CIEG 440 Water Resources Eng'g 10/3/09

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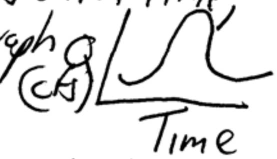
OPEN CHANNEL FLOW

- Flow open to atmosphere
- Pipe flow is flow under pressure

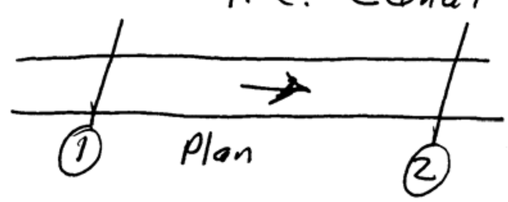
4 Types of Flow

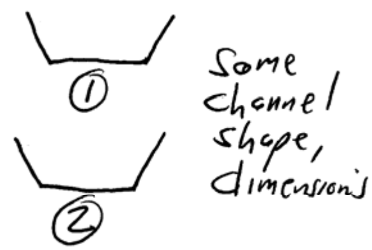
① Steady - Depth of flow does not change with time, i.e. peak flow at single moment

② Unsteady - Depth of flow changes with time, i.e. flood hydrograph



③ Uniform - Depth is same, channel shape same, i.e. canal





④ ~~B~~ Nonuniformed, varied - Depth changes, channel changes, i.e. natural river

Continuity Equation:

$$Q = V_1 A_1 = V_2 A_2$$

Mannings Equation:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

where: V = velocity in channel (fps)

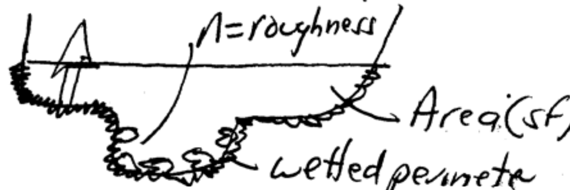
n = manning's roughness value (P. 319 Linsley Table 10.1)
= 0.013 (concrete)
= 0.035 (natural channel)

R = hydraulic radius = $\frac{A}{WP}$

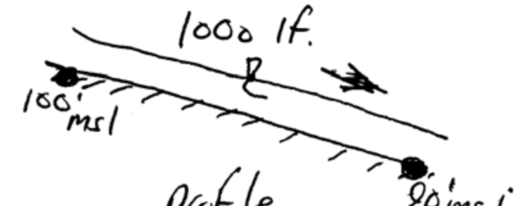
A = channel x-section area (sf)

WP = wetted perimeter (ft)

S = slope of channel (ft/ft)



(section)



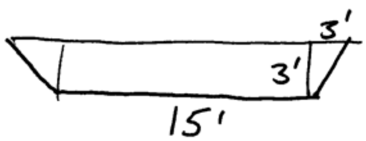
profile

$$S = \frac{100-90}{1000} = \frac{10}{1000} = 0.01 = 1\%$$

Since $Q = VA$,

then $Q = \frac{1.486}{n}(R^{2/3})(S)^{1/2}(A)$

Ex. 1 Newark water supply canal



$n = 0.030$

$S = \frac{10'}{3/4(5280 ft)} = 0.0025 \frac{ft}{ft}$

$R = \frac{A}{WP} = \frac{(3\times3)+(15\times3)=54 sf}{\sqrt{3^2+3^2}(2)+(15)} = \frac{54 sf}{23.5} = 2.3 ft$

