UNIVERSITY OF NEW ORLEANS
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

ENCE 4319 Hydraulic and Fluid Mechanics Laboratory (1cr).
Fall 2010

Tuesday 4:30-7:15

Instructor: Enrique J. La Motta, Ph.D., P.E.
Office hours: Tue 2:00-4:00 EN 815.
E-mail address: elamotta@uno.edu
Phone: 280-6093

PREREQUISITES for ENCE 4318 and 4319

ENCE 3318 or ENME 3720 and ENME 3716 or an equivalent undergraduate course in engineering fluid mechanics.

CO-REQUISITES: ENCE 4318 and 4319 must be taken concurrently, except for graduate students

STUDENT LEARNING OBJECTIVES

After successfully completing this course each student will be able to:

- To apply the principles of hydrostatics, continuity, energy and momentum to problems associated with steady state flows in pipes and open channels.
- To design components of hydraulic structures.
- To use a variety of mathematical and computer models to solve hydraulic problems.
- To conduct open channel flow measurements and appreciate the uncertainty in the data.

GRADUATE CREDIT

Students taking this course for graduate credit will be required to complete an additional physical or numerical modeling project that extends the subject matter covered in the lectures.

GRADING SYSTEM

There will be at least 12 tutorials, that will be graded, plus a short open channel design project. There will be no exams, so the course grade will be based on the work handed in by each student.

List of surfaces with roughness $k_s = 0.03$ mm

Good examples of	Wrought iron Coated steel Clayware (glazed or unglazed) with sleeve joints Sewer rising mains, mean velocity 2 m/s
Normal examples of	Asbestos cement Spun bitumen lined metal pipes Spun concrete lined metal pipes Uncoated steel Clayware (glazed or unglazed) with spigot and socket joints and 'O' ring seals — dia <150 mm Pitch fibre pipes running part full uPVC with chemically cemented joints
Poor examples of	

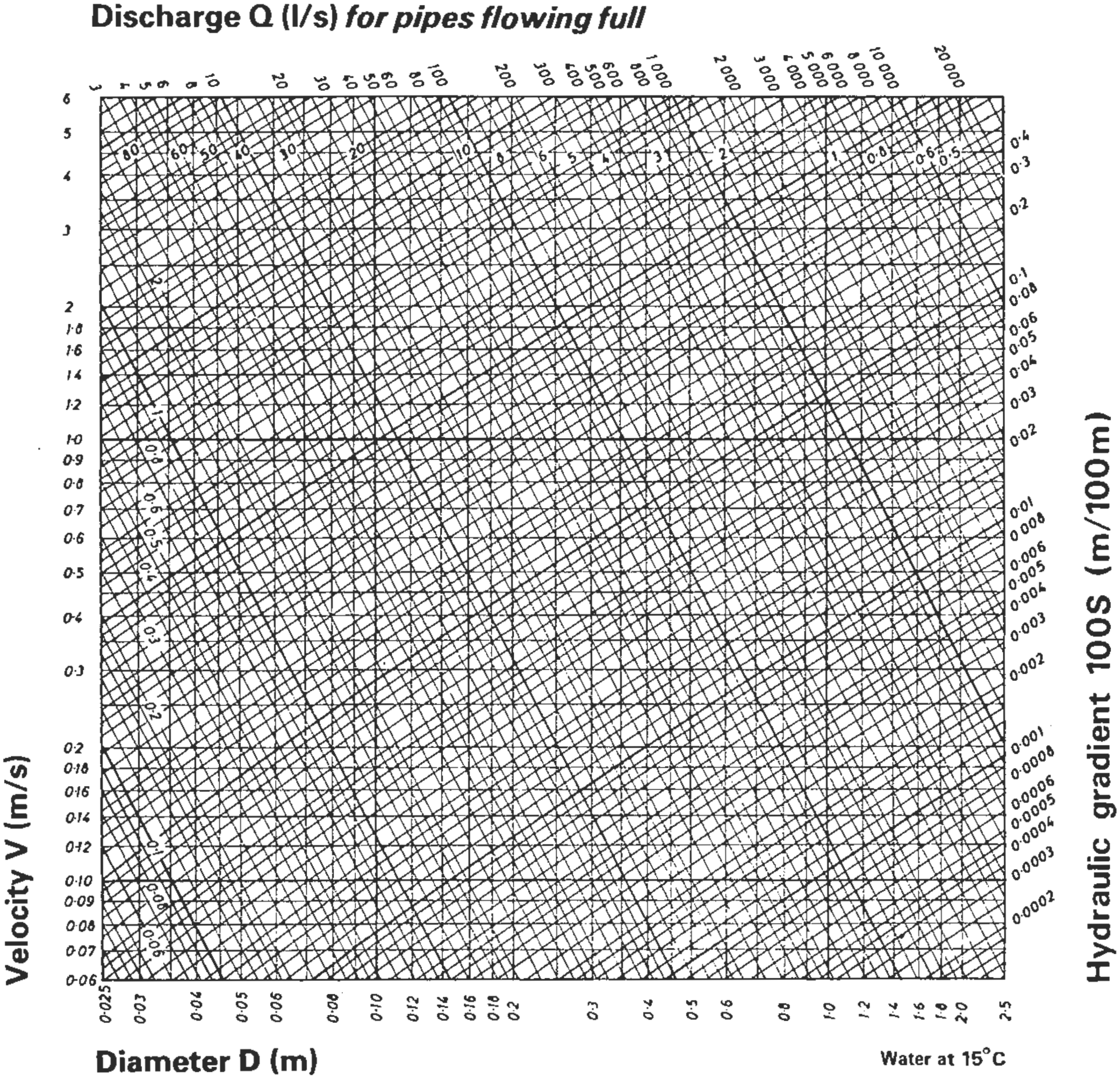
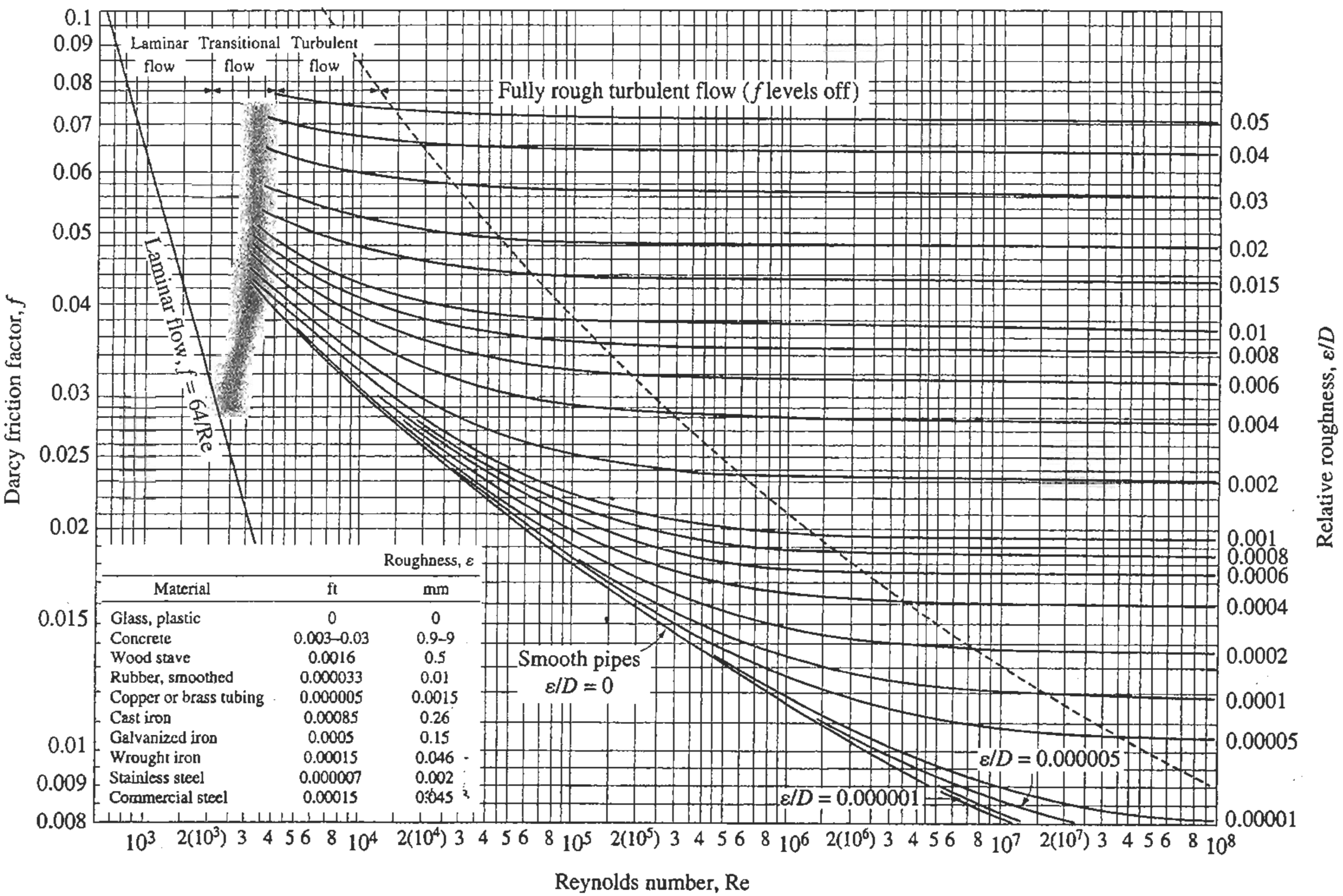


Fig 4 $k_s = 0{\cdot}03$ mm

↳ ε surface roughness



Material	Roughness, ε ft	Roughness, ε mm
Glass, plastic	0	0
Concrete	0.003–0.03	0.9–9
Wood stave	0.0016	0.5
Rubber, smoothed	0.000033	0.01
Copper or brass tubing	0.000005	0.0015
Cast iron	0.00085	0.26
Galvanized iron	0.0005	0.15
Wrought iron	0.00015	0.046
Stainless steel	0.000007	0.002
Commercial steel	0.00015	0.045

FIGURE A–12

The Moody chart for the friction factor for fully developed flow in circular pipes for use in the head loss relation $h_L = f\frac{L}{D}\frac{V^2}{2g}$. Friction factors in the turbulent flow are evaluated from the Colebrook equation $\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\text{Re}\sqrt{f}}\right)$.

ENCE 4319

Explicit solution of Darcy-Weisbach formula

Darcy's formula: $$h_f = f\frac{L}{D}\frac{V^2}{2g}$$

Solve for *f*: $$f = \frac{2gSD}{V^2}, \text{ where } S = \frac{h_f}{L}$$

Taking the inverse of the square root: $$\frac{1}{\sqrt{f}} = \frac{V}{\sqrt{2gSD}} \qquad (1)$$

Colebrook-White's equation: $$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon}{3.7D} + \frac{2.51}{N_R\sqrt{f}}\right) \qquad (2)$$

Where $N_R = \frac{DV}{\nu}$

Equate (1) and (2): $$\frac{V}{\sqrt{2gSD}} = -2\log\left(\frac{\varepsilon}{3.7D} + \frac{2.51\nu}{DV\sqrt{\frac{2gSD}{V^2}}}\right)$$

Solve for V: $$V = -2\sqrt{2gSD}\log\left(\frac{\varepsilon}{3.7D} + \frac{2.51\nu}{D\sqrt{2gSD}}\right)$$

Multiply by pipe area: $$Q = -\frac{\pi}{4}D^2 \bullet 2\sqrt{2gSD}\log\left(\frac{\varepsilon}{3.7D} + \frac{2.51\nu}{D\sqrt{2gSD}}\right)$$

Simplifying: $$\boxed{Q = -\frac{\pi}{2}D^{2.5}\sqrt{2gS}\log\left(\frac{\varepsilon}{3.7D} + \frac{2.51\nu}{D^{1.5}\sqrt{2gS}}\right)} \qquad (3)$$

ENCE 4319
Empirical Equations for Steady, Uniform Water Flow

1. Manning's Formula

- US Unit System:

$$\boxed{V_{fps} = \frac{1.486}{n} R_{ft}^{\frac{2}{3}} S^{\frac{1}{2}}}$$

- SI System:

$$\boxed{V_{m/s} = \frac{1}{n} R_{m}^{\frac{2}{3}} S^{\frac{1}{2}}}$$

In both equations, $R = \frac{\text{Wetted area}}{\text{Wetted perimeter}}$

2. Hazen-Williams Formulas

$$\boxed{V_{m/s} = 0.35457CD_{m}^{0.63}S^{0.54}}$$

$$\boxed{V_{fps} = 0.55032CD_{ft}^{0.63}S^{0.54}}$$

$$\boxed{Q_{m^3/s} = 0.2785CD_{m}^{2.63}S^{0.54}}$$

$$\boxed{Q_{mgd} = 0.2794CD_{ft}^{2.63}S^{0.54}}$$

$$\boxed{Q_{gpm} = 0.2816CD_{in}^{2.63}S^{0.54}}$$

$$\boxed{Q_{cfs} = 0.4323CD_{ft}^{2.63}S^{0.54}}$$

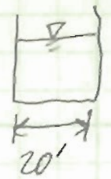
$$\boxed{S = 10.6699\left(\frac{1}{C}\right)^{1.8519} \frac{Q_{m^3/s}^{\ 1.8519}}{D_{m}^{\ 4.87037}}}$$

$$\boxed{S = 10.4538\left(\frac{1}{C}\right)^{1.8519} \frac{Q_{gpm}^{\ 1.8519}}{D_{in}^{\ 4.87037}}}$$

Donald Jerolleman Hydro Lab Tutorial 7 P. 1 of 2

$\frac{100}{100}$

1)



$E = 12'$

$Q = 400\ ft^3/s$

$A = 20y$

$$E = y + \frac{Q^2}{2gA^2} = 12 = y + \frac{400^2}{2(32.2)(20y)^2}$$

$$\boxed{y_u = 11.96' \quad y_L = 0.74'}$$ ✓

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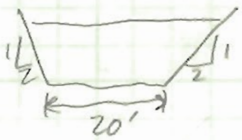
2)



$E = 12'$

$Q = 400\ ft^3/s$

$A = y(b+zy)$

$$12 = y + \frac{400^2}{2(32.2)y^2(20+2y)^2}$$

$$\boxed{y_u = 11.99' \quad y_L = 0.69'}$$ ✓

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3) a) $Q = \sqrt{2g}(A)(E-y)^{1/2}$, $A = by \rightarrow Q = \sqrt{2g}\, by(E-y)^{1/2}$

$$\frac{dQ}{dy} = \sqrt{2g}\, b\left[1(E-y)^{1/2} + y\left(\tfrac{1}{2}\right)(E-y)^{-1/2}(-1)\right]$$

set to zero $\rightarrow$ $\boxed{y_c = 8.00\ ft}$ ✓

$\rightarrow Q_c = \sqrt{2g}\,(10)(8)(12-8)^{1/2} = \boxed{1284\ ft^3/s}$ ✓

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b) $Q = \sqrt{2g}\, A(E-y)^{1/2}$; $A = y(b+zy) \rightarrow Q = \sqrt{2g}\,(by+zy^2)(E-y)^{1/2}$

$$\frac{dQ}{dy} = \sqrt{2g}\left[(b+2zy)(E-y)^{1/2} + (by+zy^2)\left(\tfrac{1}{2}\right)(E-y)^{-1/2}(-1)\right]$$

set to zero $\rightarrow$ $y_c = \boxed{9.21\ ft}$ ✓

$Q_c = \sqrt{2(32.2)}\,(9.21)(10+2(9.21))(12-9.21)^{1/2} = \boxed{3509\ ft^3/s}$ ✓

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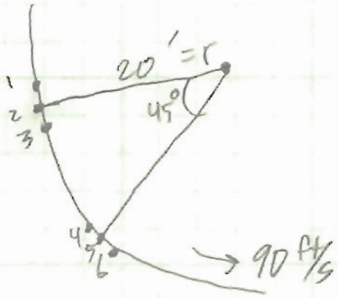
4) $A = \frac{Q}{v} = \frac{10000}{90} = 111.1\ ft^2$, $w = 20' \rightarrow d = \frac{111.1}{20} = 5.56\ ft$ ✓



Pt.1: $\frac{p_1}{\gamma} = d\cos\theta = 5.56\cos 45^\circ = \boxed{3.93\ ft}$ ✓

Pt.3: $\frac{p_2}{\gamma} = d\cos\theta + \frac{dV^2}{gr} = 3.93\ ft + \frac{5.56(90)^2}{\underbrace{32.2(20)}_{r}} = \boxed{73.86\ ft}$ ✓

Pt.4: $\frac{p_4}{\gamma} = d\cos\theta + \frac{dV^2}{gr} = (5.56)\cos(0^\circ) + " = \boxed{75.49\ ft}$ ✓

Pt.5: $\frac{p_5}{\gamma} = d = \boxed{5.56\ ft}$ ✓

5) $E_1 = y_1 + \frac{Q^2}{2g(by_1)^2} \rightarrow \boxed{y_1 = 8.92\text{ ft},\ y_2 = 0.87\text{ ft}}$

$y_c = \frac{2}{3}E = \frac{2}{3}(9) = \boxed{6\text{ ft}}$ $y_c = \frac{V_c^2}{g} \rightarrow V_c^2 = \boxed{13.9\text{ ft/s}}$

@ contraction point ; $300 = (y_c W_c)V_c \Rightarrow \boxed{W_c = 3.6\text{ ft}}$

$$y + \frac{6.211}{y^2} - 9 = 0$$

$$y^3 + 6.211 - 9y^2 = 0$$

$$y^3 - 9y^2 + 6.211 = 0$$

$y =$ 8.92 ft, 0.874 ft

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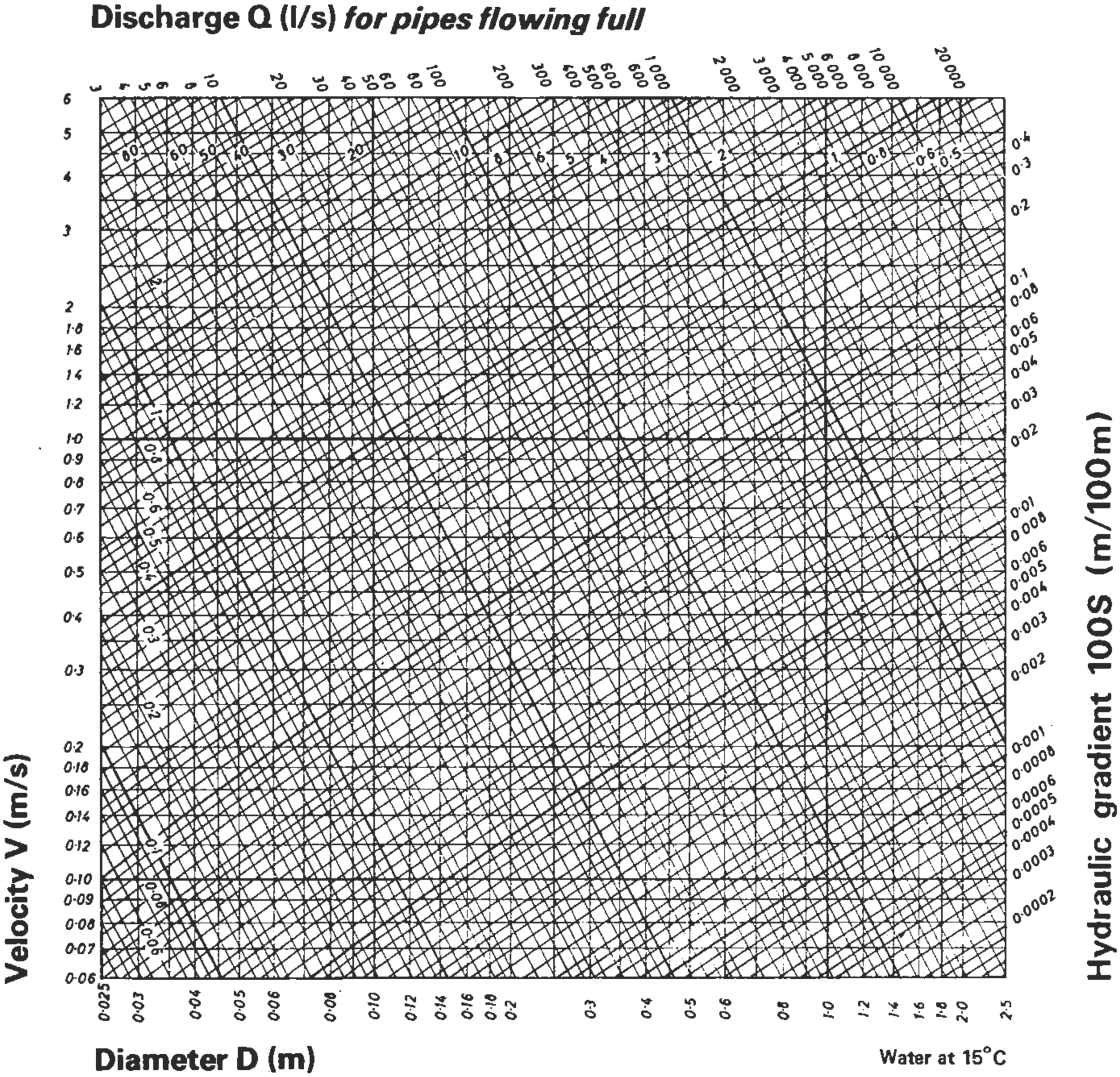

