



Find:  $y_1$

$$E_1 = E_2 + \Delta z + h_L$$

$$y_1 + \frac{Q^2}{2gA_1^2} = y_2 + \frac{Q^2}{2gA_2^2} + (-1 \text{ ft}) + K_L \left| \frac{1}{A_2^2} - \frac{1}{A_1^2} \right| \frac{Q^2}{2g}$$

$$A_2 = y_2 (b_2 + m y_2) = 22 \text{ ft} (75 \text{ ft} + 2(22 \text{ ft}))$$
$$= 2218 \text{ ft}^2$$

$$A_1 = b_1 y_1 = (49 \text{ ft}) y_1 = 49 y_1$$

See Excel sheet below

#### Problem 2.6

Upstream rectangular cross section

$$b_1 = 49 \text{ ft}$$

Downstream trapezoidal cross section

$$b_2 = 75 \text{ ft} \quad g = 32.2 \text{ ft/s}^2$$

$$m = 2$$

$$y_2 = 22 \text{ ft}$$

$$Q = 12600 \text{ cfs}$$

$$\Delta z = -1 \text{ ft}$$

$$K_L = 0.5$$

$$E_1 = E_2 + \Delta z + h_L$$

$$y_1 + \frac{Q^2}{2gA_1^2} = y_2 + \frac{Q^2}{2gA_2^2} + \Delta z + K_L \left| \frac{1}{A_2^2} - \frac{1}{A_1^2} \right| \frac{Q^2}{2g}$$

$$A_2 = y_2 (b_2 + m y_2)$$

$$A_1 = b_1 y_1$$

$A_2 \text{ (ft}^2\text{)}$	$E_2 \text{ (ft)}$	$y_1 \text{ (ft)}$	$A_1 \text{ (ft}^2\text{)}$	$E_1 \text{ (ft) rhs}$	$h_L \text{ (ft)}$	$E_2 + \Delta z + h_L \text{ lhs}$	rhs - lhs
2618	22.36	19.88	974.17	22.48	1.12	22.48	1.4E-06

5.77 ft

19.88 ft

4.47 ft



- 6/ Problem 2.10 (i) Circular culvert  $d = 1.0$  m on steep slope at entrance.  
Upstream total head  $E_1 = 1.3$  m  
Find  $Q$   
(ii) Repeat (i) for square  $1.0$  m box culvert

(i) Circular pipe - see spreadsheet for equations for partially full circular pipe.

I tried different  $Q$  values, found the corresponding  $y_c$  for that  $Q$ , then found

$$E_c = y_c + \frac{V_c^2}{2gA_c^2}$$

I stopped at  $Q = 2.12 \text{ m}^3/\text{sec}$   $y_c = 0.83 \text{ m}$

- (ii) Box culvert  $b = 1.0$  m

$$E_1 = 1.3 \text{ m} = y_c + \frac{V_c^2}{2g} = E_c$$

For rectangular channel,  $E_c = \frac{3}{2} y_c$

$$\rightarrow y_c = \frac{2}{3} (1.3 \text{ m})$$

$$= 0.87 \text{ m}$$

$$\left( E_c = \frac{3}{2} (0.87 \text{ m}) = 0.87 \text{ m} + \frac{V_c^2}{2(9.81 \text{ m/s}^2)} \right)$$

$$(0.43 \text{ m}) (2(9.81 \text{ m/s}^2)) = V_c^2$$

$$V_c = 2.92 \text{ m/sec}$$

$$Q = VA = V_c b y_c = (2.92 \text{ m/sec})(1 \text{ m})(0.87 \text{ m})$$

$$Q = 2.54 \text{ m}^3/\text{sec}$$

Problem 2.10

$g = 9.81 \text{ m}^2/\text{sec}$

Upstream total energy = 1.3 m

Circular Pipe

$d = 1 \text{ m}$

$y_c \text{ (m)}$	$\theta_c \text{ (rad)}$	$A_c \text{ (m}^2\text{)}$	$B_c \text{ (m)}$	$A_c^3/B_c$	$Q \text{ (m}^3/\text{s)}$	$E_c \text{ (m)}$
0.83	4.60	0.70	0.75	0.457	2.116	1.30

$$\theta = 2 \cos^{-1} \left[ 1 - 2 \left( \frac{y_c}{d} \right) \right]$$

$$A = (\theta - \sin \theta) \frac{d^2}{8}$$

$$B = d \sin \left( \frac{\theta}{2} \right)$$

$$\frac{Q^2}{g} = \frac{A_c^3}{B_c}$$

$$E = y_c + \frac{Q^2}{2 g A_c^3}$$

Find  $y_c$  by Goal Seek for that Q, see if  $E_c = 1.30 \text{ m}$



2.15 Given USGS study of natural channels

$$\frac{y}{D} = 1.55 \text{ for 761 measurements}$$

Find: (a)  $\frac{y}{D}$  for (i) triangular  
(ii) parabolic  
(iii) rectangular channels

