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THIS EXAM CONSISTS OF 10 PAGES (including this one). PLEASE CHECK
THAT YOU HAVE A COMPLETE PAPER

THE UNIVERSITY OF BRITISH COLUMBIA
Department of Civil Engineering

Sessional Examination – April 2005

CIVIL ENGINEERING 316
(Hydrology and Open Channel Flow)

Name (surname first): <u>Solutions</u>
UBC student number: _____

One Double sided 8 1/2 X 11" Formula Sheet. Programmable Calculators Permitted. Marks will be deducted for incorrect units and excessive significant figures.

Time: 3 Hours

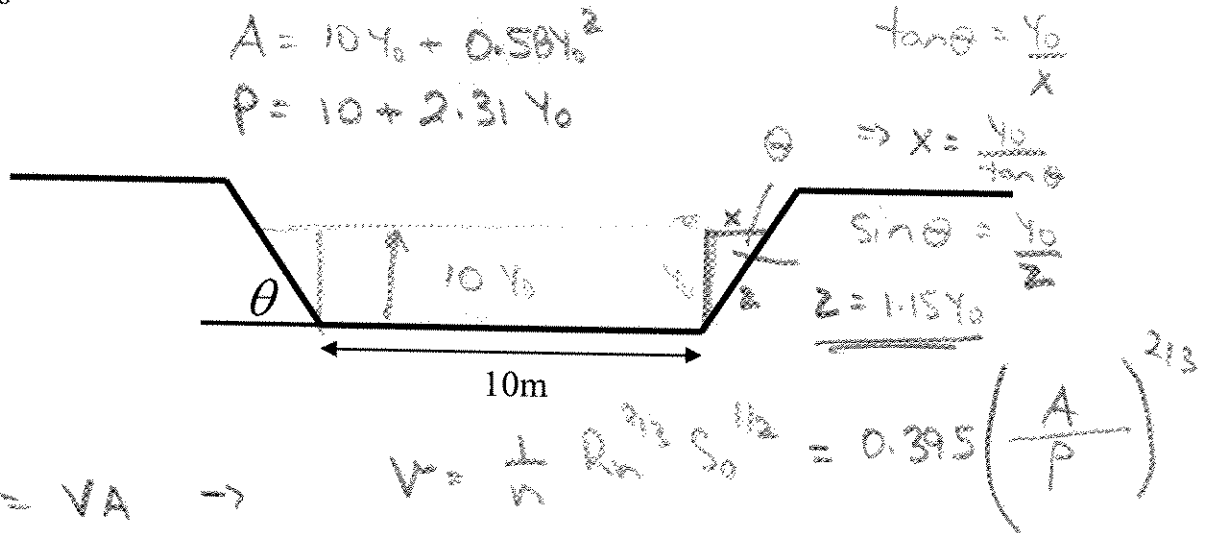
Instructions:

- Put your name and student number on this page and sign below. Write your student number in the space provided at the top of each page.
- Use the space provided on the exam pages or an exam booklet for your answers. The extra pages at the end of this exam may be used. No other paper is allowed.
- Think before writing, make your points directly and concisely. Your work must be neat, orderly, and easy to follow. If extra words do not add information, they may reduce your points.
- Any answer requiring a calculation or rational process must show the method of arriving at the answer; the answer alone is not sufficient.
- No one may enter the examination room after the expiration of one-half hour, or leave during the first half-hour of the examination room.
- You may only ask questions to the invigilators in cases of supposed errors.
- Candidates suspected of any of the following, or similar, dishonest practices will be immediately dismissed from the examination and will be liable to disciplinary action:
 - having at the place of writing any books, papers or memoranda, calculators, audio cassette players or any other memory aid devices, other than those authorized by the examiners.
 - speaking or communicating with other candidates using any communication means whatsoever (including any and all wireless technology). It is strongly recommended that no wireless communication devices be brought to the examination room.
 - purposely exposing written papers to the view of other candidates. The plea of accident or forgetfulness shall not be received.
- Smoking tobacco is not permitted during examinations

I have neither given nor received any unpermitted aid on this examination

Question 1. (20 Marks)

The trapezoidal channel shown has a bed slope of $S_0 = 0.00025$, Manning's $n = 0.04$ and a side angle of $\theta = 60^\circ$. For a discharge of $Q = 30 \text{ m}^3/\text{s}$, determine: (a) Flow depth at the centerline of the channel, (b) the mean velocity, (c) the mean shear stress



y_0	A	P	R_h	V	Q	
1.0	10.58	12.31	0.86	0.357	3.78	Wide channel
5.0	64.5	21.55	2.99	0.82	52.93	(-5)
4.0	49.2	19.24	2.56	0.74	36.43	
3.56	42.9	18.22	2.36	0.70	30.05 ✓	

(10) Centerline Depth 3.56 m

(5) Velocity 0.70 m/s

(5) Shear Stress 5.8 Pa

$\tau = \rho g R_h S_0$ wide channel (-2)
 $= 9810 \times 2.36 \times 0.00025$
 $= 5.79 \text{ Pa (N/m}^2\text{)}$

All solutions assume uniform flow.