Fig 4 k_s = 0·03 mm

ENCE 4319

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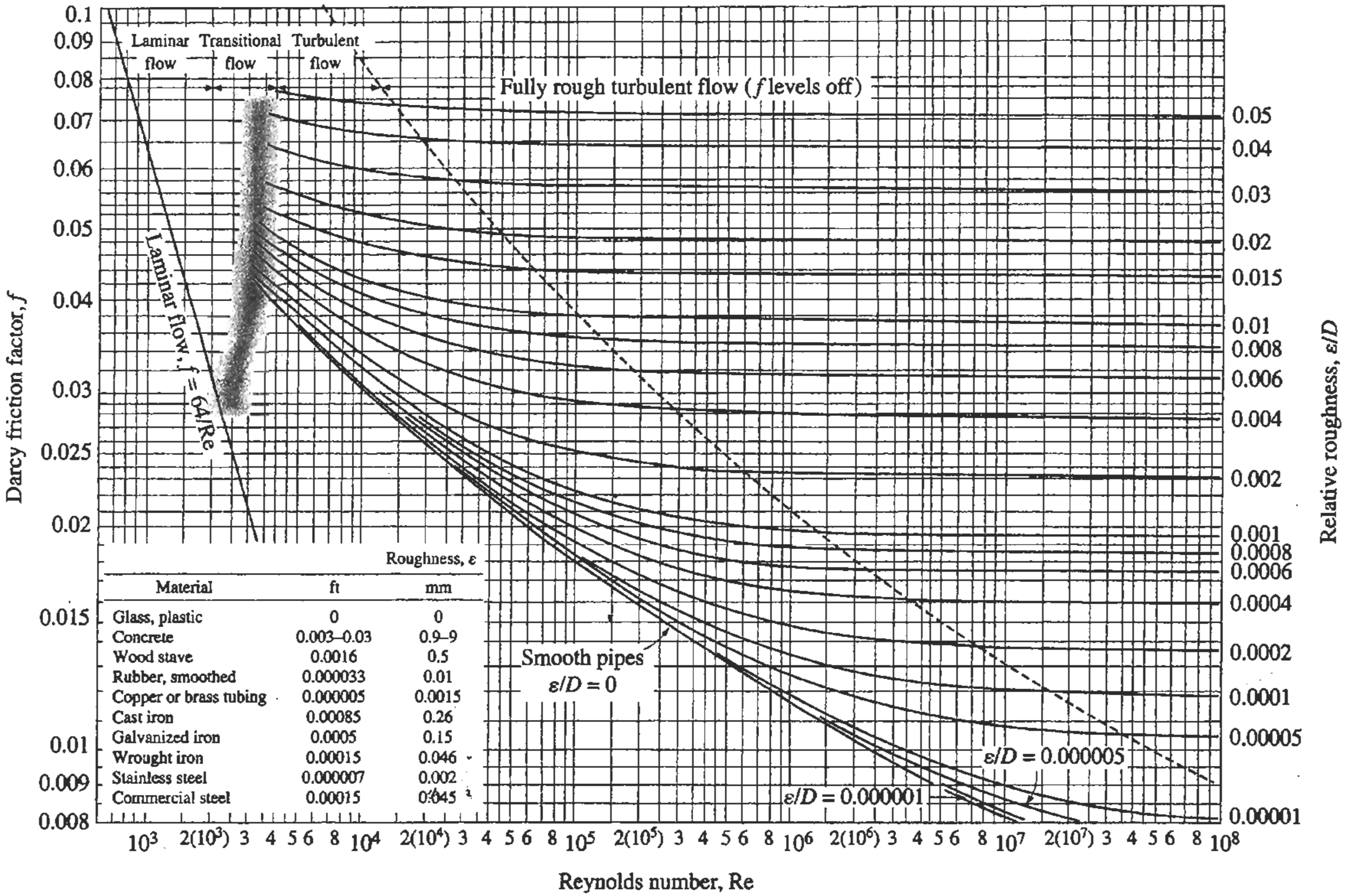

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ENCE 4319

Assignment No. 1

Due 8/31/10

100

Solve the following problem:

A gravity main conveys water from Tank A, where the liquid surface is at an elevation of 109.65 m, to Tank B, where the water surface is at 100 m. The pipeline profile is the following:

Distance, m	0 (TankA)	600	800	1000	1500 (Tank B)
Pipe Elevation, m	108.00	99.00	103.00	98.00	99.00

a) The flow rate at the end of the design period is 70 L/s. Design a PVC pipeline using Darcy's formula, and $\varepsilon = 3\text{x}10^{-5}$ m and $\nu = 1.14\text{x}10^{-6}$ m²/s. Neglect all minor losses. Draw the hydraulic gradient.

b) If the flow rate at the beginning of the design period is 35 L/s, find the pressure head at the point located at 800 m from Tank A. Draw the hydraulic gradient assuming the same pipe diameter as in (a), and that there is no valve at the end of the pipeline.

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$\frac{100}{100}$

	reservoir (el. 109.65)				reservoir (el. 100)
Distance (m)	Pt. A, 0	600	800	1000	Pt. B, 1500
Elevation (m)	108	99	103	98	99

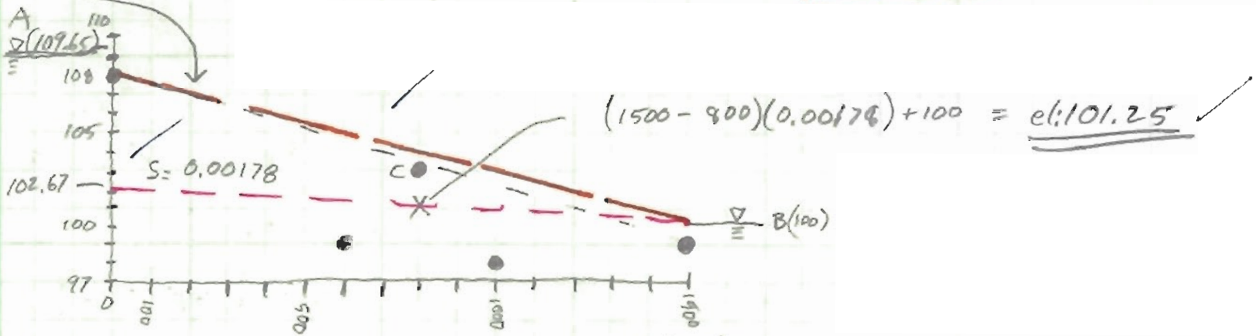
(a) Q @ end of design period = 70 $\frac{L}{s}$. Design PVC pipeline $\varepsilon = 3\times10^{-5}$ m, $\nu_{15°} = 1.14\times10^{-6} \frac{m^2}{s}$

(b) At beginning of " period Q = 35 $\frac{L}{s}$, Draw EG & calc pressure head @ point at D = 800 m.

Solution: * Total energy avail. = 109.65 − 100 = 9.65 m

* Neglect minor losses (entrance, exit) ∴ $h_f = 9.65$ m

S (slope of EG) $= \frac{h_L}{L} = \frac{9.65}{1500} = 0.00643 = \boxed{0.643\ \%}$



(1500 − 800)(0.00178) + 100 = el: 101.25 ✓

*From Handout ("Fig 4"): D = 0.25 m , $\frac{\varepsilon}{D} = \frac{3(10^{-5})\,m}{0.25\,m} = 0.00012$ * $70 \frac{L}{s} = 0.07 \frac{m^3}{s}$

$R_n = \frac{V \cdot D}{\nu}$; $V = \frac{0.07\,m^3/s}{\frac{\pi}{4}(0.25\,m)^2} = 1.426 \frac{m}{s}$ ∴ $R_n = \frac{1.426 \frac{m}{s}(0.25\,m)}{1.14\times10^{-6} \frac{m^2}{s}} = 3.12\times10^5$

From Handout "Fig A-12": $f = 0.0155$ ∴ $h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} = 9.65\,m$ ✓

If $Q = 35 \frac{L}{s} = 0.035\ m^3/s$; $V = \frac{0.035}{\frac{\pi}{4}(0.25)^2} = 0.713$; $R_n = \frac{0.713(0.25)}{1.14\times10^{-6}} = 1.56\times10^5$

From chart : $f = 1.72\times10^{-2}$; $h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} = 1.72(10^{-2})\left(\frac{1500}{0.25}\right)\left(\frac{0.713^2}{2(9.81)}\right) = 2.68\,m$ ✓

$S = \frac{2.68}{1500} = 1.78(10^{-3})$ ✓

~~$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g} + h_f$~~ ; ~~$h_f = 1.72(10^{-2})\left(\frac{800}{0.25}\right)\left(\frac{0.713^2}{2(9.81)}\right) = 1.426\,m$~~

~~Assume $\gamma = 9.8\ kN/m^3$~~

~~$109.65\,m = \frac{p_2}{\gamma} + 103\,m + 1.426\,m$~~

~~$\rightarrow \frac{p_2}{\gamma} = 5.224\,m \rightarrow p_2 =$~~

@ D = 800   H.G. = el. 101,25 m

101.25 − 103 m = −1.75 m ✓ $= \frac{p_c}{\gamma}$

$p_c = \left(-0.1785\ \frac{kN}{m^2}\right)$

Donald
Serolleman

75/100

1. Analysis of Arch Dam Neglecting Thermal Stress

B = 1148 ft
r = 625 ft
σ_w = 336000 lb/ft^2
σ_{rw} = 120000 lb/ft^2
t_{ice} = 7.44 ft
t_{maint} = 20 ft

p_{ice} = 4000 lb/ft^2
a/g = 0.1
Ss = 2.65
θ = 133.5 degrees
θ = 2.33 radians

ilt porosity = 0.5
Hs = 50 ft
γ_c = 150 lb/ft^3
γ_w = 62.4 lb/ft^3
C_m = 0.735
ht= 518 ft

Distance below top of dam, h (ft)	C_e	h_s, ft	t_{nb}, ft	Adopted t_{nb}, ft	r/t_{nb}	R_u , ft	Correction Factor = $(R_u/r)^2$	Corrected t_{nb}, ft	Abutment t, ft
0	0	0	0.0	20.0	0.0	625.0	1.00	0.00	0.0
10	0.08591455	0	1.2	20.0	31.3	625.6	1.00	1.22	3.4
20	0.12896273	0	2.4	20.0	31.3	626.2	1.00	2.45	6.9
30	0.16458499	0	3.7	20.0	31.3	626.8	1.01	3.69	10.3
40	0.1961732	0	4.9	20.0	31.3	627.5	1.01	4.95	13.8
50	0.22504748	0	6.2	20.0	31.3	628.1	1.01	6.21	17.4
60	0.25188785	0	7.4	20.0	31.3	628.7	1.01	7.49	21.0
70	0.27709997	0	8.7	20.0	31.3	629.3	1.01	8.78	24.6
80	0.30094913	0	9.9	20.0	31.3	630.0	1.02	10.07	28.2
90	0.32362031	0	11.2	20.0	31.3	630.6	1.02	11.38	31.9
100	0.34524862	0	12.4	20.0	31.3	631.2	1.02	12.70	35.6
110	0.36593639	0	13.7	20.0	31.3	631.9	1.02	14.02	39.3
120	0.38576335	0	15.0	20.0	31.3	632.5	1.02	15.36	43.0
130	0.40479304	0	16.3	20.0	31.3	633.1	1.03	16.70	46.8
140	0.42307711	0	17.6	20.0	31.3	633.8	1.03	18.06	50.6
150	0.4406582	0	18.8	20.0	31.3	634.4	1.03	19.42	54.4
160	0.45757201	0	20.1	20.1	31.0	635.1	1.03	20.79	58.2
170	0.47384874	0	21.4	21.4	29.2	635.7	1.03	22.17	62.1
180	0.48951425	0	22.7	22.7	27.5	636.4	1.04	23.55	65.9
190	0.50459085	0	24.0	24.0	26.0	637.0	1.04	24.95	69.9
200	0.51909793	0	25.3	25.3	24.7	637.7	1.04	26.35	73.8
210	0.53305248	0	26.6	26.6	23.5	638.3	1.04	27.76	77.7
220	0.54646946	0	27.9	27.9	22.4	639.0	1.05	29.18	81.7
230	0.55936212	0	29.2	29.2	21.4	639.6	1.05	30.61	85.7
240	0.57174225	0	30.5	30.5	20.5	640.3	1.05	32.04	89.7
250	0.58362039	0	31.8	31.8	19.6	640.9	1.05	33.48	93.7
260	0.59500598	0	33.1	33.1	18.9	641.6	1.05	34.93	97.8
270	0.60590752	0	34.5	34.5	18.1	642.2	1.06	36.38	101.9
280	0.61633269	0	35.8	35.8	17.5	642.9	1.06	37.85	106.0
290	0.62628841	0	37.1	37.1	16.9	643.5	1.06	39.31	110.1
300	0.63578098	0	38.4	38.4	16.3	644.2	1.06	40.79	114.2
310	0.64481611	0	39.7	39.7	15.7	644.9	1.06	42.27	118.4
320	0.65339897	0	41.0	41.0	15.2	645.5	1.07	43.76	122.5
330	0.66153431	0	42.3	42.3	14.8	646.2	1.07	45.25	126.7
340	0.66922641	0	43.7	43.7	14.3	646.8	1.07	46.75	130.9
350	0.67647918	0	45.0	45.0	13.9	647.5	1.07	48.26	135.1
360	0.6832962	0	46.3	46.3	13.5	648.1	1.08	49.77	139.4
370	0.68968071	0	47.6	47.6	13.1	648.8	1.08	51.29	143.6
380	0.69563564	0	48.9	48.9	12.8	649.5	1.08	52.81	147.9
390	0.70116368	0	50.2	50.2	12.4	650.1	1.08	54.34	152.1
400	0.70626725	0	51.5	51.5	12.1	650.8	1.08	55.87	156.4
410	0.71094851	0	52.8	52.8	11.8	651.4	1.09	57.41	160.7
420	0.71520943	0	54.2	54.2	11.5	652.1	1.09	58.95	165.1
430	0.71905175	0	55.5	55.5	11.3	652.7	1.09	60.49	169.4
440	0.72247702	0	56.8	56.8	11.0	653.4	1.09	62.04	173.7
450	0.7254866	0	58.1	58.1	10.8	654.0	1.10	63.60	178.1
460	0.72808167	0	59.4	59.4	10.5	654.7	1.10	65.16	182.4
468	0.72985995	0	60.4	60.4	10.3	655.2	1.10	66.41	185.9
470	0.73026322	2	60.9	60.9	10.3	655.4	1.10	66.96	187.5
480	0.73203208	12	63.2	63.2	9.9	656.6	1.10	69.73	195.2
490	0.73338894	22	65.5	65.5	9.5	657.7	1.11	72.51	203.0
500	0.7343343	32	67.8	67.8	9.2	658.9	1.11	75.31	210.9
510	0.73486851	42	70.0	70.0	8.9	660.0	1.12	78.12	218.7
518	0.735	50	71.9	71.9	8.7	660.9	1.12	80.38	225.1

X X

X

-10

-15

2. Analysis of Arch Dam Considering Thermal Stress

2. Analysis of Arch Dam Considering Thermal Stress

B = 1148 ft
r = 625 ft
σ_{c} = 336000 lb/ft^2
σ_{cw} = 120000 lb/ft^2
t_{ce} = 7.44 ft
t[illegible] = 20 ft

p_{ce} = 4000 lb/ft^2
a/g = 0.1
Ss = 2.65
θ = 133.5 degrees
θ = 2.33 radians

Silt porosity = 0.5
Hs = 50 ft
γ_s = 150 lb/ft^3
γ_w = 62.4 lb/ft^3
C_m = 0.735

E_c = 2.90E+08 lb/ft^2
C" = 5.00E-06 °F^{-1}
ΔT_{top} = 30 °F
ΔT_{base} = 10 °F
ht= 518 ft

