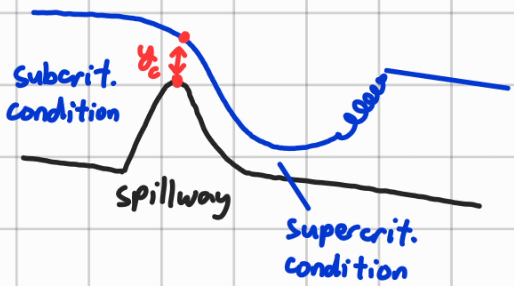
CV2020 2022/23 Sem 2

by Renardi M. (@pardirenardi)

1. (a) Crest of spillway $\longrightarrow$ choking condition $\longrightarrow$ depth is critical depth

$$y_c = 0.15\ m = \left(\frac{q^2}{g}\right)^{1/3}$$



$$\Rightarrow q = \sqrt{(0.15)^3 \times 9.81}$$
$$= 0.182\ m^2/s$$

$$Q = q \times b = 0.182 \times 30 = 5.5\ m^3/s$$ (proven)

(b) $B = 6m$; $n = 0.015$; $S_o = 1 \times 10^{-4}$

(i) $q = \frac{Q}{B} = \frac{5.5}{6} = 0.917$

$$y_c = \left(\frac{q^2}{g}\right)^{1/3} = \left(\frac{0.917^2}{9.81}\right)^{1/3} = 0.441\ m$$

(ii) $E_c = \frac{3}{2} y_c = \frac{3}{2} \times 0.44 = 0.661\ m$

(iii) $Q = \frac{1}{n} A R_h^{2/3} S_o^{1/2}$

$$5.5 = \frac{1}{0.015} (6y_n)\left(\frac{6y_n}{6+2y_n}\right)^{2/3} (1 \times 10^{-4})^{1/2}$$

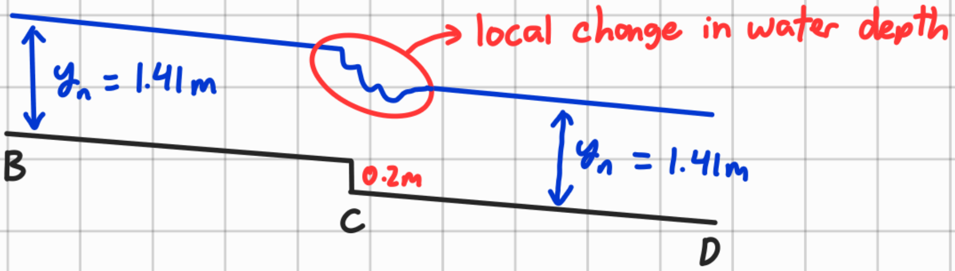
Solving for y_n, $y_n = 1.41\ m$ (use calculator's SOLVE function or plot in Graphical Calculator)

(iv) $v = \frac{Q}{A_n} = \frac{5.5}{6 \times 1.41} = 0.650\ m/s$

(v) $E_n = y_n + \frac{q^2}{2gy_n^2} = 1.41 + \frac{0.917^2}{2(9.81)(1.41)^2} = 1.432\ m$

(vi) Uniform flow depth in B-C and C-D are the same, as reach B-C and C-D have the same properties (Q, A, n, R_h, S_o).

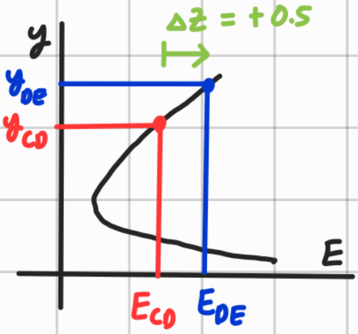
The 0.2 m drop only changes the water depth locally, but in a long enough stretch the water will return to normal depth. Hence for C-D, $y_n = 1.41$ m.