$A = 54 sf$

$V = \frac{1.486}{0.03}(2.3)^{2/3}(0.0025)^{1/2}$

$= (49.5)(1.75)\ 0.05$

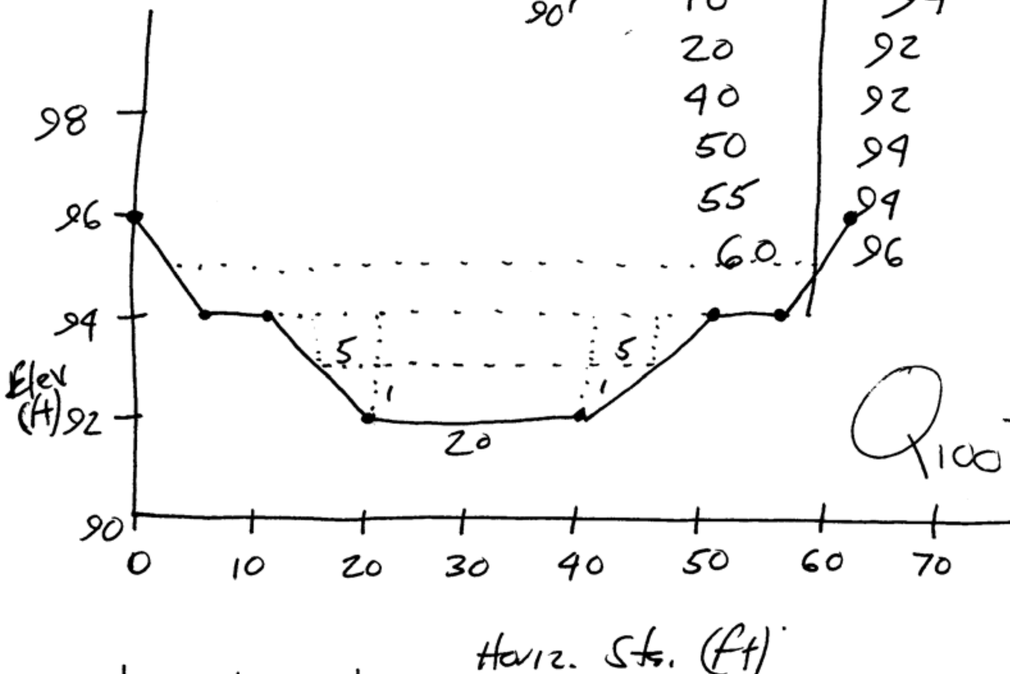
$V = 4.3$ fps

$Q = 4.3 fps (54 sf)$

$= \underline{234 cfs}$

Ex. 2:

X (Horiz. Sta.) ft.	Y (elev. msl) ft
0	96
5	94
10	94
20	92
40	92
50	94
55	94
60	96



$Q_{100} = 300$ cfs

Elev. (ft)	Depth (ft)	$\frac{1.486}{n}$ $n = 0.030$	$S^{1/2}$ $\left(\frac{ft}{ft}\right)$	A (sf)	WP (ft)	$\frac{A}{WP}$	$\left(\frac{A}{WP}\right)^{2/3}$	$V = \frac{1.486}{n} R^{2/3} S^{1/2}$ (fps)	Q = VA (cfs)
93	1	49.5	10/5000. = 0.002 $\sqrt{0.002}$ = 0.045	5(1) +20(1) =25	5.1+20 +5.1 =30.2	$\frac{25}{30.2}$ =0.83	0.88	1.96	49
94	1	49.5	0.045	~~25+20 +5+5 +5~~ =60	10+20 +10 =40	$\frac{60}{40}$ 1.5	1.31	2.92	175
95	1	49.5	0.045	60+50 +2.5 112.5	(2.5+5 +10+20 +10+5 +2.5	$\frac{112}{55}$	~~2.0~~ 1.61	~~4.45~~ 3.60	404

Find elevation & depth @ Q = 300 cfs

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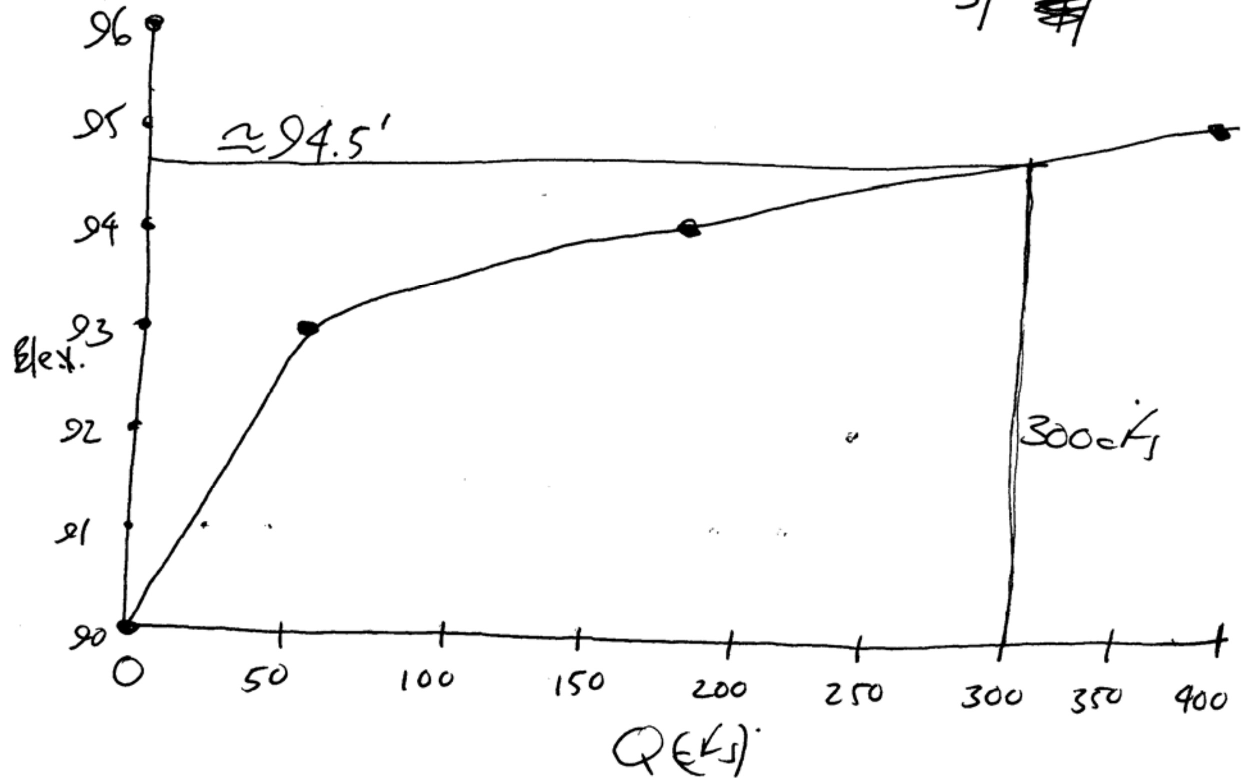