			NO THERMAL STRESS									CONSIDERING THERMAL STRESSES								
Distance below top of dam, h (ft)	C_r	h_s, ft	t_{ce}, ft	Adopted t_{ce}, ft	r/t_c	R_u, ft	Correction Factor = $(R_u/r)^2$	Corrected t_b, ft	Corrected R_u, ft	Distance below top of dam, h (ft)	ΔT, °F	t_{cb}, ft	Adopted t_{cb}, ft	r/t_{cb}	R_u, ft	Correction Factor = $(R_u/r)^2$	Corrected t_b, ft	Abutment t, ft
0	0	0	0.000	0.0	0.0	625.0	1.00	0.000	625.000	0	30.0	0.000	20.0	0.0	625.0	1.00	0.0	0.0
10	0.08591455	0	1.214	2.0	312.5	626.0	1.00	1.218	625.609	10	29.6	1.399	20.0	446.8	625.7	1.00	1.4	3.9
20	0.12896273	0	2.438	3.0	208.3	626.5	1.00	2.449	626.225	20	29.2	2.804	20.0	222.9	626.4	1.00	2.8	7.9
30	0.16458499	0	3.669	4.0	156.3	627.0	1.01	3.693	626.846	30	28.8	4.211	20.0	148.4	627.1	1.01	4.2	11.9
40	0.1961732	0	4.908	5.0	125.0	627.5	1.01	4.947	627.473	40	28.5	5.620	20.0	111.2	627.8	1.01	5.7	15.9
50	0.22504748	0	6.152	6.5	96.2	628.3	1.01	6.216	628.108	50	28.1	7.030	20.0	88.9	628.5	1.01	7.1	19.9
60	0.25188785	0	7.402	7.5	83.3	628.8	1.01	7.491	628.745	60	27.7	8.441	20.0	74.0	629.2	1.01	8.6	24.0
70	0.27709997	0	8.657	9.0	69.4	629.5	1.01	8.782	629.391	70	27.3	9.851	20.0	63.4	629.9	1.02	10.0	28.0
80	0.30094913	0	9.916	10.0	62.5	630.0	1.02	10.075	630.038	80	26.9	11.261	20.0	55.5	630.6	1.02	11.5	32.1
90	0.32362031	0	11.180	11.5	54.3	630.8	1.02	11.387	630.693	90	26.5	12.670	20.0	49.3	631.3	1.02	12.9	36.2
100	0.34524862	0	12.448	12.5	50.0	631.3	1.02	12.699	631.349	100	26.1	14.078	20.0	44.4	632.0	1.02	14.4	40.3
110	0.36593639	0	13.721	14.0	44.6	632.0	1.02	14.030	632.015	110	25.8	15.485	20.0	40.4	632.7	1.02	15.9	44.4
120	0.38576335	0	14.997	15.0	41.7	632.5	1.02	15.359	632.679	120	25.4	16.890	20.0	37.0	633.4	1.03	17.3	48.6
130	0.40479304	0	16.276	16.5	37.9	633.3	1.03	16.709	633.354	130	25.0	18.294	20.0	34.2	634.1	1.03	18.8	52.7
140	0.42307711	0	17.559	18.0	34.7	634.0	1.03	18.068	634.034	140	24.6	19.695	20.0	31.7	634.8	1.03	20.3	56.9
150	0.4406582	0	18.845	19.0	32.9	634.5	1.03	19.422	634.711	150	24.2	21.095	21.1	29.6	635.5	1.03	21.8	61.1
160	0.45757201	0	20.134	20.5	30.5	635.3	1.03	20.800	635.400	160	23.8	22.492	22.5	27.8	636.2	1.04	23.3	65.3
170	0.47384874	0	21.425	21.5	29.1	635.8	1.03	22.169	636.084	170	23.4	23.886	23.9	26.2	636.9	1.04	24.8	69.5
180	0.48951425	0	22.720	23.0	27.2	636.5	1.04	23.564	636.782	180	23.1	25.278	25.3	24.7	637.6	1.04	26.3	73.7
190	0.50459085	0	24.016	24.0	26.0	637.0	1.04	24.947	637.474	190	22.7	26.667	26.7	23.4	638.3	1.04	27.8	77.9
200	0.51909793	0	25.315	25.5	24.5	637.8	1.04	26.359	638.179	200	22.3	28.054	28.1	22.3	639.0	1.05	29.3	82.1
210	0.53305248	0	26.616	27.0	23.1	638.5	1.04	27.779	638.889	210	21.9	29.437	29.4	21.2	639.7	1.05	30.8	86.4
220	0.54646946	0	27.919	28.0	22.3	639.0	1.05	29.184	639.592	220	21.5	30.817	30.8	20.3	640.4	1.05	32.4	90.6
230	0.55936212	0	29.224	30.0	20.8	640.0	1.05	30.644	640.322	230	21.1	32.193	32.2	19.4	641.1	1.05	33.9	94.8
240	0.57174225	0	30.530	30.5	20.5	640.3	1.05	32.040	641.020	240	20.7	33.566	33.6	18.6	641.8	1.05	35.4	99.1
250	0.58362039	0	31.838	32.0	19.5	641.0	1.05	33.489	641.745	250	20.3	34.936	34.9	17.9	642.5	1.06	36.9	103.4
260	0.59500598	0	33.147	33.5	18.7	641.8	1.05	34.948	642.474	260	20.0	36.301	36.3	17.2	643.2	1.06	38.4	107.6
270	0.60590752	0	34.458	35.0	17.9	642.5	1.06	36.414	643.207	270	19.6	37.663	37.7	16.6	643.8	1.06	40.0	111.9
280	0.61633269	0	35.769	36.0	17.4	643.0	1.06	37.859	643.930	280	19.2	39.020	39.0	16.0	644.5	1.06	41.5	116.2
290	0.62628841	0	37.081	37.5	16.7	643.8	1.06	39.340	644.670	290	18.8	40.374	40.4	15.5	645.2	1.07	43.0	120.5
300	0.63578098	0	38.394	38.5	16.2	644.3	1.06	40.796	645.398	300	18.4	41.723	41.7	15.0	645.9	1.07	44.6	124.8
310	0.64481611	0	39.708	40.0	15.6	645.0	1.07	42.290	646.145	310	18.0	43.068	43.1	14.5	646.5	1.07	46.1	129.0
320	0.65339897	0	41.022	41.0	15.2	645.5	1.07	43.758	646.879	320	17.6	44.409	44.4	14.1	647.2	1.07	47.6	133.3
330	0.66153431	0	42.336	42.5	14.7	646.3	1.07	45.264	647.632	330	17.3	45.745	45.7	13.7	647.9	1.07	49.2	137.6
340	0.66922641	0	43.650	44.0	14.2	647.0	1.07	46.777	648.389	340	16.9	47.076	47.1	13.3	648.5	1.08	50.7	141.9
350	0.67647918	0	44.965	45.0	13.9	647.5	1.07	48.258	649.129	350	16.5	48.402	48.4	12.9	649.2	1.08	52.2	146.2
360	0.6832962	0	46.279	46.5	13.4	648.3	1.08	49.786	649.893	360	16.1	49.723	49.7	12.6	649.9	1.08	53.8	150.5
370	0.68968071	0	47.593	48.0	13.0	649.0	1.08	51.318	650.659	370	15.7	51.040	51.0	12.2	650.5	1.08	55.3	154.8
380	0.69563564	0	48.906	49.0	12.8	649.5	1.08	52.816	651.408	380	15.3	52.351	52.4	11.9	651.2	1.09	56.8	159.1
390	0.70116368	0	50.219	50.5	12.4	650.3	1.08	54.359	652.180	390	14.9	53.657	53.7	11.6	651.8	1.09	58.4	163.4
400	0.70626725	0	51.532	51.5	12.1	650.8	1.08	55.868	652.934	400	14.6	54.957	55.0	11.4	652.5	1.09	59.9	167.7
410	0.71094851	0	52.843	53.0	11.8	651.5	1.09	57.419	653.710	410	14.2	56.252	56.3	11.1	653.1	1.09	61.4	172.0
420	0.71520943	0	54.153	54.5	11.5	652.3	1.09	58.978	654.489	420	13.8	57.542	57.5	10.9	653.8	1.09	63.0	176.3
430	0.71905175	0	55.463	55.5	11.3	652.7	1.09	60.494	655.247	430	13.4	58.826	58.8	10.6	654.4	1.10	64.5	180.6
440	0.72247702	0	56.771	57.0	11.0	653.5	1.09	62.066	656.033	440	13.0	60.104	60.1	10.4	655.1	1.10	66.0	184.9
450	0.7254866	0	58.077	58.5	10.7	654.3	1.10	63.640	656.820	450	12.6	61.376	61.4	10.2	655.7	1.10	67.6	189.1
460	0.72808167	0	59.382	59.5	10.5	654.8	1.10	65.170	657.585	460	12.2	62.642	62.6	10.0	656.3	1.10	69.1	193.4
468	0.72985995	0	60.425	60.5	10.3	655.3	1.10	66.415	658.208	468	11.9	63.651	63.7	9.8	656.8	1.10	70.3	196.8
470	0.73026322	2	60.884	61.0	10.2	655.5	1.10	66.971	658.486	470	11.9	63.902	63.9	9.8	657.0	1.10	70.6	197.7
480	0.73203208	12	63.178	63.2	9.9	656.6	1.10	69.726	659.863	480	11.5	65.153	65.2	9.6	657.6	1.11	72.1	201.9
490	0.73338894	22	65.470	63.5	9.8	656.8	1.10	72.291	661.145	490	11.1	66.398	66.4	9.4	658.2	1.11	73.6	206.2
500	0.7343343	32	67.760	64.5	9.7	657.3	1.11	74.933	662.467	500	10.7	67.637	67.6	9.2	658.8	1.11	75.2	210.4
510	0.73486851	42	70.048	66.0	9.5	658.0	1.11	77.640	663.820	510	10.3	68.869	68.9	9.1	659.4	1.11	76.7	214.7
518	0.735	50	71.876	67.0	9.3	658.5	1.11	79.788	664.894	518	10.0	69.850	69.8	8.9	659.9	1.11	77.9	218.0

Donald Jerolleman

$\frac{88}{100}$

Hydro. Lab Sep 21 ①

Tutorial #4 Evaluate Dam (see handout)

work for hand out :

Step 1 : Find centroids from point O

* centroid of dam

Area	A_i, ft^2	absisa w/respect to 0 $\bar{x}_i$ (ft)	$\bar{Y}_i$ (ft
1	$\frac{1}{2}(400)(520) = 104{,}000$	$\frac{2}{3}(400) = 266.67$	$\frac{520}{3} = 173.33$
2	$40(520) = 20800$	$400 + 20 = 420$	$0.5(520) = 260$
3	$\frac{1}{2}(100)(197) = 9{,}850$	$440 + \frac{100}{3} = 473.33$	$\frac{1}{3}(197) = 65.67$
Σ	$134{,}650$		

$$\bar{X} = \frac{\Sigma(x_i A_i)}{\Sigma A_i} \; ; \; \bar{y} = \frac{\Sigma(y_i A_i)}{\Sigma A_i}$$

$\Sigma(x_i A_i) = 41.3 \times 10^6$; $\Sigma(y_i A_i) = 24.08 \times 10^6$; $\Sigma A_i = 134650$

$(\bar{X} = 305.51', \; \bar{y} = 178.8')$ centroid of dam

centroid of Areas Ⓘ, Ⓘⓘ

Area	A_i (ft^2)	$\bar{X}_i$	$\bar{x}_i A_i$
I	9850	506.67	4.99×10^6
II	32200	490	15.83×10^6
Σ	42150		20.82×10^6

$$\bar{X} = \frac{20.82 \times 10^6}{0.042 \times 10^6} = 493.9'$$

Hydro Lab Sep 21 ②

Seepage $\bar{x} = \frac{2}{3}(540) = 360\text{ ft}$ ✓

Analysis

Normal Force 'N' : $\Sigma F_y = \emptyset = N + U - W - P_v + E_{cv}$

$N = 1.1 \times 10^7 \text{ lb}$ ✓

Check Friction $\Sigma F_x = \emptyset = P_h + E_w + E_{ch} - F_f$

$\rightarrow F_f = 1.29 \times 10^7 \text{ lb}$ ✓

max friction factr. @ base (0.65)

$F_{f_{max}} = N(\mu_s) = 7.18 \times 10^6 \text{ lb}$ ✓ ✓

$F_{os_{sliding}} = \frac{F_{f_{max}}}{F_f} = \frac{7.18 \times 10^6}{7.29 \times 10^7} = 0.56$ No good

should be > 1.5

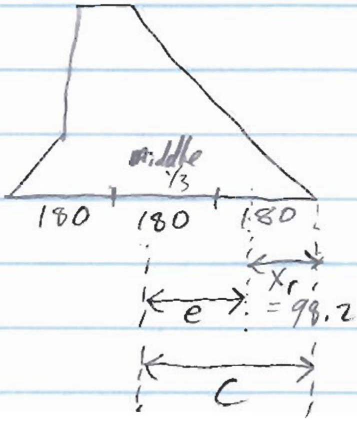
$F_{os_{O/T}} = \frac{M\curvearrowleft}{M\curvearrowright}$ (must be > 1.5) = ✓

Determine if Tension exist in Foundation

* Find location of N ie: X_r ✓

$$\Sigma M_o = 0 = -N(X_r) - \underbrace{6.39 \times 10^9}_{\Sigma M_{o/r}} + \underbrace{7.47 \times 10^9}_{\Sigma M_{w/r}} \rightarrow X_r = 98.2'$$

Hydro Lab Sep 21 ③



Per Kern rule: If N lies in middle 1/3 of the base, there will be no tension.

/

∴ there is Tension in concrete

Find compressive str. of concrete & rock

stress on concrete = stress caused by N + stress caused by the moment M which arises from the excentricity of the load

$$\sigma_c = \frac{N}{(AO)(1ft)} + \frac{M(C)}{I}$$ ← I of base a/b its centroidal axis

$$m = N(e) \ , \quad I = \frac{1}{12}(b)(h^3) = \frac{1}{12}(1ft)(540ft)^3$$

$$S.F. = \frac{\sigma_{rock}}{\sigma_c} \ (\text{want} > 2)$$

-10

Where's the calculation of stresses?

Hydro Lab Sep. 21

ENCE 4319
Tutorial No. 4
Part 1
Due 9/28/10

1. Evaluate the safety of Shasta Dam section shown on the attached Figure 1.

see notes for calculations

Assume:

- neglect ice
- neglect waves
- neglect silt
- full uplift
- earthquake a/g ~ 0.15
- maximum friction factor at base, $\mu_s = 0.65$
- Ss = 2.40 for concrete
- SF against sliding ≥ 1.5
- SF against overturning ≥ 2.0
- no tension in the base
- Sound greenstone foundation rock (1500 psi).
- Concrete strength (3000 psi)
- linear seepage uplift variation from heel to toe of dam.

Use simple shapes to approximate the concrete section.

Calculation of Reactions

For static equilibrium of the vertical slice, we have:

Normal Load Condition (excluding Silt, Ice, Earthquake etc)

$$\Sigma F_x = 0 : -F_f - P_{TW} + P_h = 0$$

$$\mathbf{F_{f\ reqired} = P_h - P_{TW}}$$

$$\textbf{Maximum Friction } \mathbf{F_{f\,available} = N\,\mu_s}$$

$$\Sigma F_y = 0 : N + U - W - P_v = 0$$

$$\mathbf{N = W - U + P_v}$$

$$\Sigma M_o = 0: \; - x_R\; N - H/3\;(P_h) - x_u\; U + x_{cg} W + x_v\;(P_v) + y_{tw} P_{tw} = 0$$

$$\mathbf{x_R = \{ H/3\;(P_h) + x_u\; U - x_{cg} W - x_v\;(P_v) - y_{tw} P_{tw} \}/N}$$

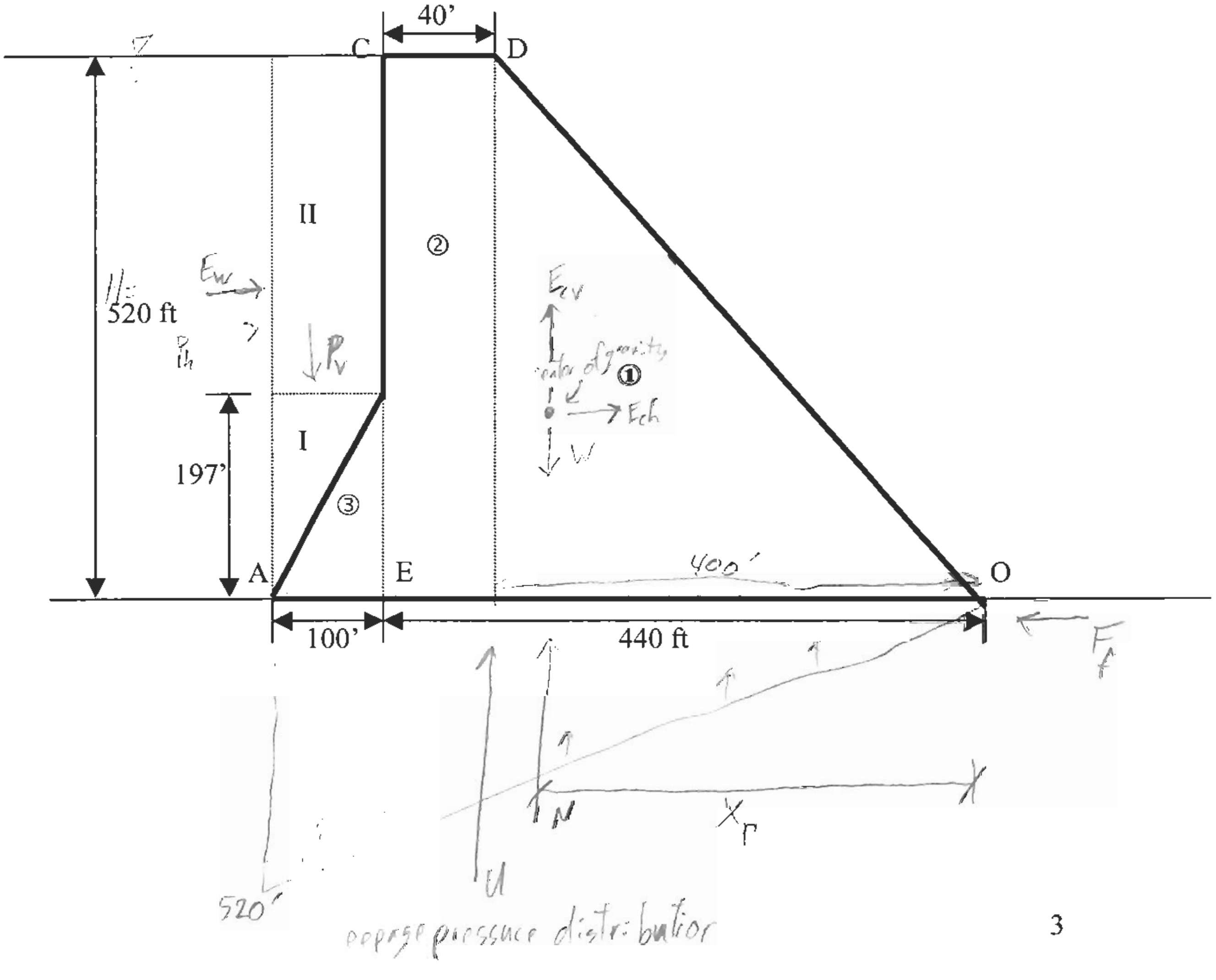
Section	ft² A	from o $\bar{x}$	$\bar{y}$	$A\bar{y}$	$A\bar{x}$
1	104,000	266.7	173.3	18023200	27736800
2	20800	420	260	5408000	8736000
3	9850	473.3	65.67	646849.5	4662005
Σ	134,650			24.08×10^6	41.3×10^6

$\bar{X} = 305.$ $\bar{Y}$ 178.8

ASSUMPTIONS:

1. Neglect ice load
2. Neglect waves
3. Neglect silt load
4. Full uplift
5. Earthquake a/g ~ 0.15
6. Maximum friction factor at base, $\mu_s = 0.65$
7. Ss = 2.40 for concrete
8. SF against sliding ≥ 1.5
9. SF against overturning ≥ 2.0
10. No tension in the base
11. Sound greenstone foundation rock (1500 psi).
12. Concrete strength (3000 psi)
13. linear seepage uplift variation from heel to toe of dam.
14. Ignore training walls in the analysis
15. Neglect grout curtain in seepage path analysis
16. Linear seepage uflift variation from heel to toe of dam
17. No tail water

$\uparrow y^+$



FORCE	FORMULA	F_X , lbs $\rightarrow +$	F_y, lbs $\uparrow +$	Moment Arm, ft	Overturning Moment, lbs.ft $-\circlearrowright$	Uprighting Moment, lbs.ft $+\circlearrowleft$
Hydro static horizontal $F_h = P_h$:	$0.5(62.4\ lb/ft^3)(520^2)$ $\frac{1}{2}\gamma H^2$	8.44×10^6	—	$\frac{1}{3}(520)$	1.46×10^9	—
Hydrostatic vertical $F_v = P_v$:	$62.4\ lb/ft\ (42,150)$ $\gamma\forall_{I+II}$	—	(-2.63×10^6)	493.9	—	1.3×10^9
U =	$0.5(62.4\ lb/ft^3)(520)(540)$ $\frac{1}{2}\gamma bH$	—	2.76×10^6	360	3.15×10^9	—
W =	$2.4(62.4)($ $)$ γ_c (Area of dam) $\hookrightarrow S_s\gamma_w$	—	(-2.02×10^8)	305.5	—	6.17×10^9
earthquake force on water E_w =	$\frac{5}{9}\gamma H^2\left(\frac{a}{g}\right)$	1.406×10^6	—	220.7 260 ft	3.656×10^8	—
earthquake force on concrete E_{ch} = horizontal component	$W\frac{a}{g}$	3.03×10^6	—	178.8	5.418×10^8	—
earthquake force on concrete E_{cv} = vertical component	$W\frac{a}{g}$	—	3.03×10^6	305.5	9.257×10^8	—
Σ=					6.44×10^9	7.47×10^9

②

$\Sigma M_o = (7.47 - 6.44)10^9 = +1.03\times10^9 \circlearrowleft +$

Hydro Lab Sep 22

excel sheet
or blackboa.