(c) Check type of flow (for principle of flow accessibility)

$E_{CD} = 1.432$ m
$E_c = 0.661$ m

$E_{CD} > E_c \Rightarrow$ subcritical flow



$$E_{DE} = E_{CD} + 0.5$$
$$= 1.432 + 0.5 = 1.932 \text{ m}$$

$$y_{DE} + \frac{q^2}{2g y_{DE}^2} = 1.932$$

$$y_{DE} + \frac{0.917^2}{2(9.81) y_{DE}^2} = 1.932$$

$\times\, y_{DE}^2$ and rearrange,

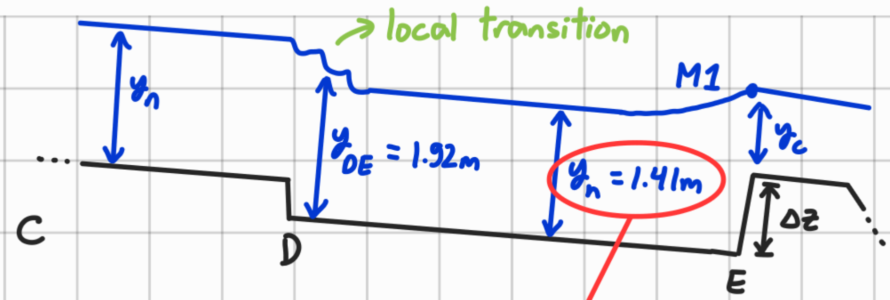
$$y_{DE}^3 - 1.932 y_{DE}^2 + 0.04286 = 0$$

Solving, $y_{DE} = 1.92$ m, 0.155 m, -0.144 m

sub. ✓ super. ✗ negative ✗

$\therefore y_{DE} = 1.92$ m (local transition near the depression)

(d)



Note:

y_1 is $y_n = 1.41m$, NOT $y_{DE} = 1.92m$. y_{DE} was the local water depth near the depression at D, but after a long while water depth at DE goes back to y_n due to same channel properties (Q, A, n, R_h, S_o) with B-C-D.

$y_c = 0.441$ m (calculated in (b))

$E_c = 0.661$ m (from (b))

$y_n = 1.41$ m (from (b))

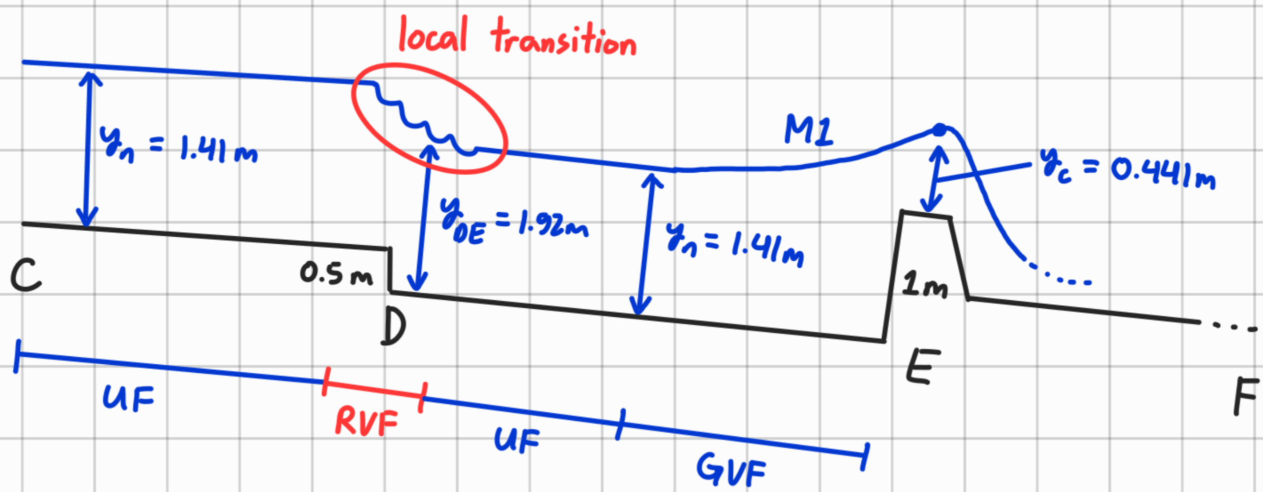
$$E_n = y_n + \frac{q^2}{2gy_n^2} = 1.41 + \frac{0.917^2}{2(9.81)(1.41)^2} = 1.432 \text{ m} \quad \text{(from (b))}$$

