University Of Technology
Building and Construction Eng. Dept.
Final Exam – 2012/2013
Subject :Hydraulic Structures
Branch :Water and Dams
Examiner :Asst. Prof. Dr. Jaafar S. Maatooq
Class:3rd year
Time : 3 Hours
Date : 9 / 6/ 2013
Form-C-

********* Closed Book Exam *********

Q1](A): Put the "True" or "False" signal for the following statements and "correct" the "False" one <u>(20%)</u>

1- As the kinematic energy increase at a specified pipe line for constant head loss , the friction factor also decrease .
2- The discharge through Module Outlet is dependent on water in supply channel .
3- The horizontal gravity force cause the flow in open channel and when it balance with the vertical component of a gravity force , the flow become uniform .
4- The steady uniform flow exists when there is no change in velocity along a channel reach .
5- The head loss is due to conversion of internal energy to potential energy .
6- The difference distance between EGL and HGL is an amount of pressure head .
7- When Fr1=3.6 , the hydraulic jump accordingly is classified as a steady jump .
8- The well representing a road crossing is "Aqueduct" structure .
9- A parshall flume is a flow measurement structures when it used in closed conduit it called gated valve .
10-When JHC is always lies above TWRC that is mean the hydraulic jump will occur above the chute of spillway .

(B): Answer <u>**One**</u> of the following improvements :- ***<u>(10%)</u>***

(a) The velocity at any section of uniform flow in open channel is according to Chezy's formula : $V=C\sqrt{R\,So}$.

(b) The General equation of critical depth computation is : $\frac{Q^2 T}{g A^3} = 1$

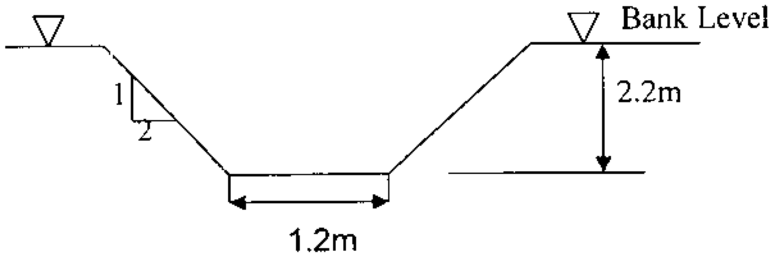
Q2] Answer <u>**one**</u> of the following :- ***<u>(15%)</u>***

(A) Compute the **friction factor** for flow having a Reynolds Number of $\mathbf{5x10^3}$ and relative roughness **e/D =0.01** by using :- (a) Moody Diagram (b) Colebrook Formula

(B) A 4ft Parshall flume is installed in an irrigation channel to monitor the rate of flow . The readings at gauges ha and hb are 2.5ft and 2ft respectively . Determine the channel discharge .

Q3] Answer <u>*One*</u> of the following :- <u>*(20%)*</u>

(A) For a trapezoidal canal its cross section shown in figure below . When using a contracted rectangular ***Sharp-crested*** weir its crest is **0.7m** above the bed of canal , the water raising above the crest **up to bank level** . **What is the safe <u>effective crest width</u> must be for the discharge 5.5m^3/s ? .**



(B) The head and velocity recorded at a gauge station of a trapezoidal shape **long-throated flume** are **0.6m** and **1.53m/s** respectively . The control section length , width , and side slope are ; **1.8m , 0.6m , and 1.5:1** respectively . Find the discharge .

Q4] The discharge is controlled from river into **4m** wide irrigation canal by vertical sluice gate . If canal has **n=0.028** and bed slope is **0.002** . Calculate the required gate opening and the flow condition downstream of the gate if the depth of flow in the river is **2m** and the irrigation demand is **11m^3/s** . <u>*(20%)*</u>

Q5] Answer <u>*One*</u> of the following :- <u>*(15%)*</u>

(A) The channel bed invert is drop **1.5m** , it convey the discharge **q=3m^3/s/m** . Use **y_{ds}= 2.1m** and find the free and submerged distance location of nappe .

(B) A concrete pipe culvert used to carry a flow rate of **5.3m^3/s.** At entrance , the max. available **HW=3.2m** above the culvert invert . The culvert length is **35m** and its slope is **0.003** . Use **n=0.024** , **Ke=0.5** and find a suitable diameter of this culvert if the exit is not submerged . (Note : Use hand calculation) .