ENCE 4319
Tutorial 4, Part 2
Due 10/5/10

Calculate and plot the safe arch thickness as a function of depth (including thermal stress), using 10-ft increments for the conditions given below.

Assume:

- Neglect waves
- Earthquake a/g ~ 0.1
- Maximum crushing strength of the concrete = 7000 psi
- Ss = 2.40 for concrete
- FOS against failure $\geq$ 3 for concrete and foundation
- Sound greenstone foundation rock, strength ~ 2500 psi.
- Minimum thickness for maintenance = 20 ft
- Valley width = 1148 ft
- Water depth, h_t = 518 ft

Arch:

Arch central angle, $\theta = 133.5^{\circ}$

Concrete:

Compression = 7000 psi

$\sigma_w = 7000*144/FOS$ lbs/ft^2

$\gamma_c = 150$ lbs/ft^3

$E_c = 2.9*10^8$ lbs/ft^2

$C" = 0.000005$ $^{\circ}F^{-1}$

$\Delta T \sim 30$ °F top

$\Delta T \sim 10$ °F base

Rock:

Compression = 2500 psi

$\sigma_w = 2500*144/FOS$ lbs/ft^2

Ice:

Thrust pressure = 4000 lbs/ft^2

Earthquake:

a/g = 0.1

Silt:

$S_s = 2.65$

porosity = 0.5

$H_s = 50$ ft

SOLUTION:

A. No Thermal Stress (Form 1)

1. Calculate radius: $r = \dfrac{B}{2\sin\dfrac{\theta}{2}}$

2. Calculate thickness to resist ice stress: $t_{ice} = \dfrac{p_I r}{\sigma_w}$ (p. 47 notes)

3. Calculate overall t_{rib} (p. 50 notes), first assuming zero thermal stress:

$$t_{rib} = \frac{\gamma h r\left[C_e \dfrac{a}{g} + 1 + (S_s - 1)(1 - porosity)\left(\dfrac{h_s}{h}\right)\right]}{\sigma_w - \dfrac{\gamma_c r^2 \theta_{radians}\left(a/g\right)}{B} - E_c C'' \Delta T\left(\dfrac{r}{R_u}\right)},$$

where

h = depth measured fro the top.

$h_s = h + H_s - h_t$, $h_s \geq 0$

$C_e = \dfrac{1}{2} C_m \left[\dfrac{h}{h_t}\left(2 - \dfrac{h}{h_t}\right) + \sqrt{\dfrac{h}{h_t}\left(2 - \dfrac{h}{h_t}\right)}\right]$, $C_m = 0.735$

h_t = total water depth

$R_u = r + \dfrac{t_{rib}}{2}$

$\Delta T = 0$ for no thermal stress

If calculated $t_{rib} > t_{maintenance}$, make adopted t_{rib} = calculated t_{rib}
If calculated $t_{rib} < t_{maintenance}$, make adopted $t_{rib} = t_{maintenance}$

4. Check thickness:

- If $\dfrac{r}{t_{rib}} > 25$, t_{rib} is OK
- If $\dfrac{r}{t_{rib}} < 25$, apply correction factor = $\left(\dfrac{R_u}{r}\right)^2$, where $R_u = r + \dfrac{t_{rib}}{2}$

5. Calculate dam abutment thickness: $t_{abutmt} = t_{rib}\left(\dfrac{\sigma_w}{\sigma_{rw}}\right)$

B. Consider Thermal Stress

1. Calculate ΔT assuming linear temperature variations from top to bottom.

2. Recalculate overall t_{rib} using:

$$t_{rib} = \frac{\gamma hr\left[C_e \frac{a}{g} + 1 + (S_s - 1)(1 - porosity)\left(\frac{h_s}{h}\right)\right]}{\sigma_w - \frac{\gamma_c r^2 \theta_{radians}\left(a/g\right)}{B} - E_c C'' \Delta T\left(\frac{r}{R_u}\right)},$$

where R_u would be the value computed w/o thermal stress.

3. If calculated $t_{rib} < t_{maintenance}$, use $t_{maintenance}$

4. Check thickness:
   - If $\frac{r}{t_{rib}} > 25$, t_{rib} is OK
   - If $\frac{r}{t_{rib}} < 25$, apply correction factor = $\left(\frac{R_u}{r}\right)^2$, where $R_u = r + \frac{t_{rib}}{2}$

     Corrected t_{rib} = Correction factor x Adopted t_{rib}

5. Recalculate dam abutment thickness: $t_{abutmt} = Corrected\ t_{rib}\left(\frac{\sigma_w}{\sigma_{rw}}\right)$

2. Analysis of Arch Dam Considering Thermal Stress

$B =$ 1148 ft
$r =$ 625 ft
$\sigma_w =$ 336000 lb/ft^2
$\sigma_{cw} =$ 120000 lb/ft^2
$t_{ice} =$ 7.44 ft
$t_{min} =$ 20 ft

$p_{ice} =$ 4000 lb/ft^2
$a/g =$ 0.1
$Ss =$ 2.65
$\theta =$ 133.5 degrees
$\theta =$ 2.33001455 radians

Silt porosity = 0.5
$Hs =$ 50 ft
$\gamma_c =$ 150 lb/ft^3
$\gamma_w =$ 62.4 lb/ft^3
$C_m =$ 0.735

$E_c =$ 2.90E+08 lb/ft^2
$C^* =$ 5.00E-06 °F^{-1}
$\Delta T_{top} =$ 30 °F
$\Delta T_{base} =$ 10 °F

			NO THERMAL STRESS							CONSIDERING THERMAL STRESSES							
Distance below top of dam, h (ft)	C_e	h_s, ft	t_{nb}, ft	Adopted t_{nb}, ft	r/t_{nb}	R_u, ft	Correction Factor = $(R_u/r)^2$	Corrected t_{nb}, ft	Corrected R_u, ft	ΔT, °F	t_{nb}, ft	Adopted t_{nb}, ft	r/t_{nb}	R_u, ft	Correction Factor = $(R_u/r)^2$	Corrected t_{nb}, ft	Abutment t, ft
0																	
10																	
20																	
30																	
40																	
50																	
60																	
70																	
80																	
90																	
100																	
110																	
120																	
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400																	
410																	
420																	
430																	
440																	
450																	
460																	
468																	
470																	
480																	
490																	
500																	
510																	
518																	

1. Analysis of Arch Dam Neglecting Thermal Stress

B = 1148 ft
r = 625 ft
σ_w = 336000 lb/ft^2
σ_{rw} = 120000 lb/ft^2
t_{ice} = 7.44 ft
t_{maint} = 20 ft

p_{ice} = 4000 lb/ft^2
a/g = 0.1
Ss = 2.65
θ = 133.5 degrees
θ = 2.33001455 radians

Silt porosity = 0.5
Hs = 50 ft
γ_c = 150 lb/ft^3
γ_w = 62.4 lb/ft^3
C_m = 0.735

Distance below top of dam, h (ft)	C_e	h_s, ft	t_{rib}, ft	Adopted t_{rib}, ft	r/t_{rib}	R_u , ft	Correction Factor = $(R_u/r)^2$	Corrected t_{rib}, ft	Abutment t, ft
0									
10									
20									
30									
40									
50									
60									
70									
80									
90									
100									
110									
120									
130									
140									
150									
160									
170									
180									
190									
200									
210									
220									
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400									
410									
420									
430									
440									
450									
460									
468									
470									
480									
490									
500									
510									
518									

Donald Jerolleman

$\frac{77}{100}$

$F = ma$

$lb = slug\left[\frac{ft}{s^2}\right]$

$slug = \frac{lb \cdot s^2}{ft}$

Fluid Lab Sep 7

ENCE 4319
Tutorial No. 2
Due 9/14/10

1. Determine the force on the wall at the open channel T-junction shown below. Assume that the force is due to hydrostatic pressure and is given by

$$P = \frac{1}{2}\gamma \overset{w}{\cancel{\;}} y^2$$

$Q = VA$

Assume $\alpha = \beta = 1.0$

Given: Q = 120 cfs; y_2 = 3.0 ft = y3; $h_{L1\text{-}2} \approx K\, V_2^2/2g$ where K = 1.0

$\frac{20}{30}$

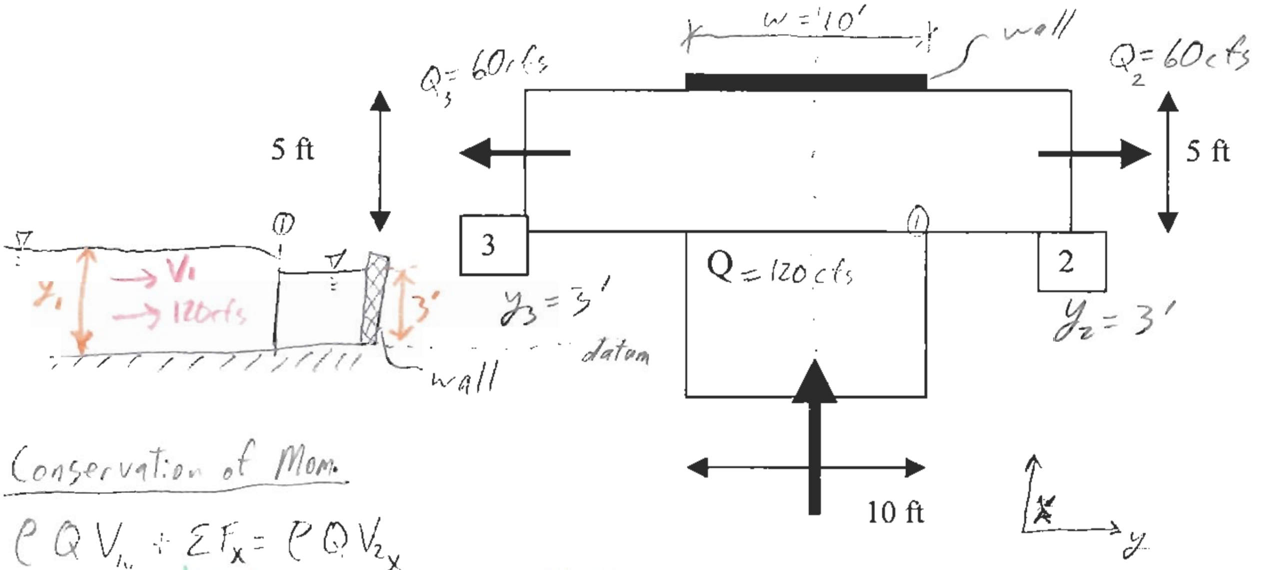
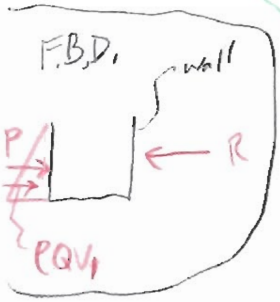


Figure 1 Plan view

Conservation of Mom.

$$\rho Q V_{1_y} + \Sigma F_x = \rho Q V_{2_x}$$



$$\rightarrow \rho Q V_{1_x} + P - R = \emptyset \quad \text{equ.①}$$

$$V_2 = \frac{60\,ft^3/s}{5'(3')} \quad 4\,ft/s$$

Energy Balance to find V_1 $\left\{V_1 = \frac{120\,ft^3/s}{y_1(10')}\right\}$

$$\frac{V_1^2}{2g} + y_1 + \cancel{Z_1} = \frac{V_2^2}{2g} + \overset{3'}{y_2} + \cancel{Z_2} + h_{L_{1-2}} \text{ — given}$$

$$\rightarrow \frac{\left(\frac{120\,ft^3/s}{y_1(10ft)}\right)^2}{64.4\,ft/s^2} + y_1 = \frac{16\,ft^2/s^2}{64.4\,ft/s^2} + 3ft + \frac{16\,ft^2/s^2}{64.4\,ft/s^2}$$

$$\rightarrow \frac{1}{y_1^2}(2.236) + y_1 = 3.497 \rightarrow 2.236 + y^3 = 3.497y^2$$

$$y_1^3 - 3.497y_1^2 + 2.236 = \emptyset$$

$$\rightarrow y_1 = \underline{3.29\,ft} \checkmark$$

$$\therefore \frac{V_1^2}{2g} + 3.29 = \frac{(4\,ft/s)^2}{2g} + 3' + \frac{4^2}{2g} \rightarrow V_1^2\ 13.32 \rightarrow V_1 = \underline{3.65\,ft}$$

$$P_{/ft} = \frac{1}{2}\, 62.4\, lb/ft^3\, (\underline{3.29\,ft})^2 = 337.7\ lb/ft$$

? ← $y = 3'$

P_{Total} = 3377 lb X (−5)

$\rho Q V_1$ = 848.8 lb

$R = P + \rho Q V_1 = \boxed{4226\ lb}$ X (−5)

R = 3657.7 lb.

$\gamma = 9.8 \frac{kN}{m^3}$ OVER

27/35

2. a) Estimate the velocity and pressures in the elbow in Figure 2.
b) Determine the force on the elbow due to the water.
c) Design the thrust block for the elbow. — Block area $A = \frac{\text{Newtons}}{150 \times 10^3 \frac{\text{Newtons}}{m^2}}$ } soil bearing capacity

The mass of the pipe is 300 kg. * Neglecting weight of water
Assume: α=β = 1; the density of the water is 1000 kg/m³ and bearing capacity of the soil is 150 kPa. Head loss ~ 0.5 $V^2/2g$.

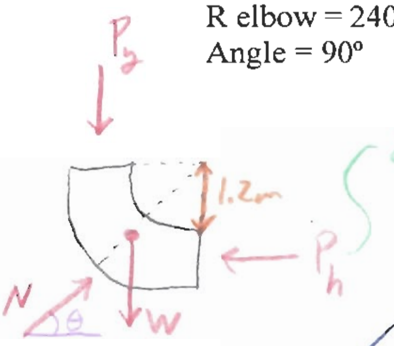
Given: All diameters are 1200 mm
Q = 3.4 m3/s
R elbow = 2400 mm
Angle = 90°

Energy balace b/t ① & ② $V_1 = V_2$

$$\frac{P_1}{\gamma} + \cancel{\frac{V_1^2}{2g}} + z_1 = \frac{P_2}{\gamma} + \cancel{\frac{V_2^2}{2g}} + \cancel{z_2} + h_{L_{1-2}}$$

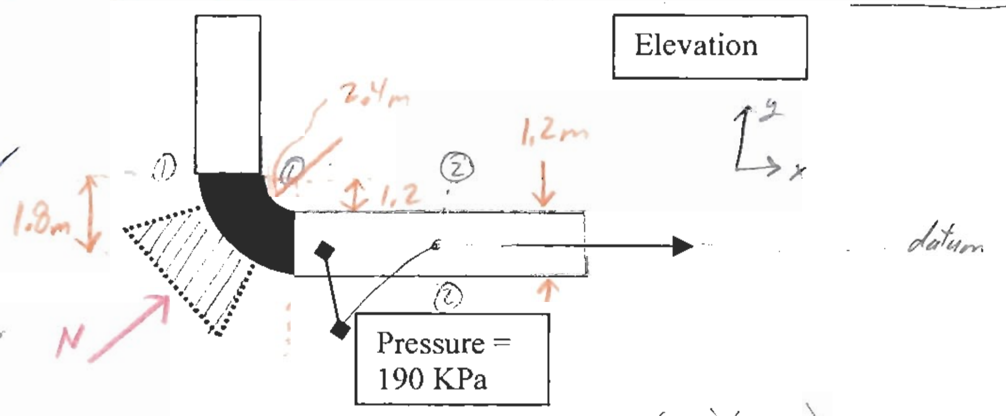
given = 190 kPa; on datum; (given: $0.5 \frac{V^2}{2g}$ = 0.23 m

$Q = A_1V_1 = A_2V_2 = AV \rightarrow V = \frac{1}{\frac{\pi}{4}(1.2m)^2}(3.4 \frac{m^3}{s}) = 3.01 \frac{m}{s}$



given, using $P_2 \cdot A$

$W = 300kg(9.81\frac{m}{s^2}) = 2943N$



$\frac{P_1}{\gamma} + 1.2m = \frac{190 \frac{kN}{m^2}}{\gamma} + 0.23m$

$P_1 = 180.5 \frac{kN}{m^2}$

Figure 2.

Impulse-mom. balance

x-direction: $\text{Mo in} + \Sigma F_x = \rho Q V_2$

No horizontal component $\emptyset$; N_x P_1A_2

$N_x - 190 \times 10^3(1.131) = 1000(3.4)(3.01)$

$\rightarrow N_x = 225.124 \text{ kN} \rightarrow$

?

No vertical on right side

$\Sigma F_y = -P_1A \boxed{-W_p} + N_y$

y-direction: $M_o \text{ in} "\rho Q V_1" + \Sigma F_y = \emptyset \rightarrow \quad \emptyset = -(\rho Q V_1) = -1000 \frac{kg}{m^3}(3.4 \frac{m^3}{s})(3.01 \frac{m}{s}) - (180.5 \frac{kN}{m^2}(1.131 m^2)) - 300kg(9.81 \frac{m}{s^2}) + N_y$

$\rightarrow N_y = 217.322 \text{ kN} \uparrow$ X $N_y = 190$ kN.