$$E_c = E_n - \Delta z - 0.66$$

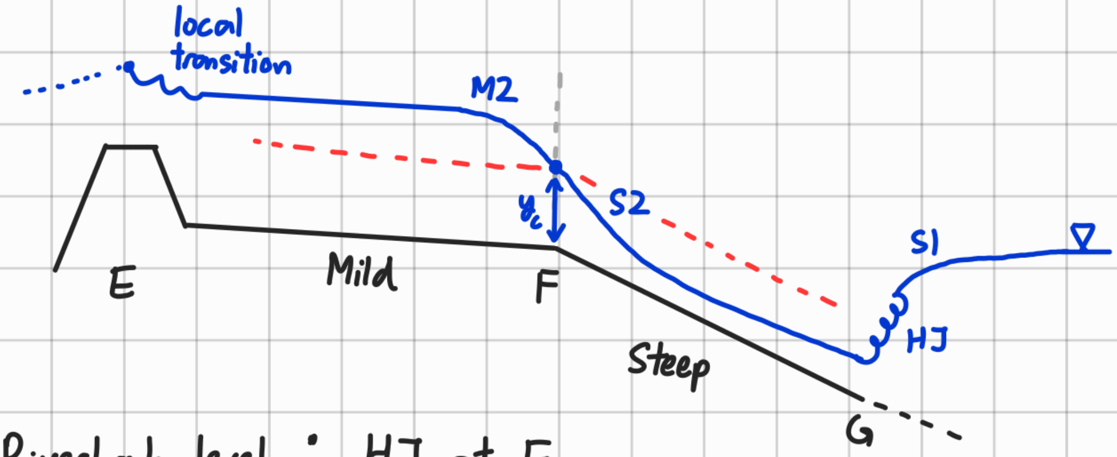
$$0.661 = 1.432 - \Delta z - 0.66$$

$$\Delta z = 1.432 - 0.661 - 0.66 \Rightarrow \therefore \Delta z = 0.111 \text{ m}$$

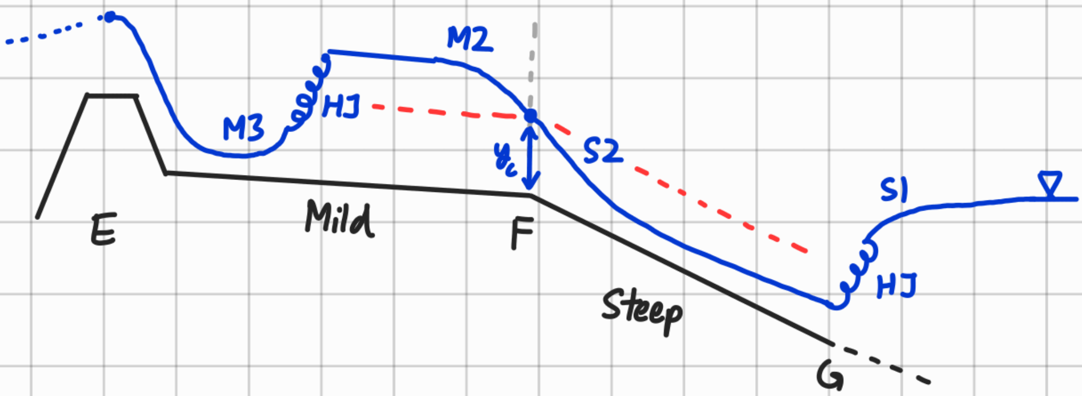
(e)



