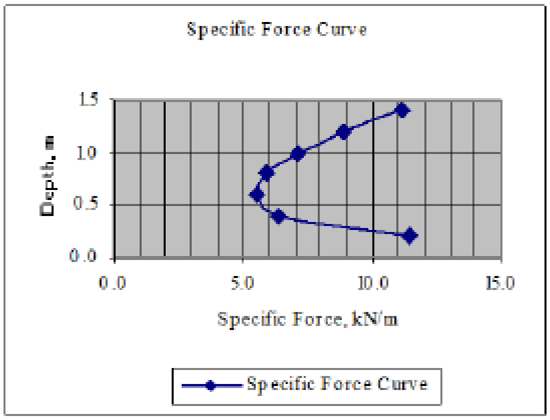
Minimum specific energy occurs at critical depth.

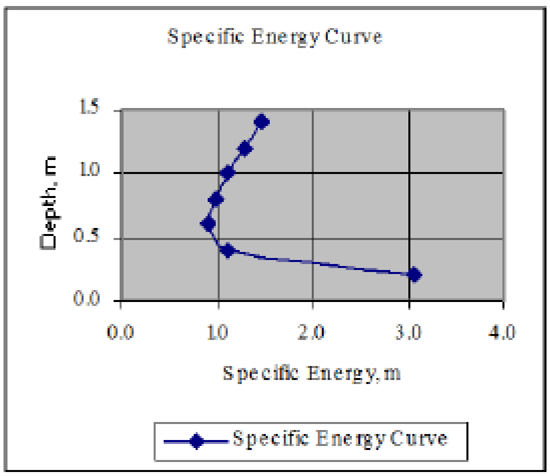
$\mathbf{E_{min}} = V_c^2/2g + y_c = [15/(10 \cdot 0.612)]^2/2g + 0.612m = \mathbf{0.918m}$

Using Eq'ns (6.8) and (6.19): $E = V^2/2g + y$ and

$F_s = F + \rho qV = (\gamma/2)y^2 + \rho(Q/b)V$; $\gamma = 9790\ N/m^3$
$\rho = 998\ kg/\ m^3$

Depth (m)	Area $(m)^2$	V (m/sec)	E (m)	F_s (kN/m)
0.2	2.0	7.50	3.1	11.4
0.4	4.0	3.75	1.1	6.4
0.6	6.0	2.50	0.9	5.5
0.8	8.0	1.88	1.0	5.9
1.0	10.0	1.50	1.1	7.1
1.2	12.0	1.25	1.3	8.9
1.4	14.0	1.07	1.5	11.2





From continuity, an increase in discharge will increase the depth. This will, in turn, increase the forces causing the specific force curve to move up and to the right.

6.8.2

Channel and flow classification requires three depths: critical, normal, and actual. Normal: use the Manning eq'n (and Table 6.1), Fig 6.4, or computer software. Critical: use Eq'n 6.14 or computer software; e.g., www.eng.auburn.edu/~xzf0001/Handbook/Channels.html

y_n = 1.18 m; y_c = 1.18 m. Since $y_n = y_c$, the channel is critical. Since y/y_c and y/y_n are greater than 1.0; flow is Type 1. **Classification is C-1** (see Fig 6.12)

6.8.5

Channel and flow classification requires three depths: critical, normal, and actual. The normal depth given can be checked using the Manning equation (and Table 6.1), Fig 6.4, or computer software. Critical depth can be checked using Equation 6.14 or computer software. Both depths check: **y_n = 6.52 ft** and **y_c = 3.68 ft.** Since $y_n > y_c$, the channel is mild. Since the depth of flow (4.00 ft) is between critical and normal, it is a type-2 curve; the full **classification is M-2** (see Fig. 6.12). Therefore, the depth rises as you move upstream. The depth of flow 100 ft upstream from the location where the depth is 4.00 ft is **5.18 ft** as computed in the following energy balance.

Note: The url for one Manning calculator is: **www.eng.auburn.edu/~xzf0001/Handbook/Channels.html**

Section	y (ft)	z (ft)	A (ft^2)	V (ft/sec)	$V^2/2g$ (ft)	P (ft)	R_h (ft)	S_e	$S_{e(avg)}$	$h_L = \Delta L \cdot S_{e(avg)}$ (ft)	Total Energy (ft)
1	4.00	0.000	160.0	10.00	1.553	48.0	3.33	1.11E-02	8.04E-03	0.804	6.356
2	5.18	0.250	207.2	7.72	0.926	50.4	4.11	4.99E-03	ΔL =	100	6.356