(5)

Force of Elbow on water $= \sqrt{N_x^2 + N_y^2} = 313 \text{ kN}$ (-1)

$\theta = \tan^{-1}\frac{N_y}{N_x} = 44°$ θ θ = 40.2°

Force of Elbow on block or Water on Elbow

F = 313 kN (-1) θ = 44° or 224° θ

Block Area

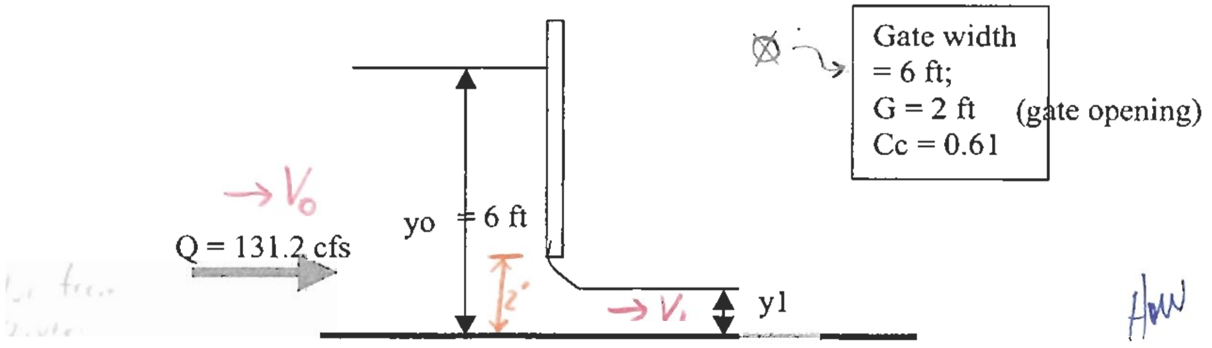
$A = \frac{313 kN \times 10^3 \frac{N}{kN}}{150 kPa \times 10^3 [\frac{N}{m^2}]}$

$= \boxed{2.087 m^2}$ (-1

A = 1.96 m²

30/35

3. Estimate the force on the sluice gate shown below.



Gate width = 6 ft;
G = 2 ft (gate opening)
Cc = 0.61

Figure 3.

$\rho Q V_0 + \Sigma F_x = \rho Q V_1$

$\Sigma F_x = F_0 - F_1 - R_x = \left(\frac{1}{2}\gamma W_0 y_0^2\right) - \left(\frac{1}{2}\gamma W_1 y_1^2\right) - R_x$

$\to 1.94 \frac{slug}{ft^3}\left(131.2 \frac{ft^3}{s}\right)\left(3.64 \frac{ft}{s}\right) + \frac{1}{2}(62.4)(6ft)(6ft)^2 - \frac{1}{2}(62.4)(6)(1.22ft)^2 - R_x = 1.94(131.2)(17.92)$

$\to \boxed{R_x = 2826 \text{ lb}}$

How did you find velocities?

-5

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$\frac{100}{100}$

ENCE 4319
Laboratory No. 1
Demonstration of Continuity and Energy Principles

A sluice gate is used to regulate the flow of water from a channel or reservoir. It may be adjusted to divert flow or increase the upstream stage. The flow upstream of the gate is subcritical and the flow downstream is supercritical.

Required: To conduct a scale model experiment on a sluice gate to demonstrate the use of the continuity and conservation of energy principles in hydraulics.

Procedure:

- Take the following measurements before starting the experiment: a) the channel width, b) the gate opening, c) the width of the sharp-edged weir, and d) the height to the crest of the sharp-edged weir.
- Start the pump and allow the flow to become steady.
- Measure the upstream and downstream water depths at the gate.
- Determine the head on the sharp-edged rectangular weir. Use the following equation (use consistent units on both sides of the equation):

$$Q = \frac{2}{3}\sqrt{2g}\left(0.604 + 0.081\frac{H}{h}\right)(L - 0.1H)H^{\frac{3}{2}}$$

where:

h = height of weir measured from the bottom;
H = head on weir (measured at 4H from the weir);
L = Length of weir

- Using the energy and continuity equations estimate the flow under the sluice gate.
- Compare the estimated flow with the flow through the weir, and calculate the percent difference.

Results:

- Channel width, b = 76.2 mm,
- The gate opening, G = 25.4 mm,
- The width of the sharp-edged weir, L = 50.8 mm,
- The height to the crest of the sharp-edged weir, h = 82 mm.
- Water Depth Data:
    - Upstream of gate, y_o = 81.7, 82.7, 80.1 ⇒ 81.5
    - Downstream of gate, y_1 = 18.9, 18.8, 18.7 ⇒ 18.8
    - Upstream of weir, y_2 = 14.8, 14.7, 14.7 ⇒ 14.7

$$Q = \frac{2}{3}\sqrt{2g}\left(0.604 + 0.081\frac{H}{h}\right)(L - 0.1H)\,H^{3/2}$$

$$\left\{\begin{matrix} Y_0 = 81.5 \text{ mm} \\ Y_1 = 18.8 \text{ mm} \\ Y_2 = 14.7 \text{ cm} \end{matrix}\right\} ✓$$

$h = 82\text{ mm} = 0.082\text{m}$

$H = y_2 - h = 14.7\text{cm}\left(10^1 \frac{\text{mm}}{\text{cm}}\right) - 82\text{ mm} = 65\text{mm} = 65 \times 10^{-3}\frac{\text{m}}{\text{mm}} = \underline{\underline{0.065\text{m}}}$ ✓

$L = 50.8\text{ mm} = 0.0508\text{m}$ ✓

$\therefore\ Q = \boxed{0.001449\ \text{m}^3/\text{s}}$ ✓

$$Q_{\text{channel}} = A_{\text{channel}}\,V_{\text{channel}} = Q_{\text{gate}} = A_{\text{gate}}\,V_{\text{gate}}$$

$$1.449 \times 10^{-3}\,\text{m}^3/\text{s} = (0.0815\text{m})(0.0762\text{m})\,V_{\text{channel}} = 1.449 \times 10^{-3}\,\text{m}^3/\text{s} = (0.0188\text{m})(0.0762\text{m})\,V_{\text{gate}}$$

<u>Assumption: neglecting loss at sluice gate</u>

$$\overset{\nearrow 0}{\cancel{\frac{p_1}{\gamma}}} + z_1 + \frac{V_1^2}{2g} = \overset{0}{\cancel{\frac{p_2}{\gamma}}} + z_2 + \frac{V_2^2}{2g} \Rightarrow y_0 + \frac{Q^2}{2gA_0^2} = y_1 + \frac{Q^2}{2gA_1^2}$$

$$\frac{Q^2}{2gA_0^2} - \frac{Q^2}{2gA_1^2} = (y_1 - y_0)$$

$$Q = \sqrt{\frac{2g\,(Y_1 - Y_0)}{\frac{1}{A_0^2} - \frac{1}{A_1^2}}}$$

$$\frac{Q^2}{2g}\left(\frac{1}{A_0^2} - \frac{1}{A_1^2}\right) = (y_1 - y_0) \rightarrow \frac{Q^2}{2g} = \frac{(Y_1 - Y_0)}{\left(\frac{1}{A_0^2} - \frac{1}{A_1^2}\right)}\,\frac{(A_1^2 A_0^2)}{(A_1^2 A_0^2)}$$

$$\frac{Q^2}{2g} = \frac{(Y_1 - Y_0)(A_1^2 A_0^2)}{(A_1^2 - A_0^2)} \rightarrow Q = \left[\frac{(Y_1 - Y_0)(A_1^2 A_0^2)\,2g}{(A_1^2 - A_0^2)}\right]^{0.5}$$

$$Q = \left[\frac{(0.0188\text{m} - 0.0815\text{m})\left[(0.0188\text{m})(0.0762)\right]^2\left[(0.0815)(0.0762)\right]^2\,2(9.81)}{\left[(0.0188)(0.0762)\right]^2 - \left[(0.0815)(0.0762)\right]^2}\right]^{0.5}$$

$$= \left[\frac{-0.00000000000097}{-0.0000036515598}\right]^{0.5} = \boxed{0.001633\ \text{m}^3/\text{s}}$$ ✓

$$\frac{Q_{\text{theory}} - Q_{\text{real}}}{Q_{\text{theory}}} \times 100 = \frac{0.001449 - 0.001633}{0.001449} \times 100 = \boxed{-11.26\%} \quad \boxed{\text{or } |\%_{\text{diff}}| = 11.26\%}$$ ✓

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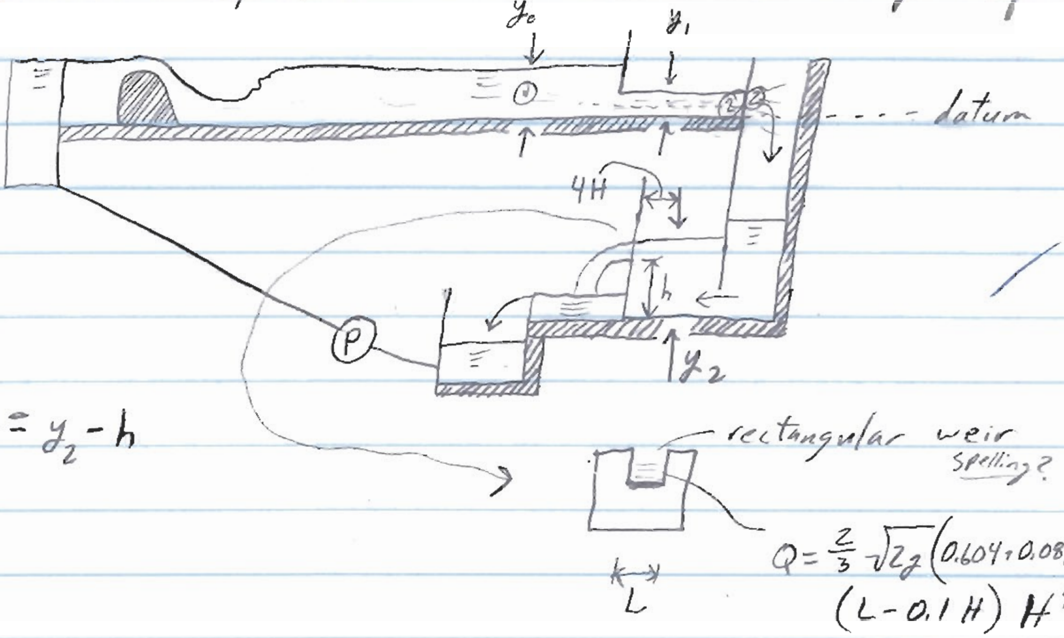
LAB 1

Hydro. Lab sep. 14 ①

p. 1 of 2



$H = y_2 - h$

$$Q = \frac{2}{3}\sqrt{2g}\left(0.604 + 0.081\frac{H}{h}\right)(L - 0.1H)\,H^{2/3}$$

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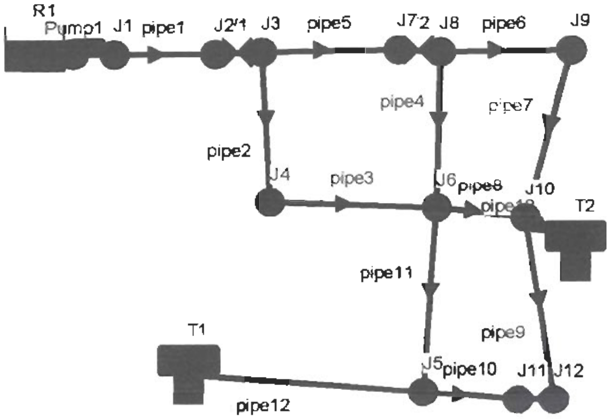
98/100

Day 1.



where are the valves?

-2

Network Table - Nodes

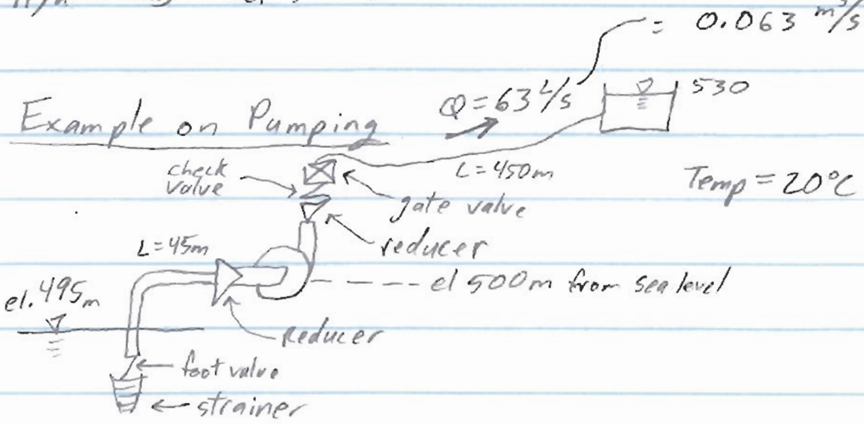
Node ID	Elevation ft	Head ft	Pressure psi
Junc J1	0	679.63	294.48
Junc J2	40	238.48	86.00
Junc J3	40	238.48	86.00
Junc J4	30	168.61	60.06
Junc J5	20	79.38	25.73
Junc J6	20	114.78	41.07
Junc J7	40	134.90	41.12
Junc J8	40	134.90	41.12
Junc J9	50	76.94	11.67
Junc J10	40	74.12	14.78
Junc J11	40	73.06	14.32
Junc J12	40	73.06	14.32
Resvr R1	20	20.00	0.00
Tank T1	79	89.00	4.33
Tank T2	59	69.00	4.33

Pipe pipe3	3000	[illegible]	[illegible]	[illegible]
Pipe pipe4	2000	[illegible]	[illegible]	[illegible]
Pipe pipe5	2000	[illegible]	[illegible]	13.11
Pipe pipe6	3000	[illegible]	[illegible]	[illegible]
Pipe pipe7	2100	[illegible]	[illegible]	[illegible]
Pipe pipe8	2000	[illegible]	[illegible]	[illegible]
Pipe pipe9	2000	[illegible]	[illegible]	[illegible]
Pipe pipe10	2000	[illegible]	100	2.90
Pipe pipe11	2000	[illegible]	100	1.90
Pipe pipe12	1000	[illegible]	100	0.00
Pipe pipe13	1000	[illegible]	100	2.51
Pump Pump1	#N/A	#N/A	#N/A	22.51
Valve V1	#N/A	[illegible]	#N/A	22.51
Valve V2	#N/A	[illegible]	#N/A	13.11
Valve V3	#N/A	[illegible]	#N/A	2.90

? No flow ?

Hydro Lab Oct 5 ①

Example on Pumping



* select pipe diameters, & pump

* check pump efficiency curve & other characteristics

① Find Suction Pipe diameter

Recommendation : Vel. = 1.2 → 1.8 m/s (to prevent turbulants)

$Q = VA \rightarrow D = \frac{2}{\sqrt{\pi}}\sqrt{\frac{Q}{V}}$; select $V = 1.28$ m/s $\rightarrow D = 0.25$m $= 250$mm

② Total suction lift (h_s)

Hazen & Williams equ. : for metric : $Q = 0.2785\, C\, D^{2.63} . S^{0.54}$

Q = flow rate [m³/s], C = $\overset{\text{"Hazen \& Williams"}}{HW}$ coefficient, D = pipe diameter [m],

S = slope of E.G. [m/m] ← New Aspestos, cement or PVC

$Q = 0.063$ m³/s, $D = 0.25$m, $C = 140 \rightarrow S = 0.005785$

$h_f = 0.005785\, (\overset{\text{Pipe length}}{45m}) = 0.26m$

$V = \frac{0.063 m^3/s}{\frac{\pi}{4}(0.25^2)\, m^2} = 1.28 m/s \quad \therefore \frac{V^2}{2g} = 0.084 m$

calc. minor losses (see blackboard)

$h_{minor} = k\frac{V^2}{2g}$ see table in handout

Hydro Lab ② oct5

Item	k	$k\frac{V^2}{2g}$ — use previous just calculated
Entrance loss	0.75	0.06
Foot valve + strainer	4.0	0.34
Bend/elbow	0.25	0.02
Reducer (assumed 3/4)	0.2	0.05
	$\Sigma: h_{minor}$	= 0.47m

For Reducer the $\frac{V^2}{2g}$ applies to the smaller section.
If v = vel. in small section;
V = vel. in larger section
then: $\frac{V}{(d/D)^2} = v = 2.28$ m/s
$\frac{v^2}{2g} = 0.26$

Suction losses:

Friction = 0.26m
minor = 0.47m
Total = 0.73

$h_s = \overset{static}{5.0} + \overset{losses}{0.73} = \boxed{5.73\,m}$ Now A Fixed #

③ Discharge pipe (Find most economical pipe dia.)

* Recommendation: Max. Vel. = 2.4 m/s

$D = \frac{2}{\sqrt{\pi}}\sqrt{\frac{Q}{V}} = 0.18\,m$, commercial diam = D = 200mm

Compaire: D = 200, D = 300, D = 400 Aspestos Concrete Pipe

(a) D = 200mm,

$$\left.\begin{array}{l} Q = 0.063\,m^3/s \\ C = 140 \\ D = 0.2\,m \end{array}\right\} S = 0.0172 \therefore h_f = 0.0172(450) = 7.72$$

$V = \frac{0.063\,m^3/s}{\frac{\pi}{4}(0.2^2)m^2} = 2.1\,m/s \quad \therefore \frac{V^2}{2g} = 0.205m$

Formula for increaser: $h_{increase} = k\left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right)$

Hydro Lab ③ Oct. 5

Minor Losses

Item	K	$k\frac{V^2}{2g}$
Increaser	0.25	0.77
check valve	2.0	0.41
gate valve (open)	0.2	0.04
Exit loss (loose one $\frac{V^2}{2g}$ b/c to open tank)	1.0	0.21

Assume pump discharge dia = 100mm ; ∴ $V = \frac{0.063\ m^3/s}{\frac{\pi}{4}(0.1^2)m^2}$

$= 8.02\ m/s,\ \frac{V^2}{2g} = 3.28\ m/s$

$h_{increaser} = 0.25\ \frac{V_1^2 - V_2^2}{2g} = 0.25(3.28 - 0.21)$

$= 0.77$

$\Sigma: h_{minor} = 1.43m$

Total discharge head (h_d) = static disch. head + friction + minor

$h_d = 30.0 + 7.72 + 1.43 = 39.15m$

$TDH = h_s + h_d = 5.73 + 39.15 = 44.88$

Total Dynamic Head (head needed to be developed by pump)

$\text{Input Power[kW]} = \frac{Q[L/s] \times H[m]}{102 \times eff_{pump}} = \frac{63(44.88)}{102(0.81)} = \underline{34.0\ kW}$

Assumed

For D = 200mm

Calc. Cost

Assume energy costs $0.091\ \frac{\$}{kW\text{-}h}$

Annual cost of energy $= 34.0\ kW\left(\frac{365d}{yr}\right)\left(\frac{24h}{d}\right)\left(0.091\ \frac{\$}{kW\text{-}hr}\right)$

$= 27,111\ \$/yr$

Put into PW: Assume 25yr operation, interest rate = 9%

$PW_{energy} = \frac{(i+1)^{n-1}}{i(i+1)^n}(\text{Annual cost}) = \$266,304$

Pipeline Cost: Assume \$13/ft + \$3/ft sand backfill = \$16/ft = 52.49 \$/m

Pipline Cost = 450m (52.49 \$/m) = \$23 622

Hydro lab Oct. 5 ④

Pump + motor + pumping sta: \$30,000

Total init. cost = \$53 622

PV energy = \$266 304

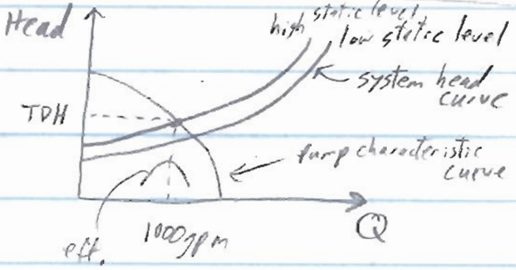
Total PV = 319 926

for D = 200 mm

Fast Forward through other choices to compare

Dia. (mm)	P.V.
200	319 926
300	315 137 ← Select D = 300 mm
400	361 490

④ Select pump



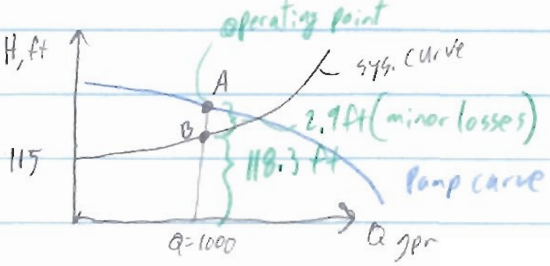
(a) Draw System Curve

$$(h_f)_{ft} = 10.454\ L_{ft}\ Q_{gpm}^{1.8519} \left(\frac{1}{C}\right)^{1.8519} \left(\frac{1}{D_{in}^{4.87}}\right)$$

max static head = 115 ft ; min static head = 108 ft

L = 1476 ft.