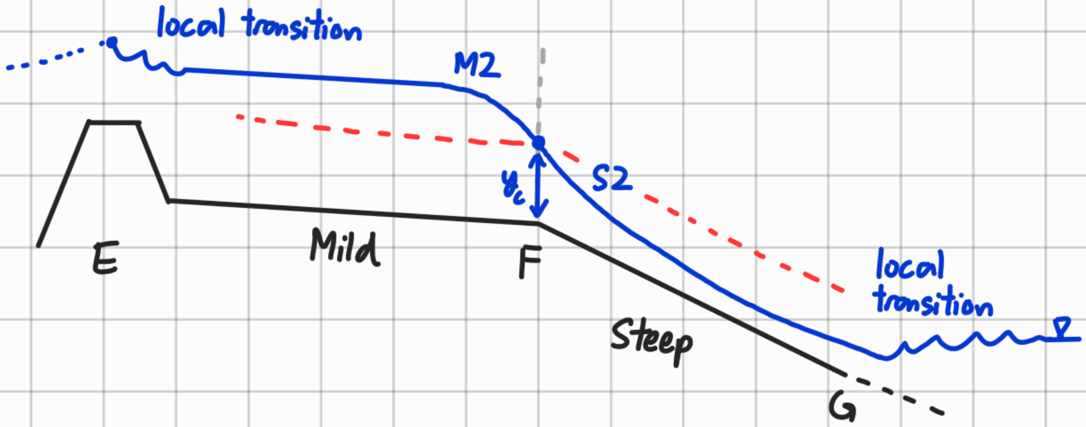
(f) (i) Riverbank level ; No HJ at E



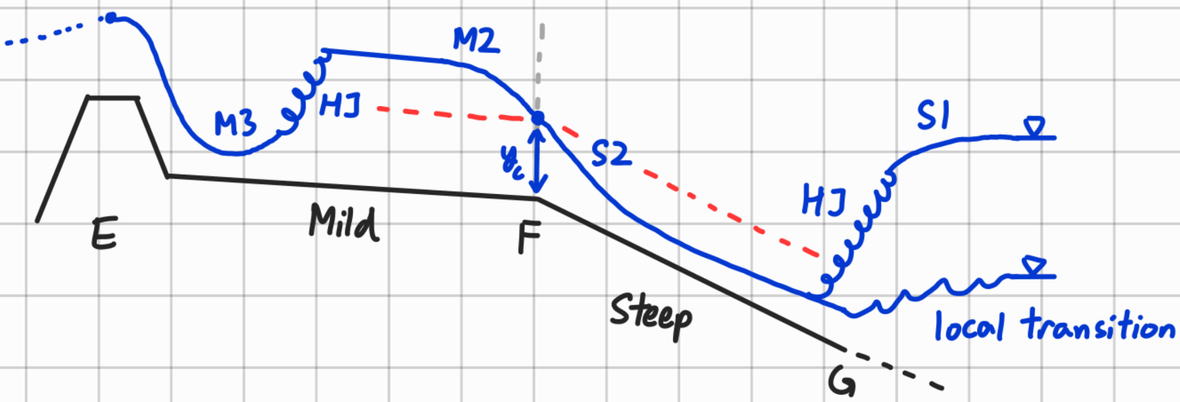
(i) Riverbank level ; HJ at E



(i) $y_0 < y_G < y_c$; No HJ at E



(i) Above y_0 ; HJ at E



2. (a) (i) Rainfall abstractions

The portion of rainfall that does not contribute to runoff.

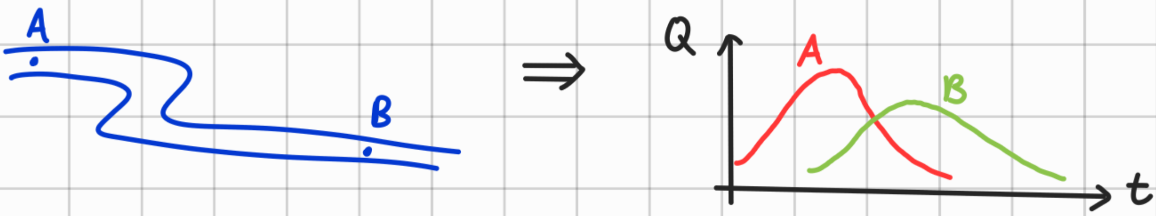
Includes: infiltration, stationary puddles (on concrete surface), etc.

(ii) Flow rating curve

The curve that relates a channel's discharge flow rate to its stage (river level).

(iii) Flood routing

The method of relating the hydrograph of one section of a river to another section's hydrograph.