******** Good Luck ********

Formulas for Solutions

- $Q = C_w B H_w^{3/2}$
- $Q = C_d A \sqrt{2g(H_w - \frac{D}{2})}$
- $H = \left(1 + k_e + \frac{20 n^2 L}{R^{4/3}}\right) \frac{V^2}{2g}$
- $H_w = h_o + H - L S_o$
- $h_f = f \frac{L}{D} \cdot \frac{V^2}{2g}$
- $\frac{1}{\sqrt{f}} = 2 \log \left(3.7 \frac{D}{e}\right)$
- $\frac{1}{\sqrt{f}} = -2 \log \left[\frac{e/D}{3.7} + \frac{2.51}{R_e \sqrt{f}}\right]$
- $Q_s = Q - Q_E$
- $B' = B - 0.1 n H$
- $Q = \frac{2}{3} \sqrt{2g}\ C_d B H^{3/2}$
- $Q = C_d \cdot \frac{8}{15} \sqrt{2g} \tan\frac{\theta}{2} \cdot H^{5/2}$
- $Q = C_o L H_o^{3/2}$
- $y/H_o = -K (X/H_o)^n$
- $Q = C B_t H^{3/2}$
- $Q = \frac{1}{n} A R^{2/3} S_o^{1/2}$
- $C_d = 0.61 / \sqrt{1 + 0.61 \left(\frac{G}{y_1}\right)}$
- $Q = C_d A \sqrt{2g(y_1 - 0.61 G)}$
- $y_1 \geq 0.81 y_2 (y_2/G)^{0.72}$
- $X_f/y_c = -0.406 + \sqrt{3.195 - 4.386 \left(\frac{h_{drop}}{y_c}\right)}$
- $X_t/y_c = -0.406 + \sqrt{3.195 - 4.386 \left(\frac{y_t + h_{drop}}{y_c}\right)}$
- $X_s/y_c = \dfrac{0.691 + 0.228 \left(\frac{X_t}{y_c}\right)^2 - \frac{h_{drop}}{y_c}}{0.185 + 0.456 \left(\frac{X_t}{y_c}\right)}$
- $y_c = \sqrt[3]{\frac{q^2}{g}}$
- $X_b = 0.8 y_c$
- $y_{end} = 0.4 y_c$
- $y_t \geq 2.15 y_c$
- $y_t = y_{ds} + y_{end}$
- $L = X_a + 2.55 y_c$
- $A = (b + zy) y$
- $P = b + 2y \sqrt{1 + z^2}$
- $T = b + 2zy$ (top width)
- $R = A/P$
- $D = A/T$ (hydraulic depth)
- $Fr = V/\sqrt{gD}$