(b) Plot operating point



@ Q = 1000 gpm , D = 300 mm

h_f = 3.3 ft , Total static head = 115 ft

Total = 118.3 ft

minor losses = 2.88 ft

∴ TDH = 121.2 ft

Select pump that goes through Point A w/ max eff.
Then correct curve so it goes through point B.

Pump Selection

- Select Pump rotational speed
  - Use Hydraulic Institute Chart (in handout Fig 99)

Max specific speed to prevent cavitation, $N_s = 1780 = \frac{N\sqrt{Q}}{H^{3/4}}$

max rotational speed, $N = \frac{1780\,(121.2^{3/4})}{\sqrt{1000}} = 2056\,rpm$

Oct. 5
Hydro LAB

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EPANET2,
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ENCE 4319

Assignment on Pumping

Due 10-12-10

1. a) Calculate the system head curve for the pumping system shown in Fig. 1. Neglect minor losses.

   b) What TDH should be developed by the pump if the total flow rate to be delivered is 350 l/s?

2. Pump 1, which is attached to a low tank, and pump 2, discharging to a high tank, are connected in series. The low tank has the liquid surface at elevation 100 and the high one, at elevation 110. A force main 500 m long, with C = 140 and D = 100 mm joins pumps 1 and 2; the force main between pump 2 and the high tank, is 500 m long, with C = 140 and D = 200 mm. Neglecting all minor losses, find the flow rate delivered by this system if the characteristic curves of both pumps are the following:

Q, l/s		0	12.6	25.2	37.8	50.4	63.0	75.7
H, m	Pump 1	23.8	23.6	23.0	21.5	18.6	13.7	7.0
	Pump 2	39.6	39.1	37.8	34.2	28.7	21.3	9.2

3. Calculate and draw the system head curve for the system shown in Fig. 2 neglecting minor losses. Use Darcy's formula to compute friction losses.

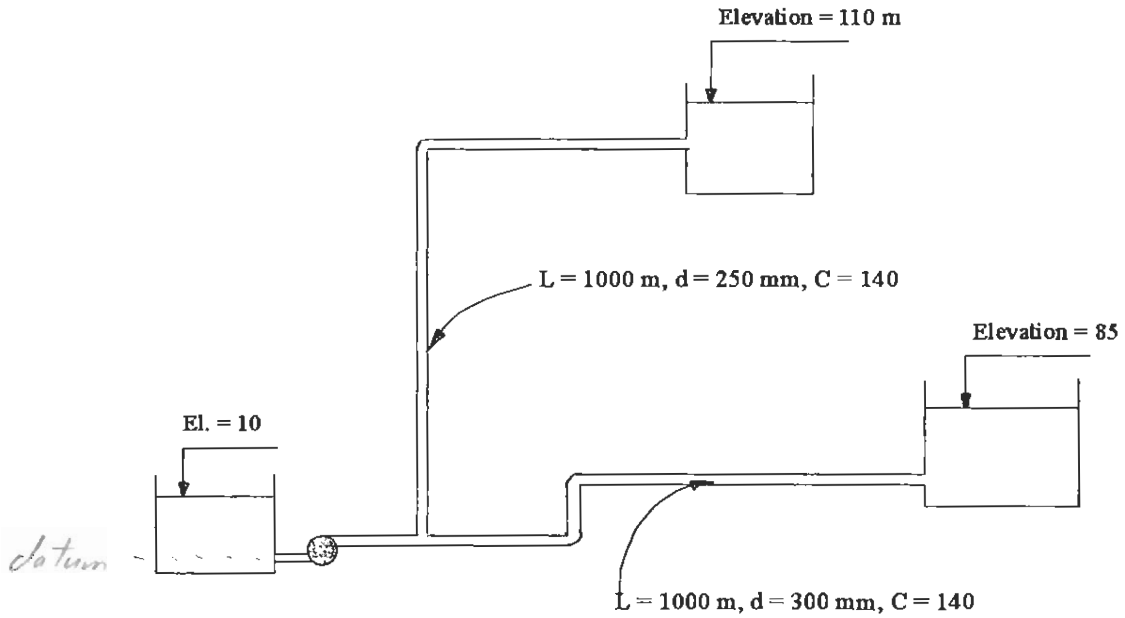


Fig. 1 Problem 1

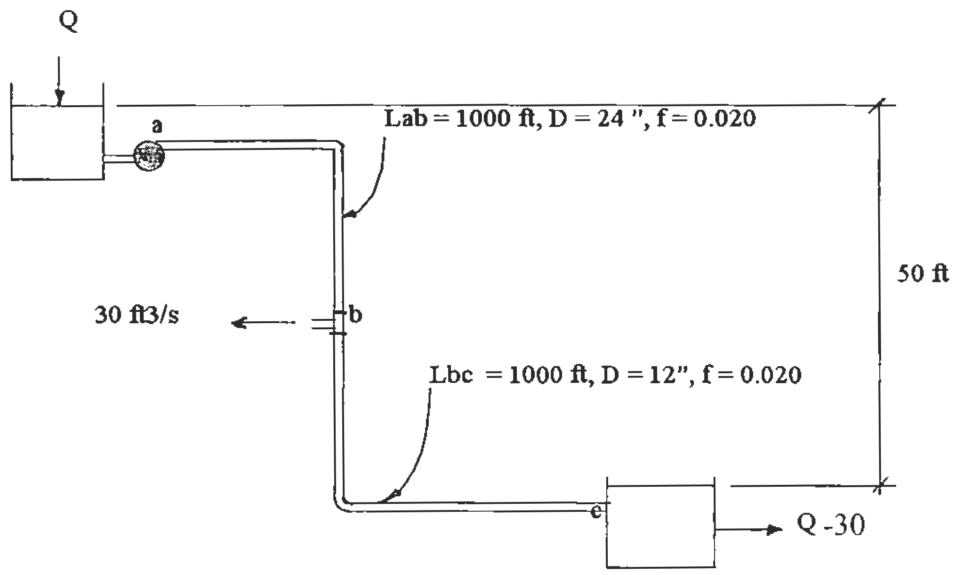


Fig. 2. Problem 3

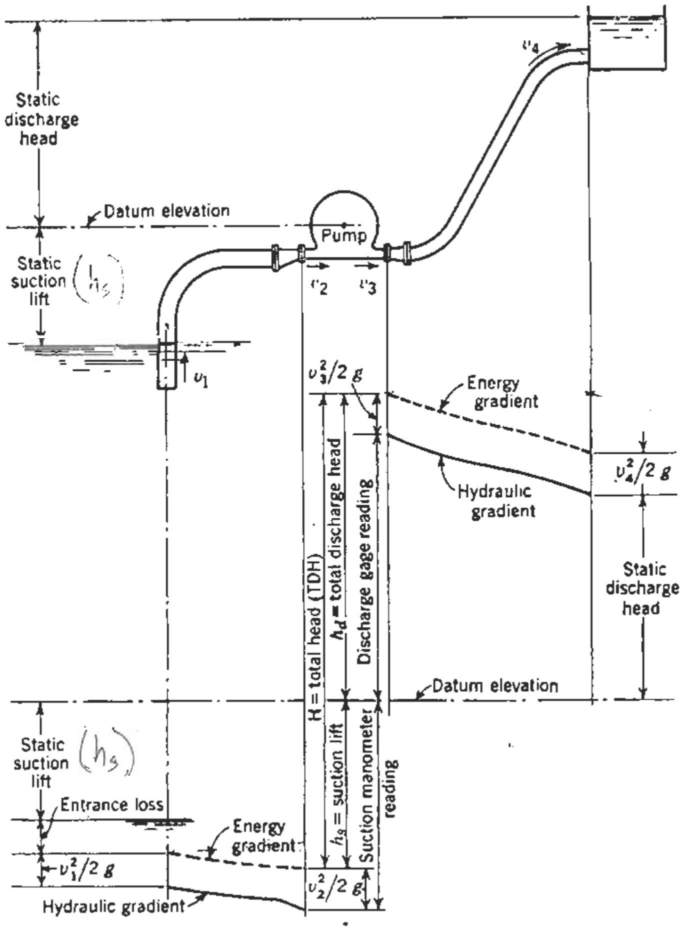


FIG. 95.—PUMP-HEAD RELATIONSHIPS (WITH SUCTION LIFT)

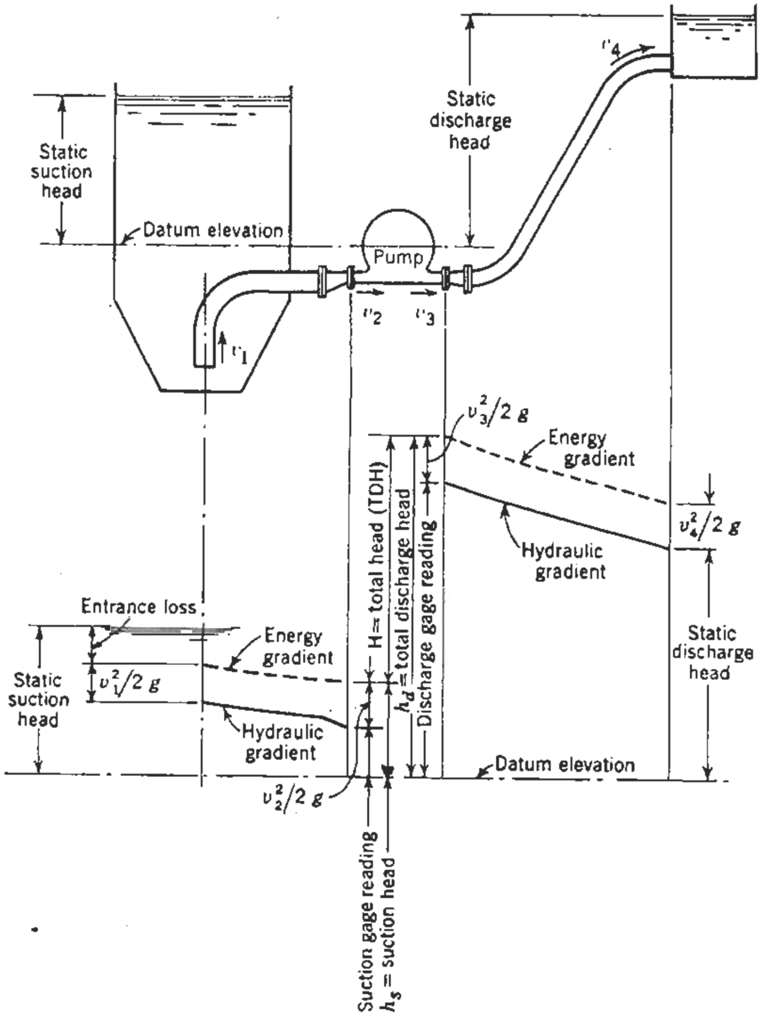


FIG. 96.—PUMP-HEAD RELATIONSHIPS (WITH SUCTION HEAD)

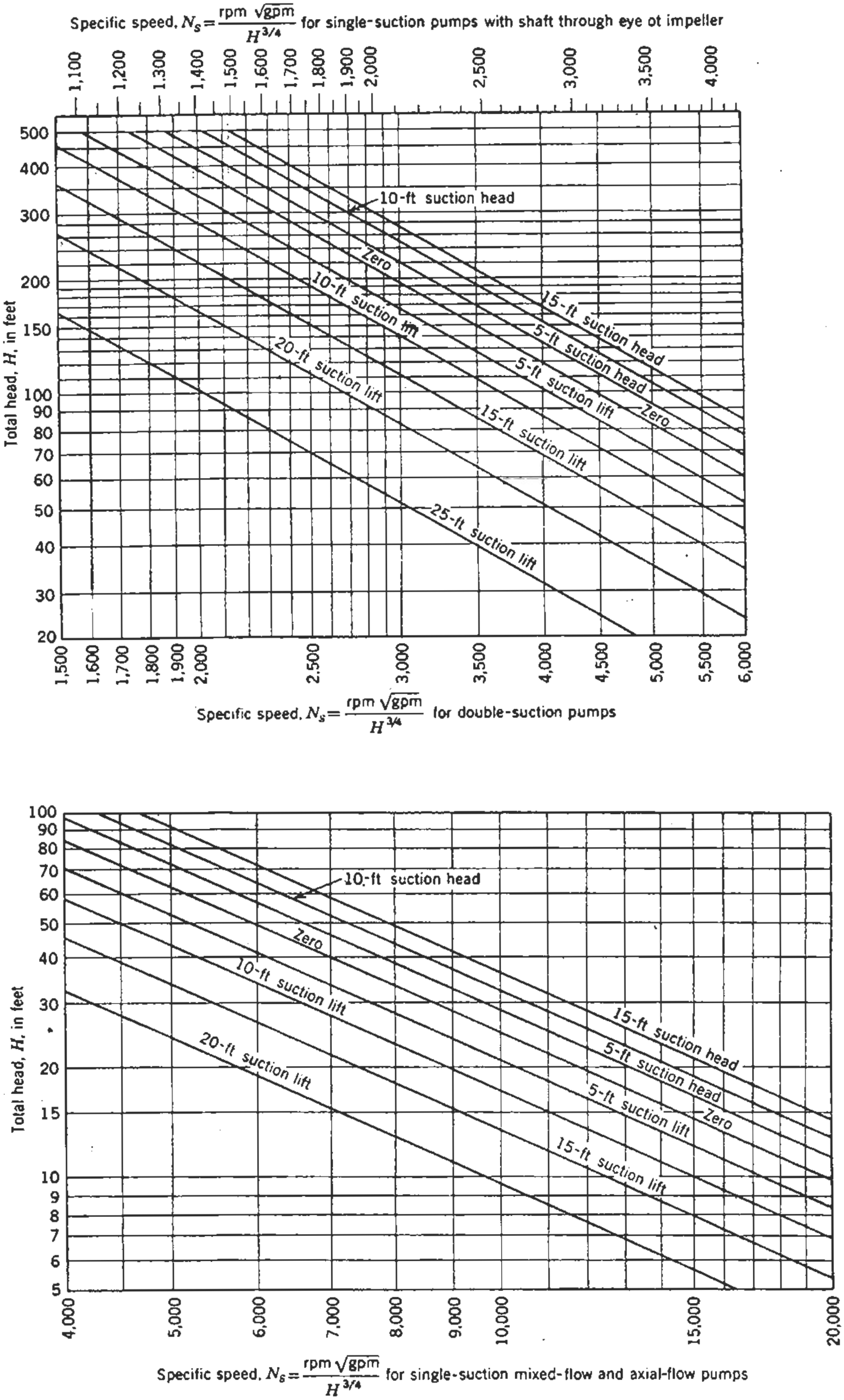


FIG. 99.—UPPER LIMITS OF SPECIFIC SPEEDS FOR CLEAR WATER AT SEA LEVEL AT 85° F, AS GIVEN BY HYDRAULIC INSTITUTE

GOULDS MODEL 3655-3755 • PERFORMANCE CURVES • 60 Cycle Speeds

710 SHEET C22
JAN. 15, 1965
(Sup. Sheet Dated 9-18-64)

INQUIRY NO. OR FACTORY ORDER NO. DATE CDS

CUSTOMER ....

ITEM ....
SERVICE ....
GPM ....
HEAD ....
EFFICIENCY ....
RPM ....

discharge diameter

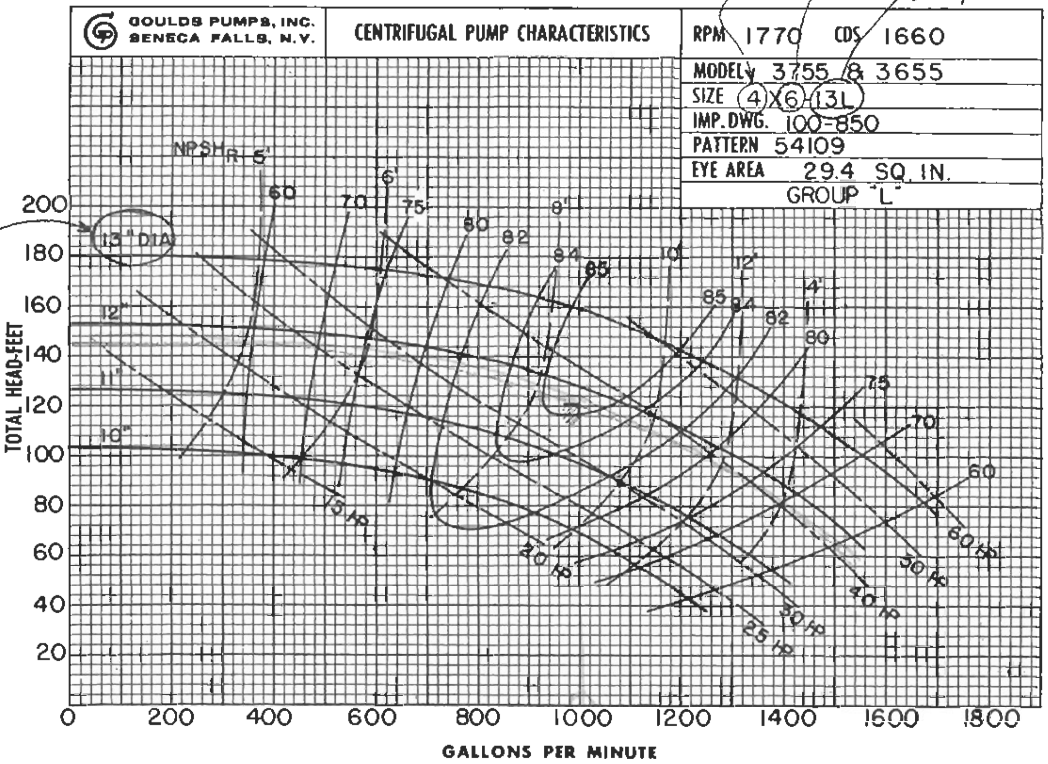
suction diameter

Impeller size

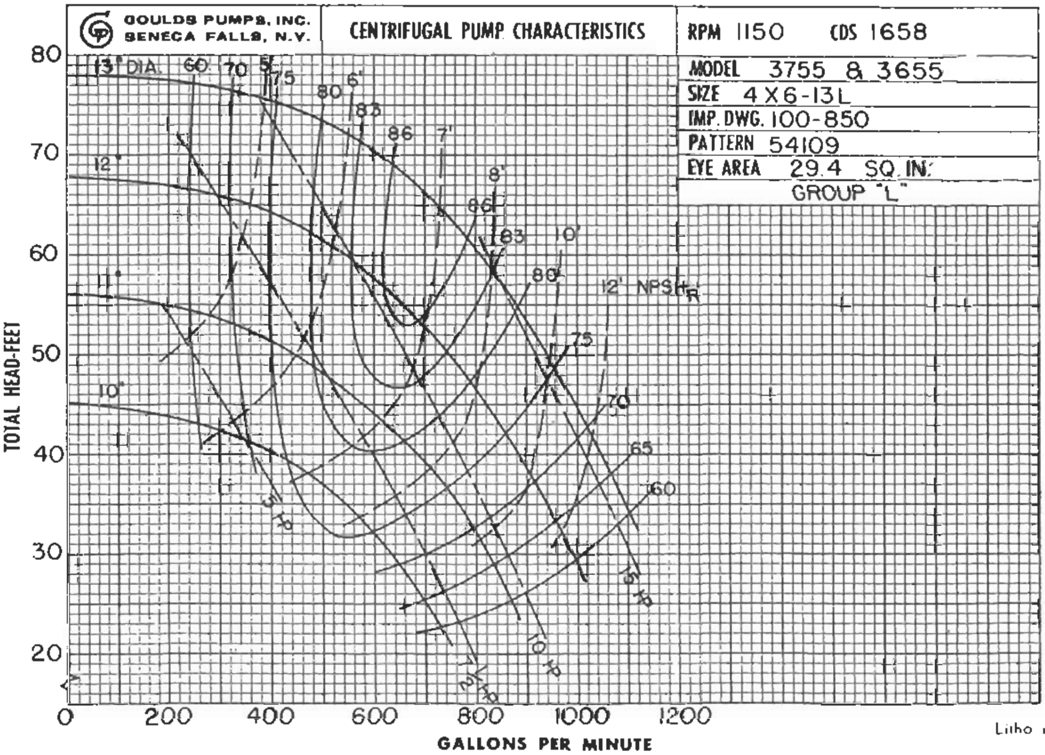
Impeller diameter

The four impellers (10" through 13") can be used with the same casing.