(b)

Area	20,000,000 m^2		Demand	7.5 million m^3/month	

Month	Runoff depth (m)	Runoff (10^6 m^3)	Cumulative Runoff (10^6 m^3)	Demand Line (10^6 m^3)	Demand - Supply (10^6 m^3)
January	0.825	16.5	16.5		
Feb	0.570	11.4	27.9		
Mar	0.510	10.2	38.1	38.1	0.0
Apr	0.100	2.0	40.1	45.6	5.5
May	0.115	2.3	42.4	53.1	10.7
Jun	0.170	3.4	45.8	60.6	14.8
Jul	0.455	9.1	54.9	68.1	13.2
Aug	0.740	14.8	69.7	75.6	5.9
Sep	0.675	13.5	83.2	83.1	-0.1
Oct	0.600	12.0	95.2	90.6	-4.6
Nov	0.575	11.5	106.7	98.1	-8.6
Dec	0.495	9.9	116.6	105.6	-11.0

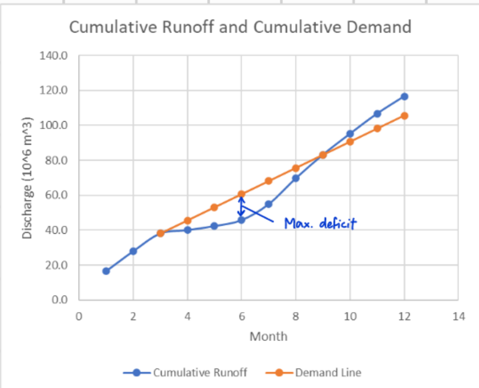
dry period starts (Mar)

+7.5, +7.5, ⋮ (Demand Line)

Max. Deficit (14.8)

$\times$ Area $\div 10^6$

$\therefore$ Reservoir size = 14.8 million m^3



← For reference

(c) (i) Volume $= \text{Area under } Q-t \text{ graph}$

$$= \frac{1}{2} \times (10 \times 3600 \text{ s}) \times 60 \text{ m}^3/\text{s}$$

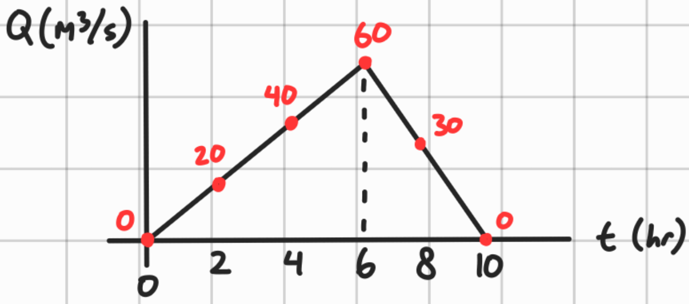
$$= 1\,080\,000 \text{ m}^3$$

Area $= \dfrac{\text{Volume}}{\text{Depth}}$ → 10mm for UH

$$= \frac{1\,080\,000}{10 \times 10^{-3}} \times 10^{-6} \text{ km}^2 = 108 \text{ km}^2$$

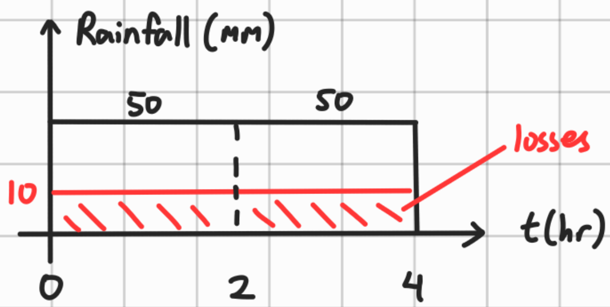
(ii)

2-hr UH	
Time (hr)	Discharge (m^3/s)
0	0
2	20
4	40
6	60
8	30
10	0



(iii) Since rain is uniform, rainfall intensity $= \dfrac{100 \text{ mm}}{4 \text{ hr}} = 25 \text{ mm/hr}$

For each 2-hours, rainfall $= 25 \times 2 = 50$ mm



Actual Rainfall Data				
Time (hr)	Rainfall (mm)	Loss (mm)	Effective Rainfall (mm)	UH scaling factor
0-2	50	10	40	4
2-4	50	10	40	4

÷ 10mm

⇒

Actual Rain Hydrograph for the 4-hr Uniform Rain			
Time (hr)	UH 1 (m^3/s)	UH 2 (m^3/s)	Hydrograph (m^3/s)
0	0		0
2	80	0	80
4	160	80	240
6	240	160	400
8	120	240	360
10	0	120	120
12		0	0