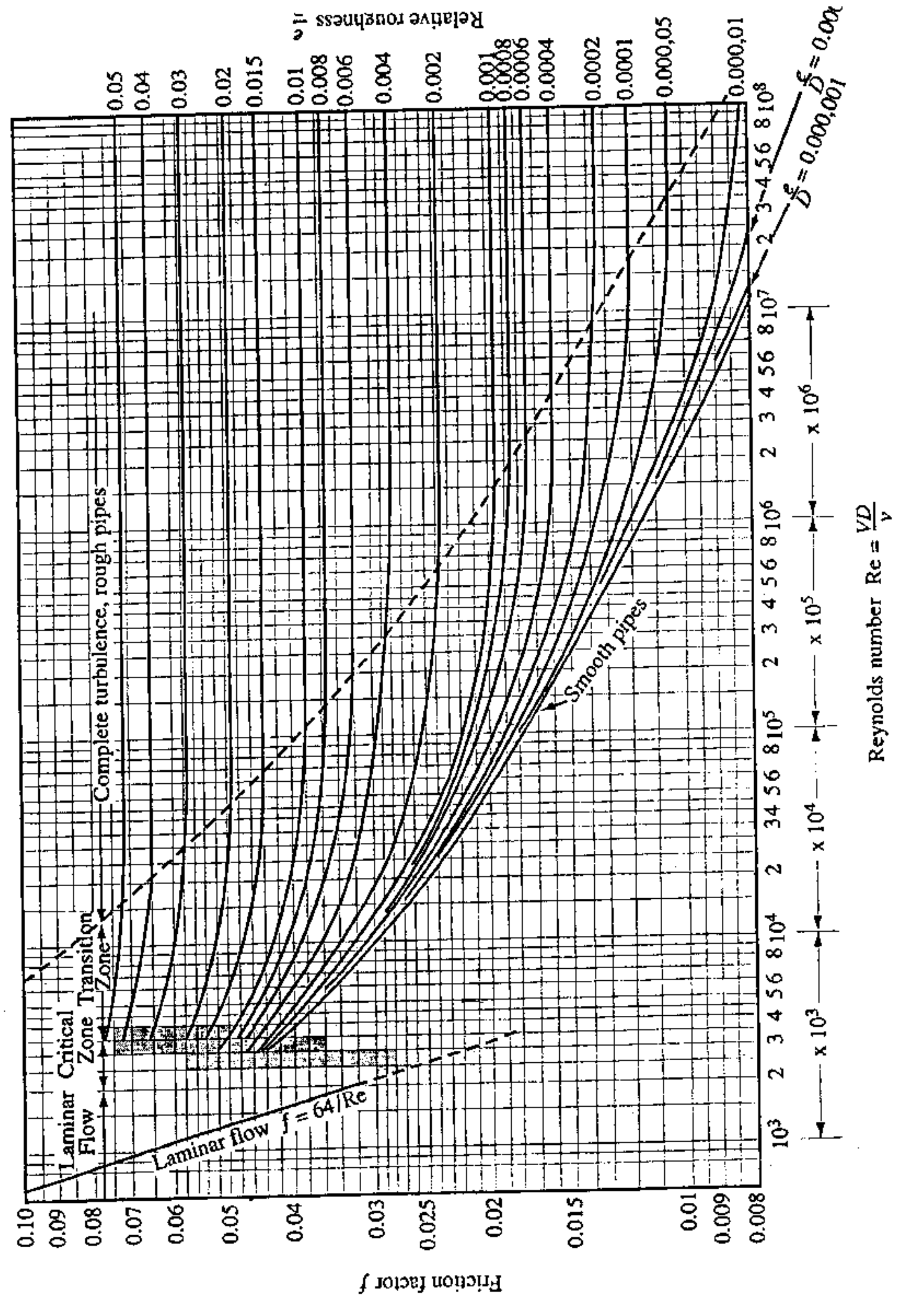


Table 7.1 Values of the ratio y_c/H_1 as a function of z_c and H_1/b_c for trapezoidal control sections

	Side slopes of channel, ratio of horizontal to vertical (z_c:1)									
H_1/b_c	Vertical	0.25:1	0.50:1	0.75:1	1:1	1.5:1	2:1	2.5:1	3:1	4:1
.00	.667	.667	.667	.667	.667	.667	.667	.667	.667	.667
.01	.667	.667	.667	.668	.668	.669	.670	.670	.671	.672
.02	.667	.667	.668	.669	.670	.671	.672	.674	.675	.678
.03	.667	.668	.669	.670	.671	.673	.675	.677	.679	.683
.04	.667	.668	.670	.671	.672	.675	.677	.680	.683	.687
.05	.667	.668	.670	.672	.674	.677	.680	.683	.686	.692
.06	.667	.669	.671	.673	.675	.679	.683	.686	.690	.696
.07	.667	.669	.672	.674	.676	.681	.685	.689	.693	.699
.08	.667	.670	.672	.675	.678	.683	.687	.692	.696	.703
.09	.667	.670	.673	.676	.679	.684	.690	.695	.698	.706
.10	.667	.670	.674	.677	.680	.686	.692	.697	.701	.709
.12	.667	.671	.675	.679	.684	.690	.696	.701	.706	.715
.14	.667	.672	.676	.681	.686	.693	.699	.705	.711	.720
.16	.667	.672	.678	.683	.687	.696	.703	.709	.715	.725
.18	.667	.673	.679	.684	.690	.698	.706	.713	.719	.729
.20	.667	.674	.680	.686	.692	.701	.709	.717	.723	.733
.22	.667	.674	.681	.688	.694	.704	.712	.720	.726	.736
.24	.667	.675	.683	.689	.696	.706	.715	.723	.729	.739
.26	.667	.676	.684	.691	.698	.709	.718	.725	.732	.742
.28	.667	.676	.685	.693	.699	.711	.720	.728	.734	.744
.30	.667	.677	.686	.694	.701	.713	.723	.730	.737	.747
.32	.667	.678	.687	.696	.703	.715	.725	.733	.739	.749
.34	.667	.678	.689	.697	.705	.717	.727	.735	.741	.751
.36	.667	.679	.690	.699	.706	.719	.729	.737	.743	.752
.38	.667	.680	.691	.700	.708	.721	.731	.738	.745	.754
.40	.667	.680	.692	.701	.709	.723	.733	.740	.747	.756
.42	.667	.681	.693	.703	.711	.725	.734	.742	.748	.757
.44	.667	.681	.694	.704	.712	.727	.736	.744	.750	.759
.46	.667	.682	.695	.705	.714	.728	.737	.745	.751	.760
.48	.667	.683	.696	.706	.715	.729	.739	.747	.752	.761
.5	.667	.683	.697	.708	.717	.730	.740	.748	.754	.762
.6	.667	.686	.701	.713	.723	.737	.747	.754	.759	.767
.7	.667	.688	.706	.718	.728	.742	.752	.758	.764	.771
.8	.667	.692	.709	.723	.732	.746	.756	.762	.767	.774
.9	.667	.694	.713	.727	.737	.750	.759	.766	.770	.776
1.0	.667	.697	.717	.730	.740	.754	.762	.768	.773	.778
1.2	.667	.701	.723	.737	.747	.759	.767	.772	.776	.782
1.4	.667	.706	.729	.742	.752	.764	.771	.776	.779	.784
1.6	.667	.709	.733	.747	.756	.767	.774	.778	.781	.786
1.8	.667	.713	.737	.750	.759	.770	.776	.781	.783	.787
2	.667	.717	.740	.754	.762	.773	.778	.782	.785	.788
3	.667	.730	.753	.766	.773	.781	.785	.787	.790	.792
4	.667	.740	.762	.773	.778	.785	.788	.790	.792	.794
5	.667	.748	.768	.777	.782	.788	.791	.792	.794	.795
10	.667	.768	.782	.788	.791	.794	.795	.796	.797	.798