Impeller ~ 11 3/4



1770 R.P.M



1150 R.P.M.

GOULDS PUMPS INC.
Seneca Falls,
New York, U.S.A.

Litho in U.S.A.

ENCE 4319

Finding the operating point in a pumping system

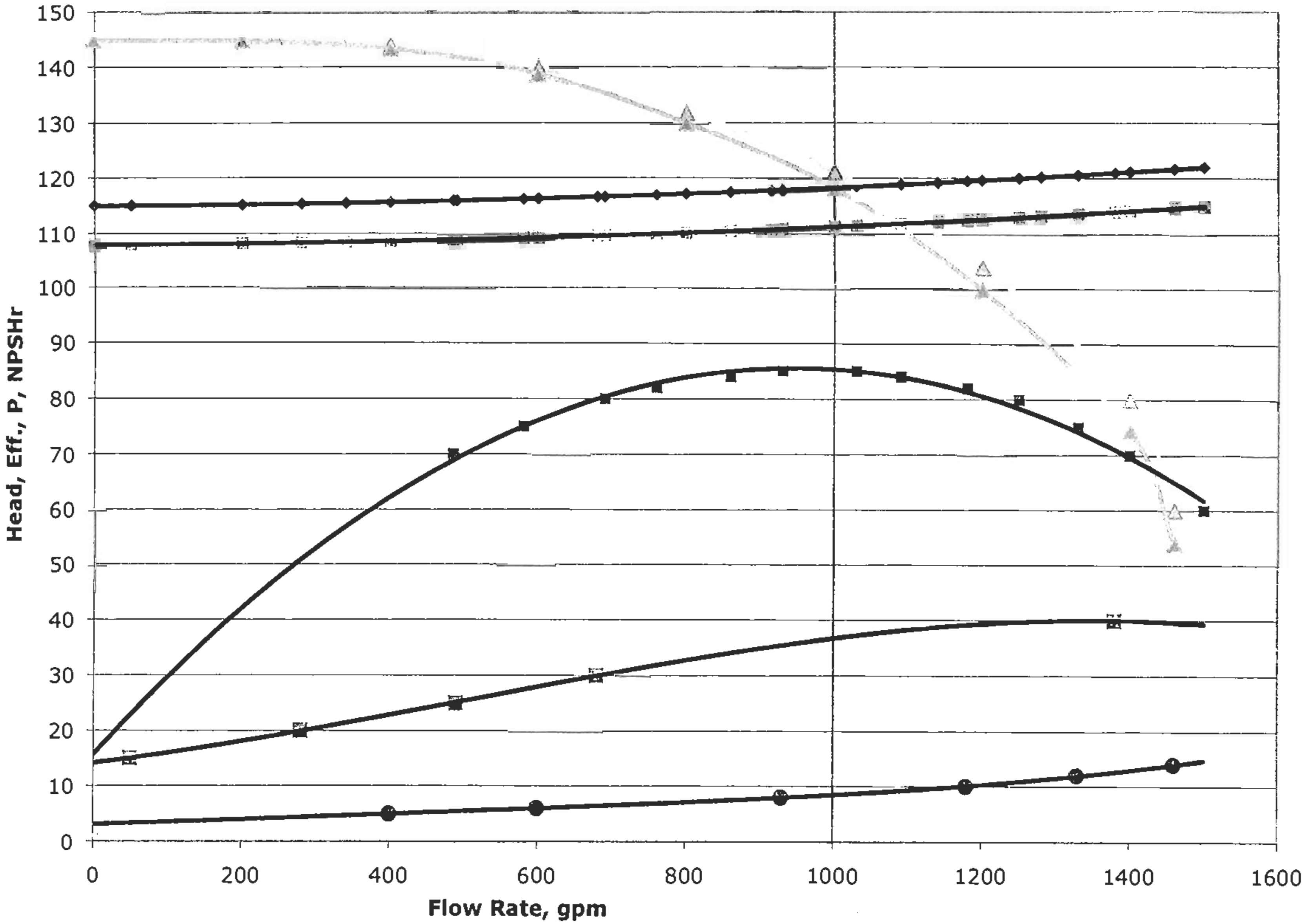
C = 140 D (in) = 12 L (ft) = 1476

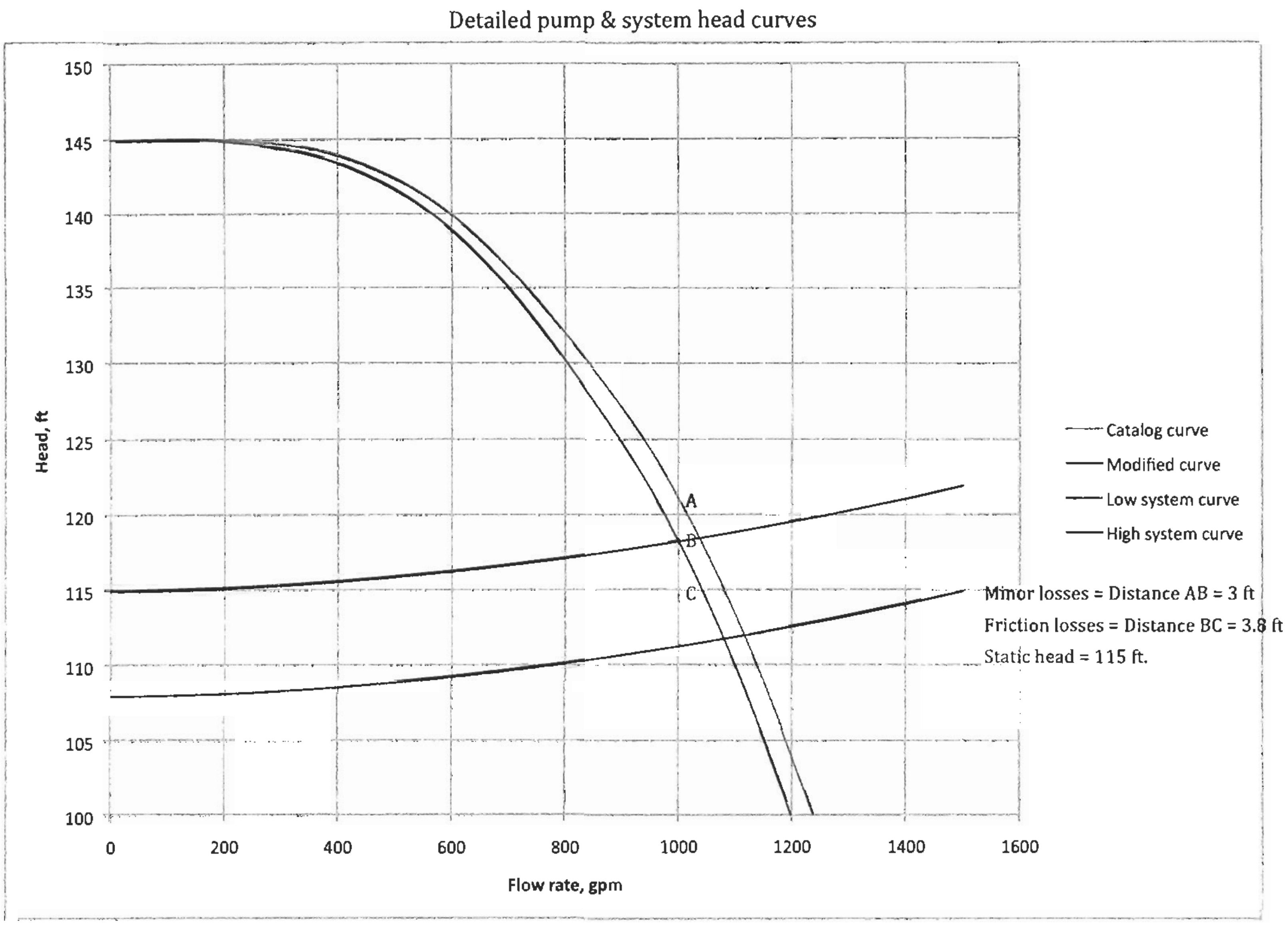
Min. Static Head (ft) = 108

Max. static Head (ft) = 115

Modified pump curve: $H_{modified} = H_{catalog} - 2.88\left(\frac{Q}{1000}\right)^2$

				Pump Curves (from catalog)				
		System Head Curves		Pump Characteristic Curve		Efficiency, %	Power,HP	NPSH Rqd., ft
Q, gpm	hf, ft	Maximum, ft	Minimum, ft	Catalog, ft	Modified, ft			
0	0	115	108	145	145.0			
50	0.01	115.01	108.01				15	
200	0.17	115.17	108.17	145	144.9			
280	0.31	115.31	108.31				20	
340	0.45	115.45	108.45					5
400	0.60	115.60	108.60	144	143.5			
485	0.86	115.86	108.86			70		
490	0.88	115.88	108.88				25	
580	1.20	116.20	109.20			75		6
600	1.28	116.28	109.28	140	139.0			
680	1.61	116.61	109.61				30	
690	1.65	116.65	109.65			80		
760	1.98	116.98	109.98			82		
800	2.17	117.17	110.17	132	130.2			
860	2.49	117.49	110.49			84		
915	2.79	117.79	110.79					8
930	2.87	117.87	110.87			85		
1000	3.29	118.29	111.29	121.2	118.3			
1030	3.47	118.47	111.47			85		
1090	3.85	118.85	111.85			84		
1140	4.19	119.19	112.19					10
1180	4.46	119.46	112.46			82		
1200	4.60	119.60	112.60	104	99.9			
1250	4.97	119.97	112.97			80		
1280	5.19	120.19	113.19					12
1330	5.57	120.57	113.57			75		
1380	5.96	120.96	113.96				40	
1400	6.12	121.12	114.12	80	74.4	70		14
1460	6.62	121.62	114.62	60	53.9			
1500	6.96	121.96	114.96			60		


150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Head, Eff., P, NPSHr
0
200
400
600
800
1000
1200
1400
1600
Flow Rate, gpm



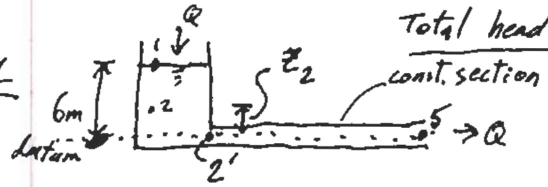
Minor losses = Distance AB = 3 ft
Friction losses = Distance BC = 3.8 ft
Static head = 115 ft.

CAB

Hydralics Aug 24 ①

Ex 1

Total head loss = 3m   Draw E.G. & H.G.



$$H = \underbrace{\frac{p}{\gamma}}_{\text{press. head}} + \underbrace{z_1}_{PE} + \underbrace{\frac{v^2}{2g}}_{KE}$$

$H_1 = 0 + 6 + 0 = 6m$ $H_2 = \underbrace{6 - z_2}_{\frac{p_2}{\gamma}} + z_2 + 0 = 6m$

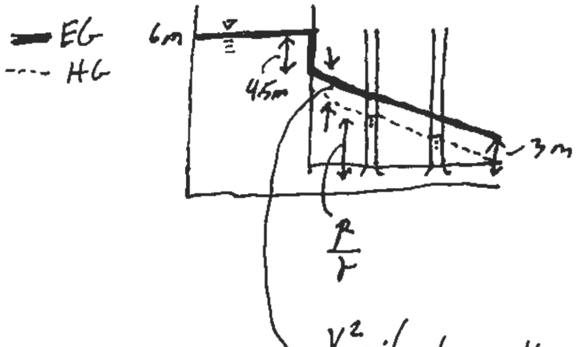
Energy balance between points 1 & 5 $H_1 = \cancel{H}_5 + H_{L_{1-5}}$; $H_5 = \overset{0}{\frac{p_5}{\gamma}} + \overset{0}{z_5} + \frac{v_5^2}{2g}$

$\therefore\ H_1 = 6m = \frac{v_5^2}{2g} + 3m$

Energy balace b/t 1 & 2' $H_1 = H_2' + h_{L_{1-2'}}$; $h_{L_{1-2'}}$ = entrance loss $\left(\text{minor loss} : h_{minor} = k\frac{V^2}{2g}\right)$

For sharp edge entrance $k = 0.5$ $\therefore\ h_{L_{1-2'}} = 0.5\frac{v_2^2}{2g} = 0.5(3m) = 1.5$

$\therefore\ H_2' = 6 - 1.5 = 4.5m$



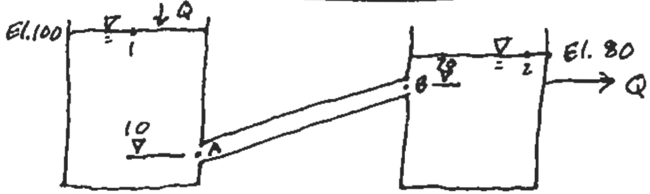
* piezometric elevation = (position of EG) − $\frac{V^2}{2g}$

* Plot of line joining piezometric elevations = H.G.

* In general $HG = z + \frac{p}{\gamma}$; $EG = z + \frac{p}{\gamma} + \frac{v^2}{2g}$

$\frac{V^2}{2g}$: (always the distance b/t EG & HG)

Ex 2



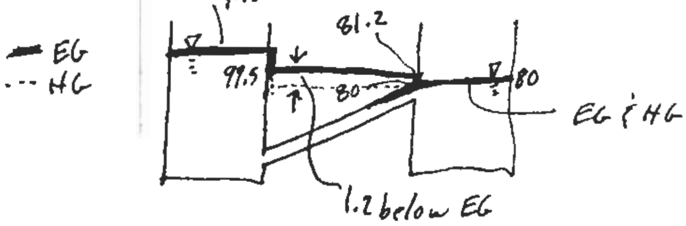
Entrance loss = 0.5m

Friction loss = 18.3m

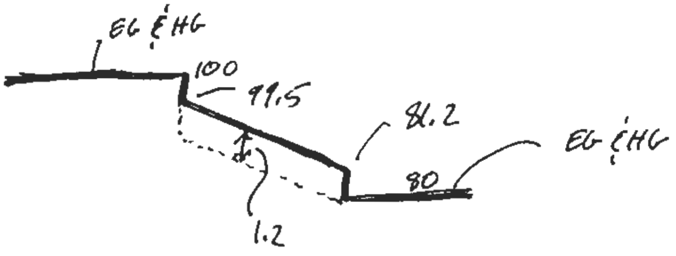
Exit loss = 1.2m

* what is direction of flow

* Plot EG & HG



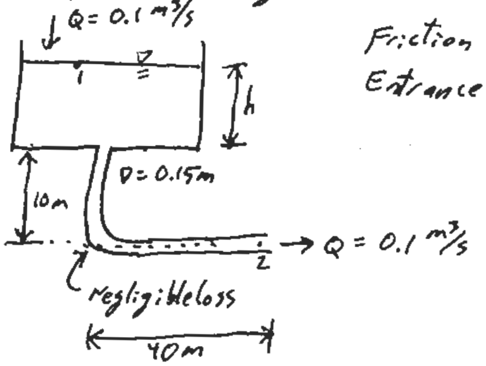
water flows from A to B b/c $H_1 > H_2$



LAB

② Hydraulics Aug 24

Ex 3



Friction factor, $f = 0.02$ (Darcy's law)

Entrance loss coeff. $= 0.5$ * Calc. h ; Draw EG, HG

$$V = \frac{0.1 \frac{m^3}{s}}{\frac{\pi}{4}(0.15^2)m^2} = 5.66 \text{ m/s} \rightarrow \frac{V^2}{2g} = 1.63 \text{ m}$$

$$h_e = 0.5\left(\frac{V^2}{2g}\right) = 0.82$$

$$h_f = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right) = 10.88$$

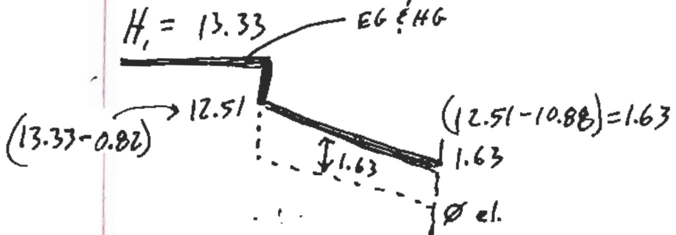
L = 50m = (10 + 40)

$$h_{L_{1-2}} = h_e + h_f = 11.7\text{m}$$

Energy balance b/t 1→2

$$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g} + h_{L_{1-2}}$$

$$0 + (10 + h) + 0 = 0 + 0 + 1.63 + 11.7 \rightarrow \boxed{h = 3.33\text{m}}$$



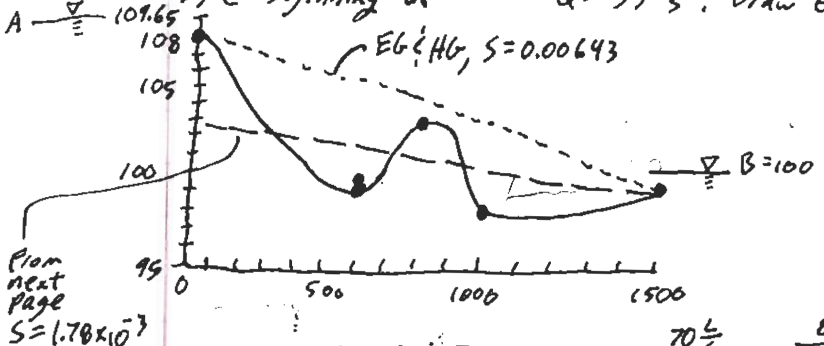
Ex A gravity main transports water from reservoir A (El 109.65) to res. B (El. 100).