4 × 2-hr UH ← 1st block of rain

2nd block of rain → 4 × 2-hr UH lag by 2 hrs

3. (a)

	2-hr UH S-curve			
Time (hr)	S-curve (m^3/s)	Lagged S-curve (m^3/s)	S - lagged (m^3/s)	1-hr UH (m^3/s)
0	0		0	0
1	11	0	11	22
2	29	11	18	36
3	52	29	23	46
4	67	52	15	30
5	73	67	6	12
6	77	73	4	8
7	77	77	0	0
8	77	77	0	
9	77	77	0	

Lag by desired t-UH (in this case 1-hr)

$\times \frac{t_1}{t_2} = \times 2$

(b) $S = KQ \Rightarrow S_1 = KQ_1$

$S_2 = KQ_2$

$\bar{I}_1 = \frac{I_1 + I_2}{2}$

From $\frac{dS}{dt} = I - Q$

$\Rightarrow \frac{\Delta S}{\Delta t} = \left(\frac{I_1+I_2}{2} - \frac{Q_1+Q_2}{2}\right)$

$$\Delta S = \Delta t\,(\bar{I}_1 - \bar{Q}_1)$$

$$KQ_2 - KQ_1 = \Delta t\left(\bar{I}_1 - \frac{Q_1+Q_2}{2}\right)$$

$$KQ_2 - KQ_1 = \bar{I}_1 \Delta t - \frac{1}{2}\Delta t\, Q_1 - \frac{1}{2}\Delta t\, Q_2$$

$$(K + 0.5\Delta t)Q_2 = \bar{I}_1 \Delta t + (K - 0.5\Delta t)Q_1$$

$$Q_2 = \left(\frac{\Delta t}{K + 0.5\Delta t}\right)\bar{I}_1 + \left(\frac{K - 0.5\Delta t}{K + 0.5\Delta t}\right)Q_1$$

Comparing with $Q_2 = C_1\bar{I}_1 + C_2 Q_1$,

$$\therefore C_1 = \left(\frac{\Delta t}{K + 0.5\Delta t}\right)$$

$$C_2 = \left(\frac{K - 0.5\Delta t}{K + 0.5\Delta t}\right)$$

(c) (i) $\frac{dS}{dt} = I - Q$

$$\frac{\Delta S}{\Delta t} = \left(\frac{I_1+I_2}{2} - \frac{Q_1+Q_2}{2}\right) \Rightarrow \Delta S = \Delta t\left(\frac{I_1+I_2}{2} - \frac{Q_1+Q_2}{2}\right)$$

Time (hr)	Inflow (m^3/s)	Outflow (m^3/s)	Storage (m^3)
0	25	30	50,000
1	55	20	104,000
2	305	80	572,000
3	385	270	1,184,000
4	225	350	1,166,000
5	135	150	914,000

$50000 + \left(\frac{25+55}{2} - \frac{30+20}{2}\right)3600$

⋮

$\therefore t = 3$ hr, $S_{max} = 1184000\ m^3$

(ii)

K =	2	hours
x =	0.25	
Δt =	1	hour

C_0 =	0
C_1 =	0.5
C_2 =	0.5

Check:

$C_0 + C_1 + C_2$ =	1	OK!

Time (hr)	I (m^3/s)	$C_0{*}I_2$ (m^3/s)	$C_1{*}I_1$ (m^3/s)	$C_2{*}Q_1$ (m^3/s)	Q (m^3/s)
0	30	0.0	15.0	15.0	30.0
1	20	0.0	10.0	15.0	30.0
2	80	0.0	40.0	12.5	25.0
3	270	0.0	135.0	26.3	52.5
4	350	0.0	175.0	80.6	161.3
5	150	0.0	75.0	127.8	255.6

where, $C_0 = \frac{-kx+0.5\Delta t}{k(1-x)+0.5\Delta t}$

$$C_1 = \frac{kx+0.5\Delta t}{k(1-x)+0.5\Delta t}$$

$$C_2 = \frac{k(1-x)-0.5\Delta t}{k(1-x)+0.5\Delta t}$$

which gives $C_0 + C_1 + C_2 = 1.0$

All the best! <3 :)