Question 2. (30 Marks)

The annual maximum series for a moderate sized coastal watershed is shown below.

Year	Instant. Peak Q (m ³ /s)
1980	1.8
1981	1.2
1982	0.9
1983	1.5
1984	0.9
1985	1.1
1986	1.1
1987	1.5
1988	0.8
1989	1.6
1990	1.4
1991	2.0
1992	1.3
1993	1.4
1994	1.5

15

$$\bar{X} = 1.33 \text{ m}^3/\text{s}$$

$$S = 0.34 \text{ m}^3/\text{s}$$

$$X_{100} = 1.33 + 3.14 \times \frac{0.34}{2}$$

$$= 2.4 \text{ m}^3/\text{s}$$

TR = 100y

- (a) Calculate the design flood with an annual probability of exceedence of 1% using the Gumbel distributions (Table attached). Estimate the return period of the largest observed flow.

Largest flow 2.0 m³/s

$$2.0 = 1.33 + K_T S \Rightarrow K_T = 1.97$$

From Table, TR ≈ 20-25y.

⑩ Discharge 2.4 m³/s

⑤ Return Period 20-25 y

- (b) A logging road is to cross a small stream that is approximately rectangular in section, with a width of 5m. The slope of the stream is 0.002 and a Manning's $n = 0.04$. Using the design discharge from the previous question, determine the number of box culverts 1.0m wide X 0.75m high that would be necessary to convey the flow under the road, so that the headwater level does not exceed the height of the culverts? Assume a contraction coefficient of $C_B = 0.9$, and that the culvert is inlet controlled.

10

For an inlet controlled box culvert ($H_w/D < 1.2$)
weir flow.

$$Q = \frac{2}{3} C_B B H \sqrt{\frac{2}{3} g H}$$

$$B = 1.0 \text{ m}$$

$$C_B = 0.9$$

$$\Rightarrow Q = 1.53 H^{1.5}$$

For $H = 0.75 \text{ m}$.

$$Q = 1.0 \text{ m}^3/\text{s} \quad \therefore \text{Need 3 culverts}$$

Number of Culverts 3

(c) Finally, determine the actual headwater depth based on the proposed number of culverts

For each culvert: $Q = 0.8 \text{ m}^3/\text{s}$ 2

⑤

$$Q = 1.53 H^{1.5}$$

$$\Rightarrow H = 0.75 Q^{2/3}$$

$$\Rightarrow H = 0.646 \text{ m}$$

Headwater Depth 0.65 m 3

Question 3. (15 Marks)

Determine the design return period that minimizes the total expected cost for a bridge design. Several designs have been costed for a range of return periods. In the event of failure, the total cost (bridge replacement, temporary crossing, economic hardship, social disruption) is estimated at \$35M. The costs for design and construction for a range of design scenarios are given in the Table below:

Return Period (years)	Cost (\$M)	R	Expected Damage $R = 35$	Total Expected Cost
25	25	0.9831	34.4	59.4
50	25	0.8674	30.4	55.4
100	30	0.6340	22.2	52.2
200	35	0.3942	13.8	48.8 A
500	50	0.1814	6.4	56.4

Assume a service life of 100 years. $n = 100$

5

Calculate the total expected costs for each design scenario. Determine the optimum return period for design that minimizes the total expected cost.

$$R = 1 - \left(1 - \frac{1}{TR}\right)^n \leftarrow \text{probability of occurring in "n" years}$$