(b) Bankfull  $Q$  for  $F_r = 1.0$ ,  $\frac{y}{D} = 1.55$ ,  $B_1 = 100 \text{ ft}$ ,  $y_1 = 10 \text{ ft}$

(a) (i) triangular

$$D = \frac{A}{B} = \frac{\frac{1}{2} m y^2}{2 m y} = \frac{y}{2}$$

$$\frac{y}{D} = \frac{y}{y/2} = 2$$

(ii) parabolic

$$D = \frac{A}{B} = \frac{\frac{2}{3} B y}{B (y/y_1)^{3/2}} = \frac{\frac{2}{3} B y_1}{B} = \frac{2}{3} y_1$$

$$\frac{y}{D} = \frac{y}{\frac{2}{3} y_1} = \frac{y = y_1}{\frac{2}{3} y_1} = 1.5$$

(iii) rectangular

$$D = \frac{A}{B} = \frac{b y}{b} = y$$

$$\frac{y}{D} = \frac{y}{y} = 1$$

Natural channel closer to parabolic

$$(b) F_r = \frac{Q B_1^{1/2}}{g^{1/2} A_1^{3/2}}$$

$$Q = \frac{F_r g^{1/2} A_1^{3/2}}{B_1^{1/2}}$$

$$A_1 = D B_1 = \frac{y}{1.55} B_1 = \left( \frac{10 \text{ ft}}{1.55} \right) (100 \text{ ft}) = 645 \text{ ft}^2$$

$$Q = \frac{(1.0) (32.2 \text{ ft/s}^2)^{1/2} (645 \text{ ft})^{3/2}}{(100 \text{ ft})^{1/2}}$$

$$Q = 9300 \text{ cfs}$$

$F_r = 1$ , so this would be critical discharge

# Problem 2.19

Given: (i) Rectangular sharp-crested weir,  $L = 1.0$  ft,  $b = 5$  ft,  $P = 1.0$  ft  
(ii) 90° V-notch,  $P = 1.0$  ft

Find: Plot head vs.  $Q$  for  $H = 0$  to  $0.5$  ft

(i)

$$Q = \frac{2}{3} \sqrt{2g} C_{de} L_e H_e^{3/2}$$

$$L_e = L + k_L$$

$$H_e = H + k_H$$

$k_L = 0.0025$  m = 0.0082 ft Fig. 2.23[c]  
 $L_e = 1.0082$  ft  $C_{de}$  Fig. 2.23[b]  
 $k_H = 0.003$  ft  
 $L = 1$  ft  
 $b = 5$  ft  
 $P = 1$  ft  
 $L/b = 0.2$   
 $g = 32.2$  ft/s<sup>2</sup>

H (ft)	He (ft)	He/P	Cde	Q (cfs)
0	0	0	0.58	0.00
0.05	0.053	0.053	0.58	0.04
0.1	0.103	0.103	0.58	0.10
0.15	0.153	0.153	0.58	0.19
0.2	0.203	0.203	0.58	0.29
0.25	0.253	0.253	0.58	0.40
0.3	0.303	0.303	0.575	0.52
0.35	0.353	0.353	0.575	0.65
0.4	0.403	0.403	0.575	0.79
0.45	0.453	0.453	0.575	0.95
0.5	0.503	0.503	0.575	1.11

(ii)

$$Q = C_{de} \frac{8}{15} \sqrt{2g} \tan \frac{\theta}{2} H_e^{5/2}$$

$$H_e = H + k_H$$

$k_H = 0.0008$  m = 0.0026 ft Fig. 2.24[b]  
 $C_{de} = 0.578$

H (ft)	He (ft)	Q (cfs)
0	0	0.000
0.05	0.053	0.002
0.1	0.103	0.008
0.15	0.153	0.023
0.2	0.203	0.046
0.25	0.253	0.079
0.3	0.303	0.125
0.35	0.353	0.183
0.4	0.403	0.254
0.45	0.453	0.341
0.5	0.503	0.443