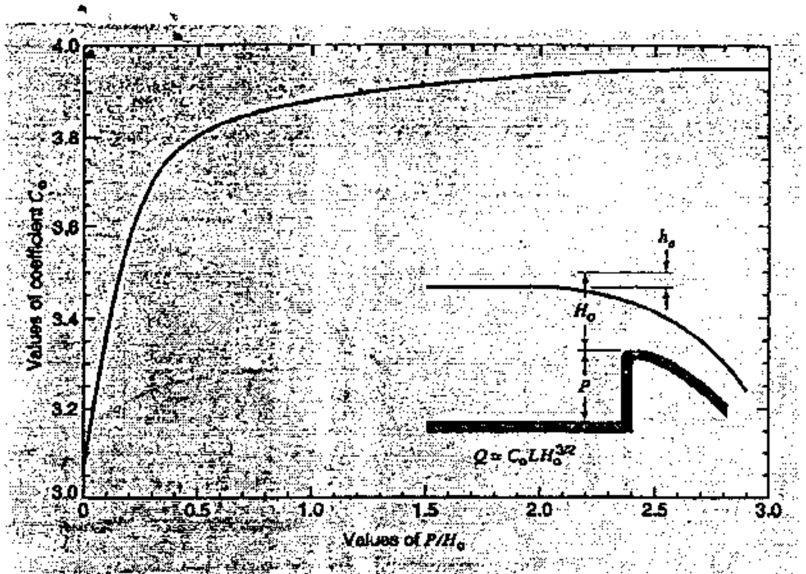


Figure 4 Discharge coefficients for vertical-faced ogee crest (from U.S. Bureau of Reclamation (1987)).

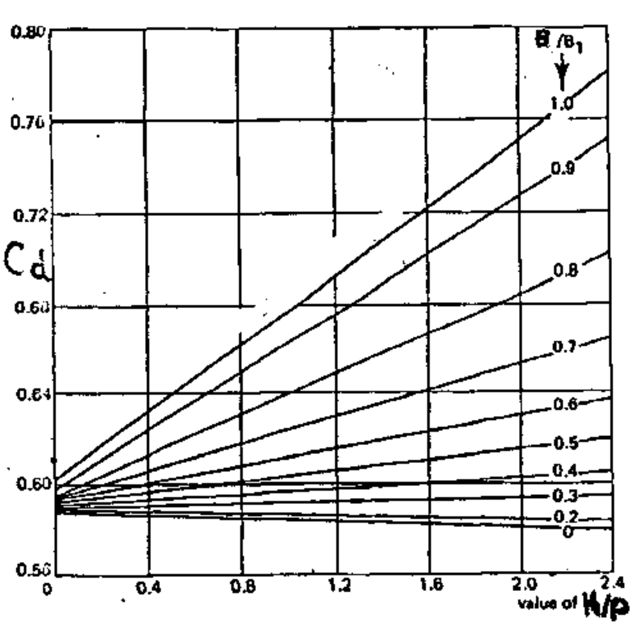
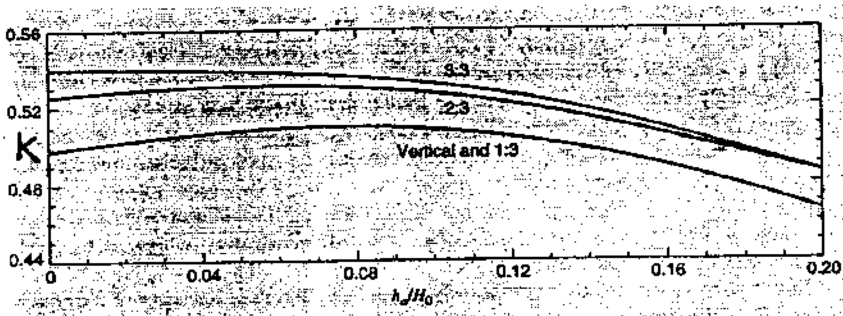
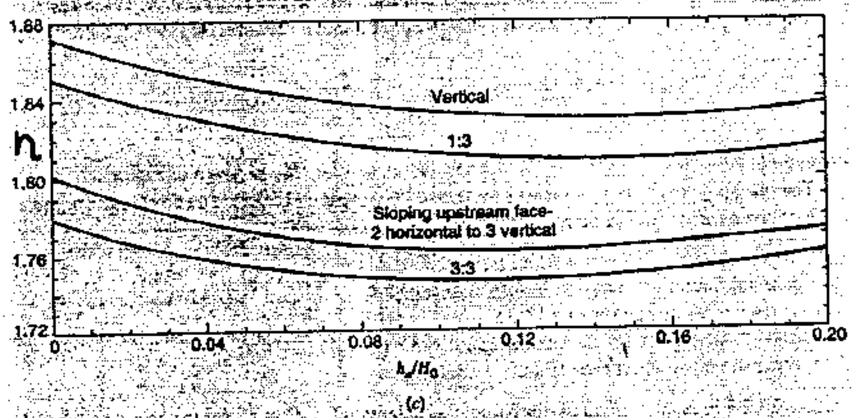