Notes: A spreadsheet is an efficient way to solve this iterative problem. The depth at section 1 is known, and the depth at section 2 is to be found. Assume a channel bottom elevation at section 1 (in this case, we assumed 0.00 ft, MSL.) The channel elevation at section 2 can be determined with the channel slope and distance between sections. The usual equations are applied to solve for area, velocity, velocity head, wetted perimeter, and hydraulic radius. The energy grade line slope S_e is found using the Manning equation; in this case $S_e = n^2V^2/[2.22*R_h^{4/3}]$ (Eq'n 6.27b). Total energy is found by adding energy components (Figure 6.14). Once the spreadsheet equations are programmed, guess the depth at section 2 until total energies at sections 1 and 2 are equal. In this case, the distance step (and thus the elevation difference) is probably too great to be very accurate.

6.8.10

The complete solution to Example 6.10 is displayed in the spreadsheet program results shown below based on the direct step method and the prescribed depths. Refer to example 6.10 to determine the appropriate equations for the various cells. Note that the downstream distances obtained compare very closely to the distances prescribed in the original problem. In other words, the standard step method and the direct step method yield very similar results.

Sec #	U/D	y (ft)	A (ft^2)	P (ft)	R_h (ft)	V (ft/sec)	$V^2/2g$ (ft)	E (ft)	S_e	ΔL (ft)	Distance to Dam (ft)
1	U	2.76	24.90	15.843	1.571	7.431	0.8575	3.6175	0.00659		0
2	D	**2.66**	23.46	15.396	1.524	7.885	0.9655	3.6255	0.00773	1.66	**1.66**
	Determine how far downstream it is before the depth reduces to 2.66 ft.										
2	U	2.66	23.46	15.396	1.524	7.885	0.9655	3.6255	0.00773		1.66
3	D	**2.58**	22.34	15.038	1.486	8.280	1.0646	3.6446	0.00882	5.12	**6.78**
	Determine how far downstream it is before the depth reduces to 2.58 ft.										
3	U	2.58	22.34	15.038	1.486	8.280	1.0646	3.6446	0.00882		6.78
4	D	**2.51**	21.39	14.725	1.452	8.651	1.1621	3.6721	0.00992	10.4	**17.2**
	Determine how far downstream it is before the depth reduces to 2.51 ft.										
4	U	2.51	21.39	14.725	1.452	8.651	1.1621	3.6721	0.00992		17.2
5	D	**2.42**	20.18	14.323	1.409	9.166	1.3047	3.7247	0.01159	42.3	**59.5**
	This is within 2% of normal depth.										

6.8.14

Normal/critical depths: **y_n = 2.190 m; y_c = 1.789 m.** **(Rf: http://www.eng.auburn.edu/~xzf0001/Handbook/Channels.html)**
Since $y_n > y_c$, the channel is mild. Since the depth of flow (5.8 m) is greater than both, it is a type-1 curve; the full classification is **M-1** (see Fig. 6.12). Thus, the depth decreases as you move upstream. The water surface profile is given below. (Note: $R_h = A/P$ and $S_e = n^2V^2/R_h^{(4/3)}$; from the Manning Eq'n)

Water Surface Profile (Problem 6.8.12)

Q =	44.0	m^3/sec				y_c =	2.19	m
S_o =	0.004		b =	3.6	m	y_n =	1.789	m
n =	0.015		m =	2		g =	9.81	m/sec^2

Section	y (m)	z (m)	A (m^2)	V (m/sec)	$V^2/2g$ (m)	R_h (m)	S_e	$S_{e(avg)}$	$\Delta L \cdot S_{e(avg)}$ (m)	Total Energy (m)
1	5.80	0.000	88.16	0.499	0.013	2.985	1.30E-05	2.24E-05	0.006	5.818
2	**4.79**	1.000	63.13	0.697	0.025	2.523	3.18E-05	ΔL =	250	5.815
2	4.79	1.000	63.13	0.697	0.025	2.523	3.18E-05	6.32E-05	0.016	5.831
3	**3.77**	2.000	42.00	1.048	0.056	2.053	9.47E-05	ΔL =	250	5.826
3	3.77	2.000	42.00	1.048	0.056	2.053	9.47E-05	2.43E-04	0.061	5.887
4	**2.73**	3.000	24.73	1.779	0.161	1.565	3.92E-04	ΔL =	250	5.891
4	2.73	3.000	24.73	1.779	0.161	1.565	3.92E-04	1.22E-03	0.220	6.112
5	**1.84**	3.720	13.40	3.285	0.550	1.132	2.06E-03	ΔL =	**180***	6.110

*Note: The last interval only needed to be 180 m to get within 2% of the normal depth.