Pipeline profile:

Distance (m)	A = 0	600	800	1000	1500 = B
Elevation	108	99	103	98	99

a) Q @ end of design period = 70 L/s. Design PVC pipeline $\varepsilon = 3 \times 10^{-5}$ m ; $\nu_{15°} = 1.14(10^{-6})$ m²/s

b) @ beginning of " " Q = 35 L/s. Draw EG & calc press. head @ point indicated @ 800m



* Total energy avail. = 109.65 − 100 = 9.65
* Neglect minor losses (entrance − exit) ∴ $h_f = 9.65$

$$S\left(\substack{\text{slope of}\\ \text{EG}}\right) = \frac{h_L}{L} = \frac{9.65}{1500} = 0.00643 = 0.643\%$$

From chart (Fig 4) D = 0.25m

$$\frac{\varepsilon}{D} = \frac{3(10^{-5})\text{m}}{0.25\text{ m}} = 0.00012$$

$$R_n = \frac{V \cdot D}{\nu}, \quad V = \frac{\overset{70\frac{L}{s}}{0.07 \text{ m}^3/\text{s}}}{\frac{\pi}{4}(0.25^2)\text{m}^2} = 1.426 \frac{m}{s} \rightarrow R_n = \frac{1.426(0.25)}{1.14 \times 10^{-6}} = 3.12 \times 10^5$$

from chart (Fig A-12) $f = 0.0155$ ∴ $h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} = 9.65\text{m}$

③ Hydraulics LAB Aug 25

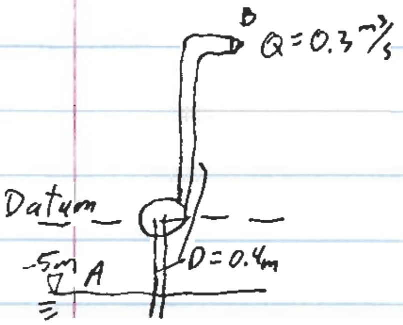
If $Q = 35 \frac{L}{s} \left(0.035 \, m^3/s\right)$; $V = \dfrac{0.035 \frac{m^3}{s}}{\frac{\pi}{4}\left(0.25^2\right)m^2}$; $V = 0.713 \frac{m}{s}$

$$R_n = \frac{0.713(0.25)}{1.14\left(10^{-6}\right)} = 1.56 \times 10^5 \xrightarrow{\text{From chart}} f = 1.72\left(10^{-2}\right)$$

$$h_f = f\left(\frac{L}{D}\right)\frac{V^2}{2g} = 1.72\left(10^{-2}\right)\left(\frac{1500}{0.25}\right)\left(\frac{0.713^2}{2(9.81)}\right) = 2.68m$$

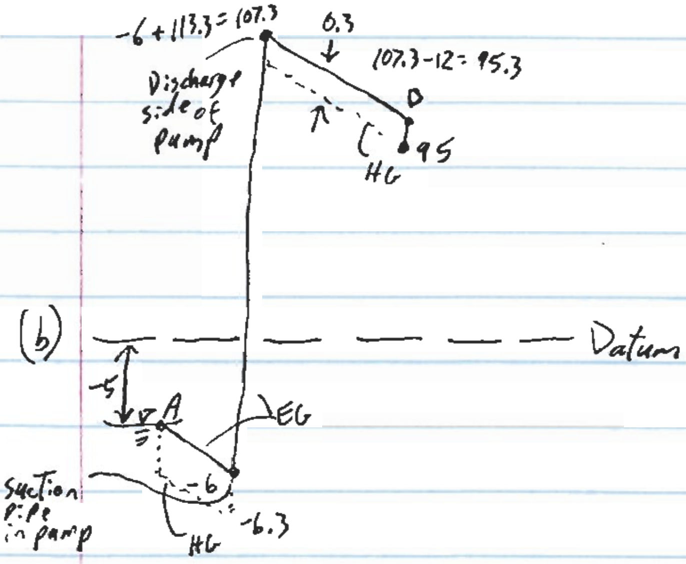
$$S = \frac{2.68}{1500} = 1.78\left(10^{-3}\right)$$

Fluid Lab 8-31 ① (Need to get notes)



Head loss in suction pipe = 1.0m
" " " discharge " = 12.0m } $H_{L_{AB}} = 13m$

(a) Find head developed by pump
(b) Draw EG & HG
(c) Find p head @ suction side & discharge side of pump
(d) " power developed by pump



Fluid Lab Sep 7 ①

Basic Relationships

1) Momentum : mass × vel. : $M_o = m \cdot V = (\rho \forall) V$

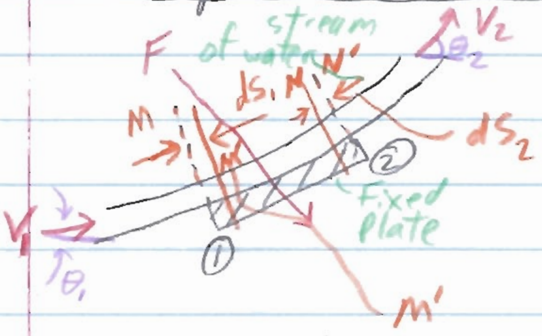
2) Force : mass × accel. : $F = m \cdot \frac{dV}{dt}$

3) Rate of change of momentum = $\frac{dM_o}{dt}$

(1) $\frac{dM_o}{dt} = \overset{\text{(If mass} = C^{st}}{m} \cdot \frac{dv}{dt}$

(2) $\frac{dM_o}{dt} = F$ i.e. rate of change of momentum = force (w/constant mass)

The inpulse - momentum principle



F = resultant of all elementary forces exceited by liquid on the body

Newton's 2nd Law $F = m \frac{dV}{dt}$

$F dt = m \, dV = d M_o$

momentum balance

(change in momentum w/in control vol.) = (momentum in) − (momentum out)

momentum in @ ① : $\underbrace{\overset{\text{desity}}{\rho_1} \cdot \overbrace{A_1 dS_1}^{\text{vol}}}_{\text{mass}} \cdot V_1$

momentum @ ② : $\rho_2 A_2 dS_2 V_2$

Fluid lab Sep7 ②

∴ change in momentum $dM_0 = \rho_1 A_1 dS_1 \vec{V}_1 - \rho_2 A_2 dS_2 \vec{V}_2$ Ⓐ

Mass Balance: mass through ① = mass|②

$$\rho_1 A_1 dS_1 = \rho_2 A_2 dS_2$$

Now divide through by dt ⇒ $\rho_1 A_1 \overbrace{\frac{dS_1}{dt}}^{V_1} = \rho_2 A_2 \overbrace{\frac{dS_2}{dt}}^{V_2} = \rho Q$ Ⓑ

$\Rightarrow \rho_1 A_1 V_1 = \rho_2 A_2 V_2$ in general: $= \rho A V = \underbrace{\rho Q}$

Divide ① by dt: $\frac{dM_0}{dt} = \rho_1 A_1 \frac{dS_1}{dt} \vec{V}_1 - \rho_2 A_2 \frac{dS_2}{dt} \vec{V}_2$

$$\rightarrow \overbrace{\frac{dM_0}{dt}}^{=F} = \rho Q (\vec{V}_1 - \vec{V}_2).$$

$$\rightarrow \boxed{F = \rho Q \Delta\vec{V}}$$

In general, impulse-mom. equ.:

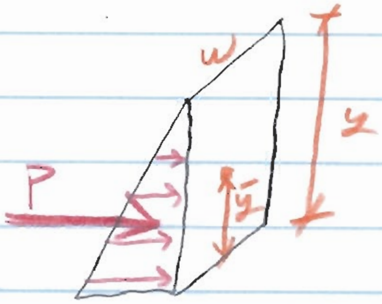
* In 'x' direction: Initial Linear momentum + Σ linear impulse = Final Linear momentum (p. 276 Schaum's)

$$\boxed{\rho Q V_{1_x} + \Sigma F_x = \rho Q V_{2_x}}$$

* In 'y' direction: $\boxed{\rho Q V_{1_y} + \Sigma F_y = \rho Q V_{2_y}}$

Fluid Lab Sep 7 ③

Hydrostatic force:



$$P = \gamma \bar{y} A$$

$$= \gamma \left[\frac{y}{2}\right]\left[y(w)\right]$$

$$= \boxed{\frac{1}{2}\gamma w y^2}$$

Hydro CAD

Nov. 9

Tutorial 10

Due 11/16/10

1. Use the Regime method to compute the dimensions (depth, width and slope) of a channel to carry Q = 3500 cfs and bed material D_{50} = 0.5 mm. Use the USACE formulas (Table 5.9, p. 166 Design Manual).

2. Design a gravel bed channel to carry Q = 10,000 cfs; D_{50} = 1 inch; $D_{25>}$ = 1.25 inches; n = 0.03; angle of repose = 33° and S_o = 0.0006. Use the maximum permissible velocity method.

3. Design a gravel bed channel to carry Q = 10,000 cfs; D_{50} = 1 inch; $D_{25>}$ = 1.25 inches (slightly rounded); S_o = 0.0006. Use the maximum permissible unit tractive force (shear) method. Assume a bed resistance $\tau_b = 0.4(D_{25>}$ in inches) [lbs/ft^2].

1) Silt factor, $f_s = 8\sqrt{D_{50}[\text{in}]} = 1.122$; $P = 15$[illegible] ; $R =$ [illegible] ft ; $A = 1077.6$;

$V = 3.24$ ft/s ; [illegible] $1.8(10^{-4})$; Depth ⇒ $y_1 = 7.76$ ft, $y_2 = 56.14$ ft

Assume $z = 2$ → $b = P - 2y(1+z^2)^{1/2}$ {using 2 different y's} → $b = \begin{cases} \text{[illegible]}3.3 \text{ ft} \\ 93.1 \text{ ft} \end{cases}$ (Dimen[illegible]

[illegible] choose $y = 7.76$ ft Dimensions: $y = 7.8$ ft, $b = 123.3$ ft, [illegible] S[illegible]

1b) USACE formuals, Table 5.9 p.166 Design Manu[illegible]

$P = C_1 Q^{.512}$; $C_1 = 3.3$ for sand bed & sand banks ; $R = C_2 Q^{\text{[illegible]}}$; $C_2 = 0.37$

$A = C_3 Q^{0.873}$, $C_3 =$ 1.2[illegible] ; $V = C_4 (R^2 S)^{1/3}$, $C_4 =$ [illegible] ; $\frac{Q}{A} = \frac{3500}{A} =$ 2.31 ft/s

* Q [illegible] above = 3500 [illegible] ; use [illegible] → [illegible]

$$y = \frac{P \pm \sqrt{P^2 - 4A(2\sqrt{1+z^2} - z)}}{2(2\sqrt{1+z^2} - z}$$ $\begin{cases} y_1 & 7.72 \text{[illegible]} \\ y_2 & 79.38 \text{[illegible]} \end{cases}$

$b = P - 2y\sqrt{1+z^2}$ $\begin{cases} \text{[illegible]} & 181 \text{ ft} \\ b_2 & -139.7 \text{ ft} \end{cases}$ × (can not be neg)

Demirsion[illegible] y, [illegible]7 ft, $b =$ 180.[illegible] , [illegible] , [illegible] $= 9.26(10^{-5})$

2) Design flow 10000 c

Bed slope $6(10^{-4})$

Side slope : $\theta_f = 33^0$

$z = \frac{1}{\tan 33} = 1.54$ (smallest value)

use ? for extra safety

4 Manning $n = 0.03$ (given)

5. V_{max}: Table 7.3, p.113 notes

water transporting silts; coarse gravel bed,

$V_{max} = 6 fps$

6) Calc $A = \frac{Q}{V_{max}} = 1666.7 \; ft^2$

7) Hydro Radius $R = \left(\frac{V_{max}(n)}{S_0^{1/2}}\right)^{3/2} = \; ft$

8) $P = \frac{A}{R} = 151.6 \; ft$

9) $y = \frac{P \pm \sqrt{P^2 - 4A(2\sqrt{1+z^2} - z)}}{2(2\sqrt{1+z^2} - z}$ $\left\{\begin{array}{l} y_1 = 14.4 ft \\ y_2 = 17.0 ft \end{array}\right\}$

10) $b = P - 2y(1+z^2)^{1/2}$ $\left\{\begin{array}{l} b = 87.2 ft \\ b = -58.6 ft \; X \end{array}\right\}$

11) Rework problem using $V_{design} = k V_{max}$ $\Big\}$ $V_{design} = 7.68 \; ft$

$k = \left(\frac{y[ft]}{3.28}\right)^{1/6}$; $k = 1.28$

$A = \frac{10000 \; ft^3/s}{7.68 \; ft/s} = 1302 \; ft^3$

$R = \left(\frac{V_{design}(n)}{S_0^{1/2}}\right)^{3/2} = 15.9 ft$; $P = \frac{A}{R} = 81.9 ft$

$\sqrt{\;} = \underbrace{\sqrt{81.8^2 - 4(1302)(2\sqrt{5}) - 2}}_{<0}$ ∴ not feasible

must work w/ $V = 6 \; ft/s$

12) Add freeboard

$F_{B_2} = 0.475 \ln Q_{cfs} - 0.2 = 4.2 \; ft$

3) ① Calc manings n using strickler ...

$n = 0.034\left(D_{50}[ft]\right)^{1/6}$ eq 5.11 notes (lecture)

$n = 2.25(10^{-2})$

② Friction angle of bed material ; $\theta_f = 36°$

use chart from Nov. 9 Hydro. class

③ Set $\tau_b = \tau_o$; $\tau_b = 0.4(D_{25} \;) = 0.4(1.25) = 0.5 \; lb/ft^2$

select $\left.\begin{array}{l} C_b = 0.97 \\ C_s = 0.76 \end{array}\right\}$ assuming $\frac{b}{y} > 4$, Fig 7.7

$\tau_b = C_b \gamma y S_0 \rightarrow y = \frac{0.5}{0.97(\gamma)(6(10^{-4}))} = 13.8 \; ft$

④ Set $\tau_{sr} = \tau_{so}$

equ 19.6 $\tau_{so} = \tau_b K$ $\Big\}$ $K = \frac{\tau_{sr}}{\tau_b} = \frac{C_s \gamma y S_0}{C_b \gamma y S_0} = \frac{C_s}{C_b}$

$\rightarrow K = 0.78$

equ 19.7 : $K = \sqrt{1 - \left(\frac{\sin\phi}{\sin\theta_f}\right)^2}$; $\sin\phi = \sin\theta_f \sqrt{1-K^2}$

$\sin\phi = \underset{\text{from step ②}}{\sin 36°}\sqrt{1 - 0.78^2} \rightarrow \phi = 21.6°$

$\cot\phi \rightarrow z = 2.53$

⑤ Use mannings

$\overset{1000}{Q} = \frac{1.486}{\underset{0.0225}{n}} A R^{2/3} \overset{6(10^{-4})}{S_0^{1/2}}$ $\boxed{\text{* solve for } b}$

$y = 13.8$

$b = 63 \; ft$

⑥ check $\frac{b}{y} = \frac{63}{13.8} = 4.6 > 4$ ∴ OKAY

⑦ check N_F

* Find $A = 1351.2 \; ft^2$

* Find $V = 7.4 \; ft/s$

* Find top width : $B = 132.8 \; ft$

* " Hydraulic Depth $D = \frac{A}{B} = 10.2 \; ft$

* Calc. $N_F = \frac{V}{\sqrt{gD}} = 0.41 < 0.8$; OKAY

⑧ Add Freeboard

FB_2

(Don't need F_B here)

Trapazoid: $P = b + 2y(1+z^2)^{1/2}$, $A = y(b+zy)$ $\xrightarrow{\text{combine}}$ $A = Py - y^2(2\sqrt{1+z^2} - z)$

1. Use the Regime method to compute the dimensions (depth, width and Slope) of a channel to carry Q = 3500 cfs and bed material D_{50} = 0.5 mm.

   Q = 3500 cfs; d_{50} = 0.5 mm. Find channel depth, width, slope.

See Lecture 18, class notes, Lacey's equations:

Item	**Formula**	**Numerical value**
Silt Factor	$f_s = 8\sqrt{(d_{50})_{in}}$	
Wetted perimeter	$P = 2.67\sqrt{Q_{cfs}}$	
Hydraulic radius	$R = \left(\dfrac{Q}{1.17P\sqrt{f_s}}\right)^{\frac{2}{3}}$	
Area	A = R P	
Velocity	$V = 1.17\sqrt{f_s R}$	
Slope	$S_0 = \left(\dfrac{V}{16R^{\frac{2}{3}}}\right)^3$	
Depth	$y = \dfrac{P \pm \sqrt{P^2 - 4A\left(2\sqrt{1+z^2} - z\right)}}{2\left(2\sqrt{1+z^2} - z\right)}$	
Channel width	$b = P - 2y\left(1+z^2\right)^{\frac{1}{2}}$	

2. Design a gravel bed channel to carry $Q = 10{,}000$ cfs; $D_{50} = 1$ inch; $D_{25>} = 1.25$ inches; $n = 0.03$; angle of repose = 33 ° and $S_o = 0.0006$. Use the maximum permissible velocity method.

1. Determine the design flow, Q.		
2. Determine the design bed slope, So		
3. Use soil properties estimate the side slope, z		
4. Based on the bed material, estimate Mannings n		
5. Based on the bed material and sediment load, estimate *Vmax*		
6. Calculate the flow area *A*	$A = \frac{Q}{V_{\max}} = y(b+zy)$	
7. Calculate the hydraulic radius from Mannings Eq	$R = \left(\frac{V_{\max} n}{c' S_0^{\frac{1}{2}}}\right)^{\frac{3}{2}}$	
8. Calculate P	$P = \frac{A}{R}$	
9. Calculate depth	$y = \frac{P \pm \sqrt{P^2 - 4A\left(2\sqrt{1+z^2} - z\right)}}{2\left(2\sqrt{1+z^2} - z\right)}$	
10. Channel width	$b = P - 2y\sqrt{(1+z^2)}$	
11. Use $V_{design} = k\ V_{max}$	$k = \left(\frac{y_{ft}}{3.28}\right)^{\frac{1}{6}}$	
12. Add freeboard	$FB_2 = 0.475 \ln Q_{cfs} - 0.2$	

3. Design a gravel bed channel to carry Q = 10,000 cfs; D_{50} = 1 inch; $D_{25>}$ = 1.25 inches (slightly rounded); S_o = 0.0006. Use the maximum permissible unit tractive force (shear) method. Assume a bed resistance $\tau_b = 0.4(D_{25>}$ in inches) [lbs/ft^2].

Lecture 19:

Manning's n	$n = 0.034\left[(D_{50})_{ft}\right]^{\frac{1}{6}}$	
Friction angle of bed material	Figure 7-9, p. 118 notes	
Max. permissible unit shear stress	$\tau_b = 0.4(D_{25>})_{in}$	
Set $\tau_b = \tau_0$	$y = \frac{\tau_b}{C_b \gamma S_0}$, C_b = 0.97 (if $b/y > 4$)	
Set effective side stress = max. side stress, $\tau_{sr} = \tau_{s0} = \tau_b K$	$K = \frac{C_s}{C_b}$	
Side slope	$\sin\phi = \sin\theta_f \sqrt{1-K^2}$	
Solve for b from Manning's Equation	$Q = \frac{1.486}{n} y(b+zy)\left[\frac{y(b+zy)}{b+2y\sqrt{1+z^2}}\right]^{\frac{2}{3}} S_0^{\frac{1}{2}}$	
Check if $b/y > 4$		
Wet area	$A = y(b+zy)$	
Velocity	$V = \frac{Q}{A}$	
Top width	$B = b + 2zy$	
Mean hydraulic depth	$D_m = \frac{A}{B}$	
Check Froude Number	$N_F = \frac{V}{\sqrt{gD_m}}$ (it should be < 0.8)	