Figure 5.5 C_d as a function of the ratios B/B$_1$ and H/p (after Geo





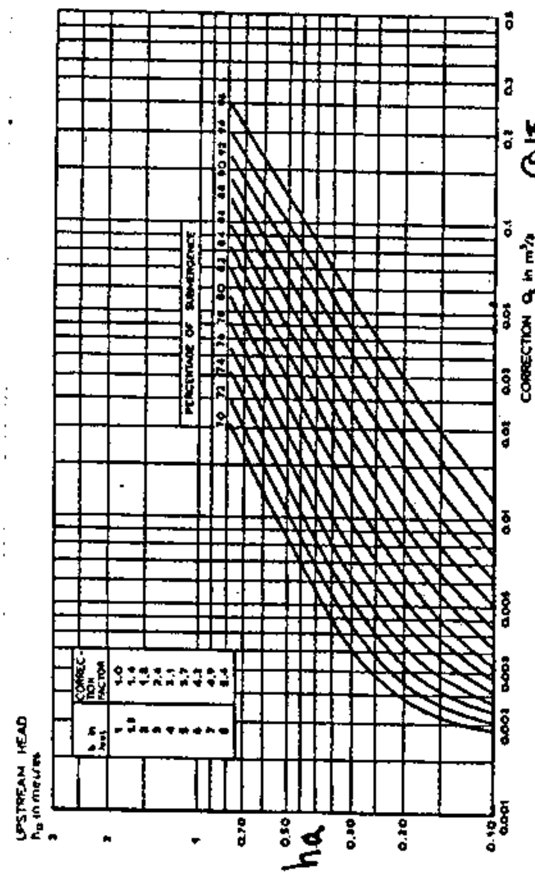


Figure 7.15 Discharge correction for submerged flow; 1' Parshall flume, correction Q_E (m^3/s)

U/S Slope	Vertical	3:1	3:2	3:3
R1/Ho	0.5	0.68	0.48	0.45
R2/Ho	0.2	0.21	0.22	-

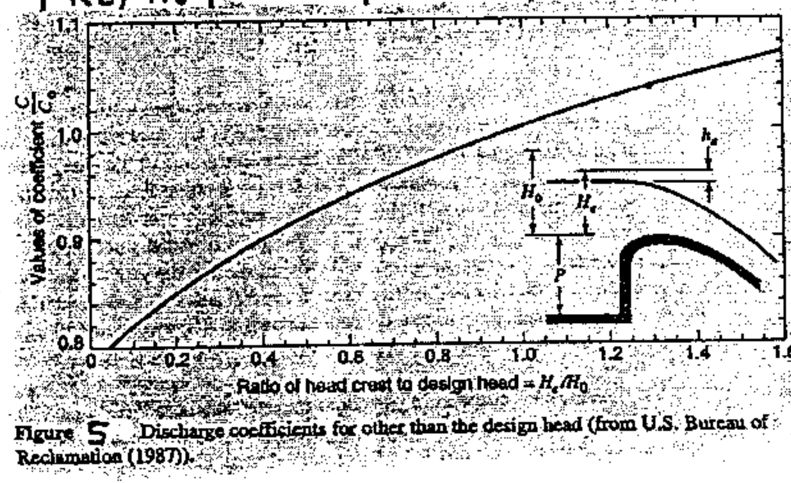
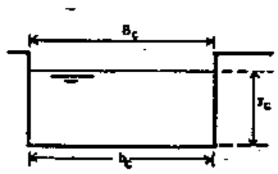
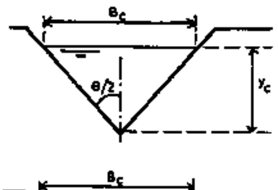


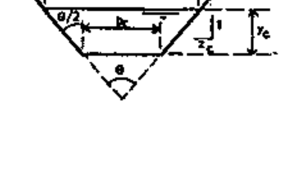
Figure 5 Discharge coefficients for other than the design head (from U.S. Bureau of Reclamation (1987)).