Minimum Total expected Cost \$48.8 M 5

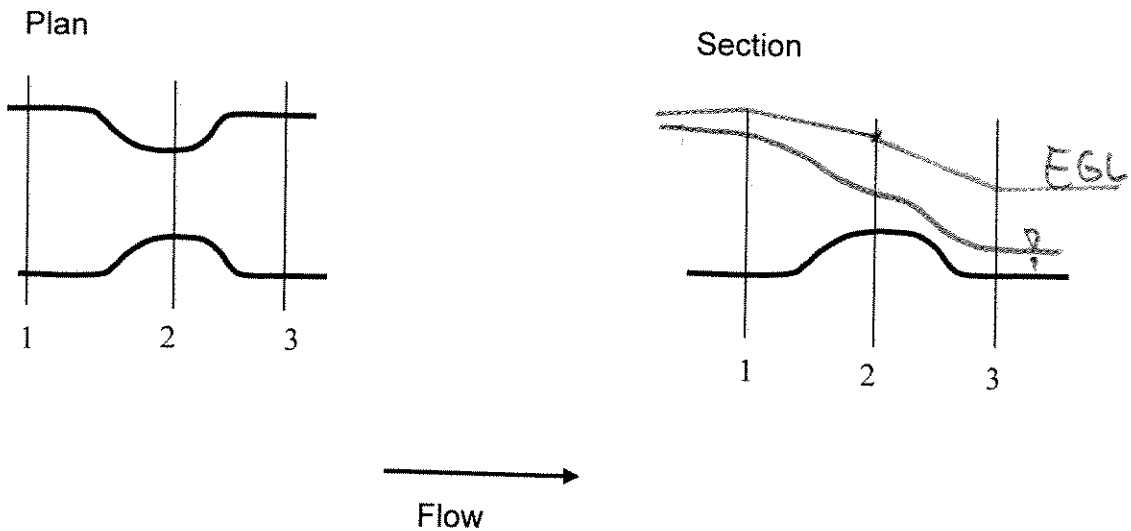
Design Return Period 200 y 5

Question 3. (35 Marks)

A 5m wide rectangular canal is used to supply irrigation water to a commercial rice growing area in the desert of central California (Take a moment to ponder the wisdom of that).

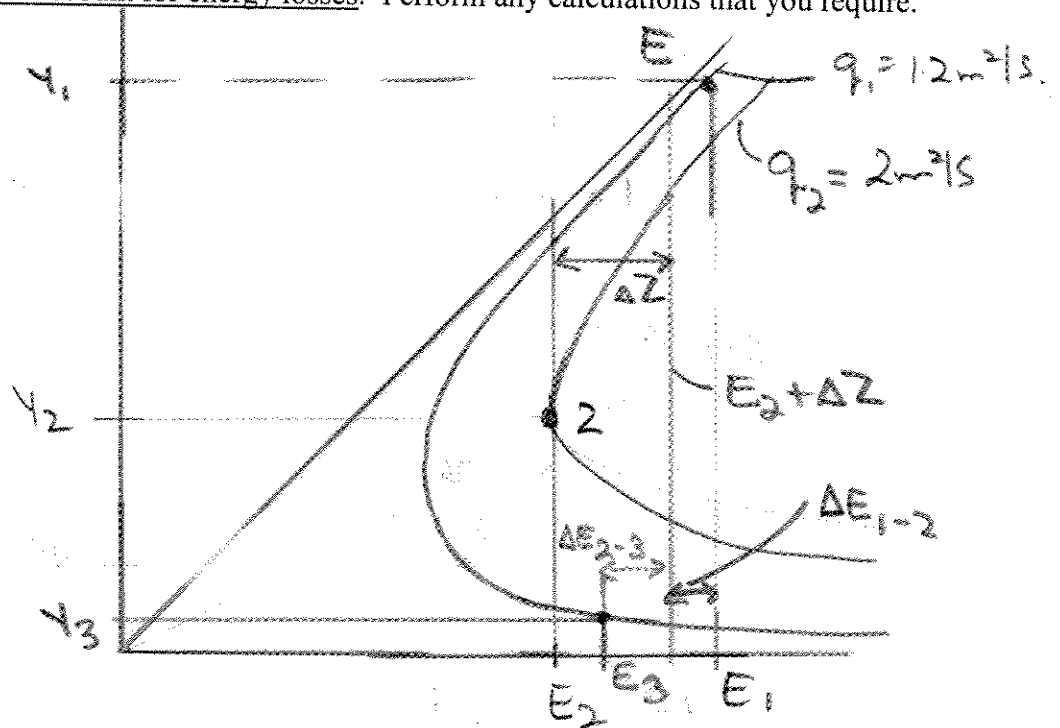
A combination broad crested weir and contraction has been constructed for flow measurement and control. At the control station, the canal contracts to 3m width, and then expands downstream back to the original 5m width. Simultaneously within the contraction, there is an upward step of 0.3m. Downstream of the contraction, the bed remains drops 0.3m to the original elevation.