Download Mannings Equation software:

① www.waterengr.com

② Register name, OD, email

③ Free software

④ Download Hydraulics utility program
CHNLS - XY

Hydraulic Jump

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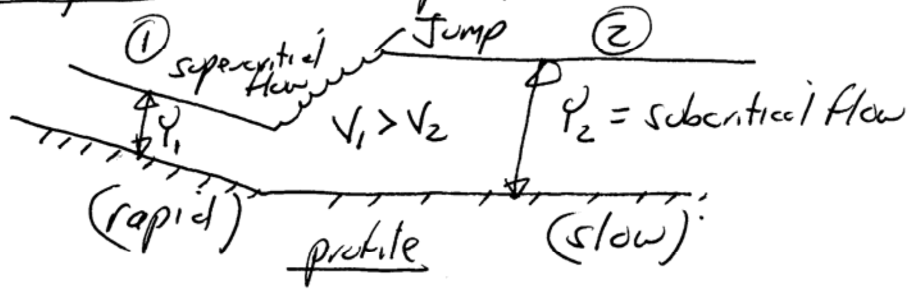
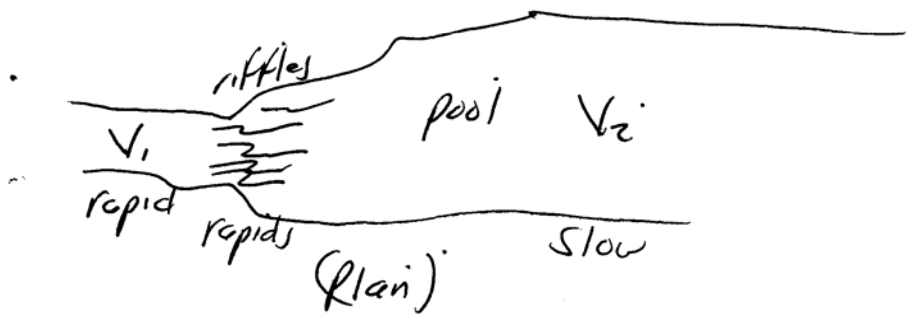
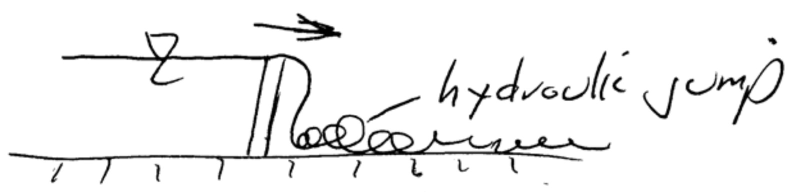