$$Q = C_d C_v \frac{2}{3}\left(\frac{2}{3}g\right)^{1/2} b_c h_1^{3/2}$$



$$Q = C_d C_v \frac{16}{25}\left(\frac{2}{5}g\right)^{1/2} \tan\frac{\theta}{2}\, h_1^{5/2}$$



$$Q = C_d\, [b_c y_c + z_c y_c^2][2g(H_T - y_c)]^{1/2}$$

Table 7.4 Discharge characteristics of Parshall flumes

Throat width b_c in feet or inches	Discharge range in $m^3/s \times 10^{-3}$ minimum	Discharge range in $m^3/s \times 10^{-3}$ maximum	Equation $Q = K h_a^u$ (Q in m^3/s)	Head range in metres minimum	Head range in metres maximum	Modular limit h_b/h_a
1"	0.09	5.4	$0.0604\, h_a^{1.55}$	0.015	0.21	0.50
2"	0.18	13.2	$0.1207\, h_a^{1.55}$	0.015	0.24	0.50
3"	0.77	32.1	$0.1771\, h_a^{1.55}$	0.03	0.33	0.50
6"	1.50	111	$0.3812\, h_a^{1.58}$	0.03	0.45	0.60
9"	2.50	251	$0.5354\, h_a^{1.53}$	0.03	0.61	0.60
1'	3.32	457	$0.6909\, h_a^{1.522}$	0.03	0.76	0.70
1'6"	4.80	695	$1.056\, h_a^{1.538}$	0.03	0.76	0.70
2'	12.1	937	$1.428\, h_a^{1.550}$	0.046	0.76	0.70
3'	17.6	1427	$2.184\, h_a^{1.566}$	0.046	0.76	0.70
4'	35.8	1923	$2.953\, h_a^{1.578}$	0.06	0.76	0.70
5'	44.1	2424	$3.732\, h_a^{1.587}$	0.06	0.76	0.70
6'	74.1	2929	$4.519\, h_a^{1.595}$	0.076	0.76	0.70
7'	85.8	3438	$5.312\, h_a^{1.601}$	0.076	0.76	0.70
8'	97.2	3949	$6.112\, h_a^{1.607}$	0.076	0.76	0.70
	in m^3/s					
10'	0.16	8.28	$7.463\, h_a^{1.60}$	0.09	1.07	0.80
12'	0.19	14.68	$8.859\, h_a^{1.60}$	0.09	1.37	0.80
15'	0.23	25.04	$10.96\, h_a^{1.60}$	0.09	1.67	0.80
20'	0.31	37.97	$14.45\, h_a^{1.60}$	0.09	1.83	0.80
25'	0.38	47.14	$17.94\, h_a^{1.60}$	0.09	1.83	0.80
30'	0.46	56.33	$21.44\, h_a^{1.60}$	0.09	1.83	0.80
40'	0.60	74.70	$28.43\, h_a^{1.60}$	0.09	1.83	0.80
50'	0.75	93.04	$35.41\, h_a^{1.60}$	0.09	1.83	0.80

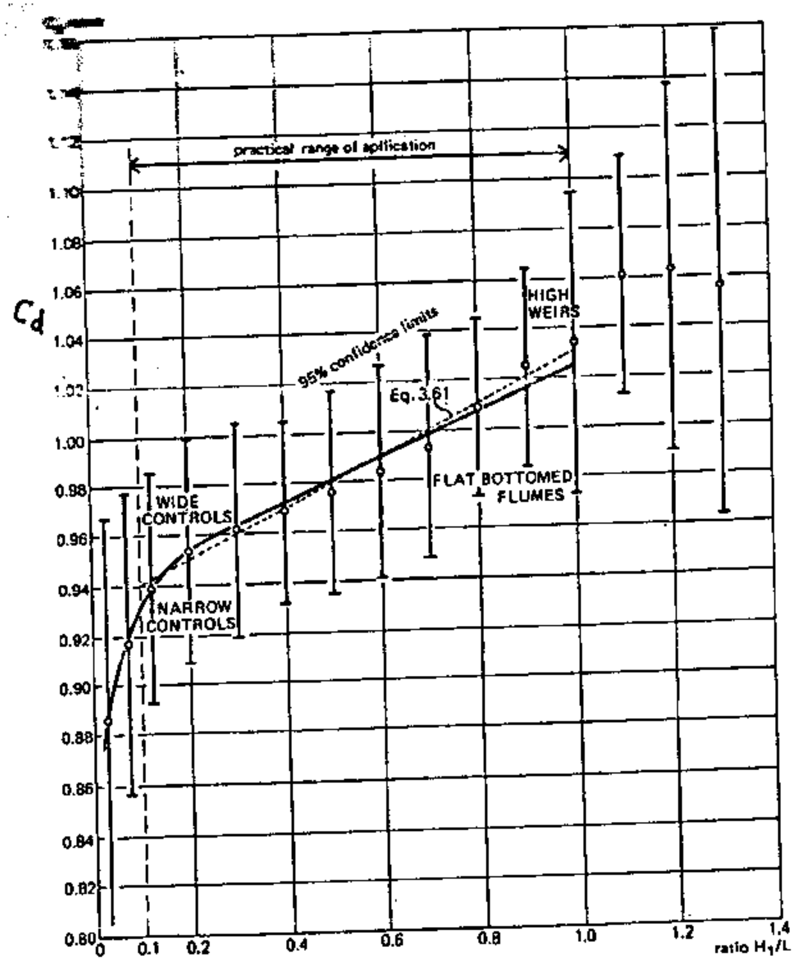


Figure 7.3 C_d values as a function of H_1/L for long-throated flumes of all shapes and