The control station has been designed to pass a maximum design discharge of $6\text{m}^3/\text{s}$.



There are significant energy losses associated with the contraction and expansion. Assume a 5% loss during the upstream contraction, and a 15% loss in the downstream expansion. You are to analyse the flow through the control station.

- (a) Draw a specific energy diagram and clearly indicate y_1, y_2, y_3 and E_1, E_2 and E_3 .
You must account for energy losses. Perform any calculations that you require.



- (b) Determine the flow depths and specific energy values at the three sections

At 2. $y_c = \sqrt[3]{\frac{q^2}{g}} = 0.74 \text{ m}$
 $E_2 = \frac{3}{2} y_c = 1.11 \text{ m}$

$E_1 = (E_2 + \Delta Z) = 1.51 \text{ m}$
 0.95

Solve for subcritical root ($q = 1.2 \text{ m}^2/\text{s}$)

$E_3 = 0.85 (E_2 + \Delta Z)$
 $= 1.22 \text{ m}$

⑤ y_1 / E_1 1.46 m / 1.49 m

⑤ y_2 / E_2 0.74 m / 1.11 m

⑤ y_3 / E_3 0.28 m / 1.22 m

(c) Determine the horizontal force acting on the step and contraction.

$$\frac{P}{\gamma} = M_1 - M_3 = \left(\frac{Q^2}{gY_1} + \frac{Y_1^2}{2} \right) - \left(\frac{Q^2}{gY_2} + \frac{Y_2^2}{2} \right)$$

$$= 1.17 - 0.56$$

⑤ $\frac{P}{\gamma} = 0.61 \text{ m}^2/\text{s}$

Total force = $B P \gamma$
 $= 5 \times 0.61 = 9810$
 $= 29.9 \text{ kN}$

Horizontal Force 30 kN (Downstream)

⑤ (d) The control station is located at the midpoint of a long, straight section of canal with a uniform depth of 1.0 m at the design discharge. Sketch the flow profile and the EGL, and label any nonuniform flow profiles.

$Y_0 = 1.0 \text{ m}$

$Y_c = \sqrt[3]{\frac{Q^2}{gS}} = 0.53 \text{ m}$

∴ Mild Slope.

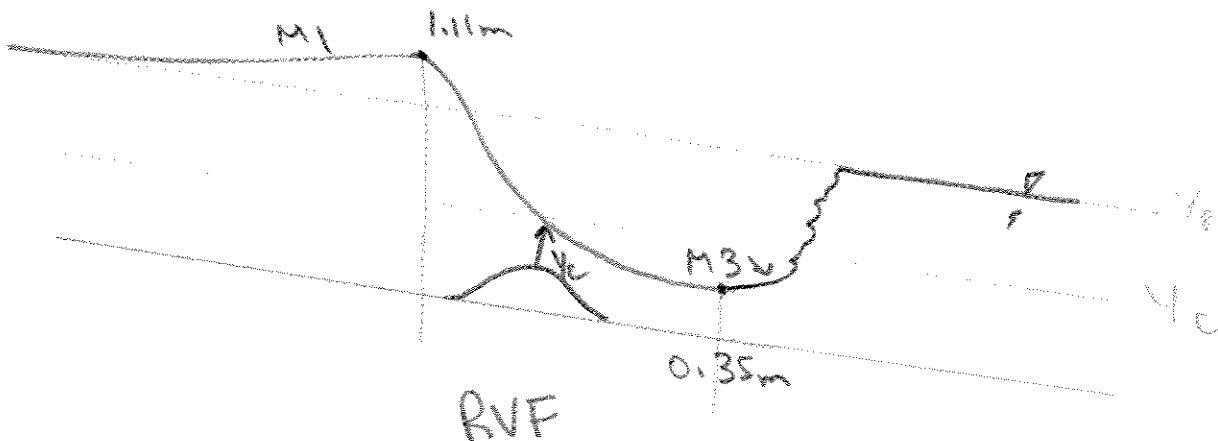


Table of Gumbel Frequency factors

T	$K(T)$	T	$K(T)$	T	$K(T)$
1	$-\infty$	10	1.30	80	2.94
2	-0.16	15	1.64	90	3.07
3	0.25	20	1.86	100	3.14
4	0.52	25	2.04	200	3.68
5	0.72	30	2.20	400	4.08
6	0.88	40	2.40	600	4.52
7	1.01	50	2.61	800	4.76
8	1.12	60	2.73	1000	4.94
9	1.21	70	2.88		