$D >$ normal depth (d_n), subcritical flow, $V \downarrow$

$D <$ normal depth (d_n), supercritical flow, $V \uparrow$

$D =$ normal depth (d_n, flow @ normal depth $V \rightarrow$



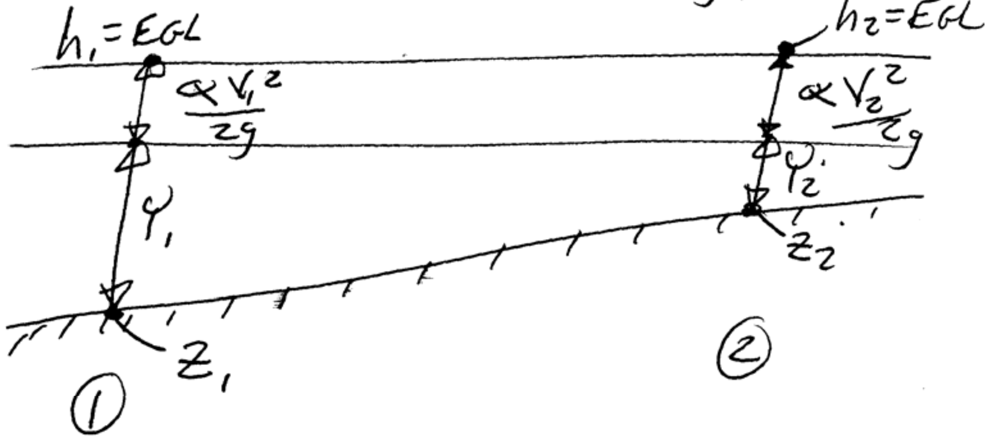
Flow over dam

Energy Gradeline

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

and so on.....

where: h = head of channel, EGL
y = depth of flow
$\alpha\frac{V^2}{2g}$ = velocity head, $\alpha = 1.0 - 1.5$
z = elevation of channel bottom (thalweg)



Open channel flow models balance out $Q = VA$, $V = \frac{1.486}{n}R^{2/3}S^{1/2}$, and EGL equation

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Gate Flow

$$Q = C_d \, (b)(Y_g)(\sqrt{2gh})$$

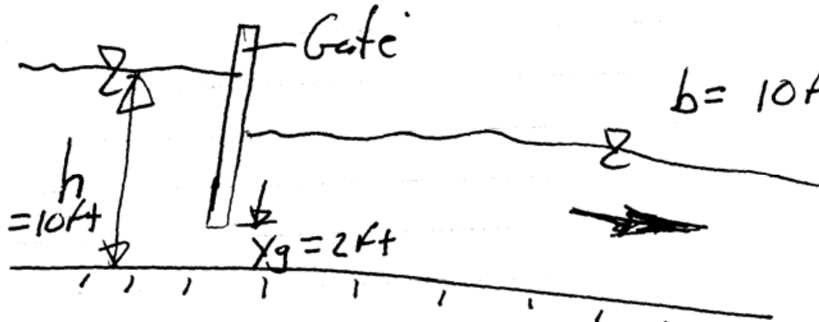
where: $C_d = 1.0$

b = channel width (ft)

Y_g = gate opening

$g = 32.2 \; ft/sec^2$

h = depth of water behind gate



$$Q = (1)(10ft)(2ft)(\sqrt{2(32.2)(10)})$$

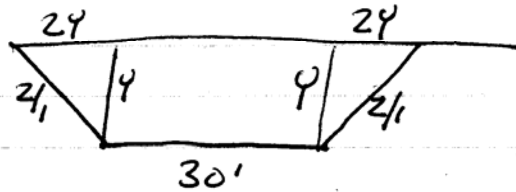
$$= 20(25.4) = \underline{508 \text{ cfs}}$$, through a 2'x10' wide gate.

Critical Flow Depth

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

where: Q = flow (cfs)
g = 32.2 ft/sec²
A = Area (sf)
T = width of channel

Ex. 1



$T = 30 + 4Y$

$A = 30Y + \frac{Y(2Y)}{2} + \frac{Y(2Y)}{2}$

$= 30Y + 2Y^2$

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$$\frac{(\cancel{100})^2}{32.2} = \frac{(30Y+2Y^2)^3}{30+4Y}$$

Try Y = 1 ft

$$310 = \frac{(30(1)+2(1)^2)^3}{30+4(1)} = \frac{(32)^3}{34} = 963 > 310 \text{ NG}$$

Try Y = 0.5 ft

$$310 = \frac{(30(0.5)+2(0.5)^2)^3}{30+4(0.5)} = \frac{15.5^3}{32} = 116 < 310 \text{ NG}$$

Try Y = 0.7 ft

$$310 = \frac{(30(0.7)+2(0.7)^2)^3}{30+4(0.7)} = \frac{(21.98)^3}{32.8} = 323 \simeq 310$$

OK

$Y_c \cong$ **0.7 ft**