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Water & Dams (Solutions of Form-C-)

Q1] (A)

1- T   2- F (independent)   3- F (with shear force)

4- T   5- F (Kinetic energy to heat)   6- F (velocity head)

7- F (oscillating jump)   8- F (culvert)   9- F (venturi)

10- F (may be outside a stilling basin)

(B)

ⓐ - The gravity force in the direction of flow is :-

$F_G = \gamma A L \sin\theta$

- The boundary shear force :-

$F_S = \tau_o P L$

- For uniform flow $\Rightarrow F_G = F_S$

$\gamma A L \sin\theta = \tau_o P L$

$\sin\theta = \tan\theta = S_o$ $\tau_o = \dfrac{\gamma A S_o}{P} = \gamma R S_o$

also $\tau_o = K V^2$

then $K V^2 = \gamma R S_o \Rightarrow V = \sqrt{\dfrac{\gamma}{K} R S_o} = \underline{\underline{C\sqrt{R S_o}}}$

ⓑ The specific energy for any cross-section :-

$$E = y + \frac{V^2}{2g} = y + \frac{Q^2}{2g A^2}$$

The critical depth occur at minimum specific Energy Where :-

$$\frac{dE}{dy} = 0 = 1 + \frac{Q^2}{2g}\left(\frac{2}{A^3}\right)\frac{dA}{dy} \quad \& \quad dA = T\,dy$$

then $1 + \dfrac{Q^2}{2g} \cdot \dfrac{2}{A^3} \cdot T = 0 \Rightarrow \underline{\underline{\dfrac{Q^2 T}{g A^3} = 1}}$

Q2] (A)

$$R = 5 * 10^3 \quad \& \quad \frac{e}{D} = 0.01$$

* If using Moody diagram $\longrightarrow$ $\underline{\underline{f = 0.0468}}$

* If using Colebrook formula :-

$$\frac{1}{\sqrt{f}} = -2 \log \left[\frac{0.01}{3.7} + \frac{2.51}{5000 \sqrt{f}} \right]$$

by trial & Error :-
assume $f = 0.0473 \implies$ then $\frac{1}{\sqrt{0.0473}} \cong 4.603 \cong 4.6$

$\therefore$ O.K use $\underline{\underline{f = 0.0473}}$

(B)

$$Q = 2.953\, h_a^{1.578} \quad \text{(from Table 7.4)}$$

$$h_a = 2.5\, \cancel{ft} * \frac{1\,m}{3.28\, \cancel{ft}} = 0.762\ m$$

$$\therefore Q = 2.953\, (0.762)^{1.578} = 1.923\ m^3/s$$

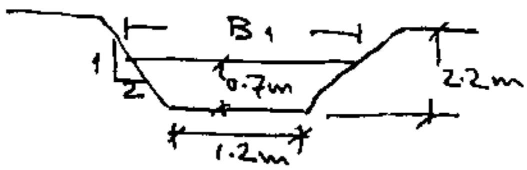
$\frac{h_b}{h_a} = \frac{2}{2.5} = 0.8 > 0.7$ $\therefore$ the flow is Submerged

from fig.(7.15) $\longrightarrow$ $Q_E = 0.055$

and Correction for (4') flume $= 3.1 * 0.055 = 0.1705\ m^3/s$

then $Q_s = 1.923 - 0.1705 = \boxed{1.753\ m^3/s}$

Q3] (A)



$$B_1 = 1.2 + 2 * 2 * 0.7 = 4m$$

$$H = 2.2 - 0.7 = 1.5\ m$$

$\frac{H}{P} = \frac{1.5}{0.7} = 2.143$; $\frac{B}{B_1} = 0.8$ (assumed)

$$\implies B = 0.8 * 4 = 3.2\ m$$

from Fig.(5.5) $\implies C_d \cong 0.69$

$\therefore Q = \frac{2}{3} \sqrt{2g}\ C_d\ B'\ H^{3/2}$ & $B' = 3.2 - 0.2 * 1.5 = 2.9m$

then $Q = 10.86\ m^3/s \gg 5.5\ m^3/s$ (not good assumption) ume $B/B_1 = 0.45 \longrightarrow B = 1.8\,m$ & $B' = 1.5\,m$

and $C_d \simeq 0.62$ (fig.5.5)

then $Q \cong 5.05\ m^3/s$ (not good)

assume $B/B_1 = 0.46 \Longrightarrow B_1 \simeq 1.85\,m$

$\Longrightarrow Q \simeq 5.5\ m^3/s$ ∴ O.K

(B)

$V_1 = 1.53\ m/s \longrightarrow \frac{V_1^2}{2g} = 0.119\,m$ & $h_1 = 0.6\,m$

then $H_1 = 0.6 + 0.119 = 0.7193\,m$

from fig. (7.2)

$$Q = C_d\left[b_c y_c + Z_c y_c^2\right]\left[2g\,(H_1 - y_c)\right]^{1/2}$$

$L = 1.8\,m$; $b_c = 0.6\,m$; $Z_c = 1.5$

$\frac{H_1}{b_c} = \frac{0.7193}{0.6} = 1.1988 \simeq 1.2$

From fig. (7.1) $\longrightarrow \frac{y_c}{H_1} = 0.759$ then $y_c = 0.546\,m$

$\frac{H_1}{L} = \frac{0.7193}{1.8} \simeq 0.4$ ∴ from fig. (7.3) $\rightarrow C_d \simeq 0.97$

then $Q = 1.386\ m^3/s$

Q4]

$Q = \frac{1}{n} A R^{2/3} S_o^{1/2}$ assume $y_n = 1.73\,m$

$\Longrightarrow A = 4 * 1.73 = 6.92\,m$ $P = 2*1.73 + 4 = 7.46\,m$

$R = \frac{6.92}{7.46} = 0.928\ m \Longrightarrow Q \simeq 11\ m^3/s$

hence $y_n = 1.73\,m$ also assume $G = 1\,m$

then $C_d = \frac{0.61}{\sqrt{1 + 0.61(\frac{1}{2})}} = 0.534$

now $0.8 * 1.73\left(\frac{1.73}{1}\right)^{0.72} = 2.08$

∵ $y_2 < y_1 < 2.08$ ∴ the flow D/s gate is Submerged

5]

(A)

$$y_c = \sqrt[3]{\frac{q^2}{g}} = \sqrt[3]{\frac{3^2}{9.81}} = 0.972\,m$$

$y_{end} = 0.4 * 0.972 = 0.389\,m$

$y_t = 2.1 + 0.389 = \underline{2.489\,m}$

$y_t \geq 2.15\,y_c = \underline{2.088\,m}$ then $\underline{O.K}$

$\therefore y_t = \underline{2.489\,m}$

$h_{drop} = -1.5 - 0.389 = -1.889\,m$

$$\frac{X_f}{y_c} = -0.406 + \sqrt{3.195 - 4.386\left(\frac{-1.889}{0.972}\right)} = 3.018$$

$\Longrightarrow X_f = 3.018 * 0.972 = \underline{2.93\,m}$ (free Nappe location)

$$\frac{X_t}{y_c} = -0.406 + \sqrt{3.195 - 4.386\left(\frac{2.489 - 1.889}{0.972}\right)} = 0.292$$

$\Longrightarrow X_t = 0.292 * 0.972 = 0.284\,m$

then $$\frac{X_s}{y_c} = \frac{0.691 + 0.228\left(\frac{0.284}{0.972}\right)^2 - \left(\frac{-1.889}{0.972}\right)}{0.185 + 0.456\left(\frac{0.284}{0.972}\right)} = 8.338$$

$\Longrightarrow X_s = 8.338 * 0.972 = \underline{8.1\,m}$ (submerged Nappe location)

(B)

1 for Inlet Control

* If inlet unsubmerged :- $Q = C_w B H_w^{3/2} \rightarrow B = 0.31\,m$

* If inlet submerged :- $Q = C_d A \sqrt{2g\left(H_w - \frac{D}{2}\right)}$

by trial & Error $D = 1.24\,m$ then use $\underline{D = 1.24\,m}$

2 for outlet control

$$H = \left(1 + K_e + \frac{20\,n^2 L}{R^{4/3}}\right)\frac{V^2}{2g}$$

$R = \frac{D}{4}$, $V = \frac{Q}{A} = \frac{6.748}{\pi D^2}$; $V^2 = \frac{45.538}{\pi^2 D^4}$

$$H = \left(1 + 0.5 + \frac{20 * 0.024^2 * 35}{(D/4)^{4/3}}\right) * \frac{45.538}{2 * 9.81\, D^4} \quad \text{—(1)}$$

$$H_w = h_o + H - LS_o \longrightarrow H = H_w - h_o + LS_o$$

assume $h_o = T_w = D$

$$\therefore H = 3.2 - D + 35 * 0.003 \longrightarrow H = 3.305 - D \quad \text{—(2)}$$

put (2) in (1) & Simplifying

$$3.305 = \left(1.5 + \frac{0.4032}{(D/4)^{4/3}}\right) * \frac{2.321}{D^4} + D$$

by trial & Error $\longrightarrow$ $D \simeq \underline{1.4\ m}$

The outlet Control the flow in culvert So the Suitable design to use the pipe diam. = $\boxed{1.4\ m}$