UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: January 2022

Module Number: CE 6302 **Module Name: Engineering Hydrology (C-18)**

[Three Hours]

[Answer **all questions**, each question carries 12.5 marks]

Q1. a) i) Distinguish between Evaporation and Evapotranspiration.

[2.0 Marks]

ii) Briefly explain the concept of potential evapotranspiration and reference crop evapotranspiration.

[2.0 Marks]

b) i) Describe the factors that influence the evaporation from an open water surface.

[2.0 Marks]

ii) During a 30-day month, a reservoir had an average water spread area of 25 km^2 and the average rainfall over the reservoir was 10 cm. The mean rates of inflow and outflow to the reservoir were 10 m^3/s and 15 m^3/s, respectively. If the depletion in storage was 15 MCM, estimate the depth of evaporation during the month, assuming seepage loss to be 1.5 cm.

[2.0 Marks]

c) i) Briefly explain the merits and demerits of the arithmetic mean method and the Thiessen polygon method in determining the average areal precipitation.

[2.0 Marks]

ii) For a catchment having an area of 500 km^2, isohyetals were drawn for a storm and the resulting data were given in Table Q1. Estimate the average depth of precipitation over the catchment.

[2.5 Marks]

Q2. a) i) Using the first principles, prove that the governing equation for groundwater discharge from a well in a confined aquifer is given by $Q = 2\pi BK\frac{(h_1 - h_2)}{\ln r_1/r_2}$.

All the notations have their usual meanings and as given in Figure Q2.

[3.0 Marks]

ii) State the assumptions used in above part (i).

[3.0 Marks]

b) i) A well having 30 cm diameter completely penetrates a confined aquifer having thickness of 20 m and permeability of 45 m/day. What will be the steady discharge if the drawdown of the piezometric surface is not to exceed 3 m at the well? The radius of influence is 300 m.

[4.0 Marks]

ii) If the well diameter is increased by 50%, calculate the percentage increase in the discharge.

[2.5 Marks]

Q3. a) A catchment area of 7.8 km^2 received a 16-inch rainfall for 5-h duration. The flow measured at the catchment outlet is given in Table Q3.1. Recession time with usual notations is given by $N=bA^{0.2}$ where b=0.83 with A measured in km^2.

i) Draw the streamflow hydrograph resulting due to the rainfall event.

[2.5 Marks]

ii) Estimate the time to peak discharge from start of direct runoff, and the recession time.

[0.5 Marks]

iii) Separate the baseflow by straight-line method. If the streamflow volume is 3.5 Mm^3, what is the direct runoff volume generated over the catchment?

[2.0 Marks]

iv) Determine the ϕ index for the catchment.

[1.5 Marks]

b) i) A catchment area of 500 ha comprises of Group C hydrologic soil with antecedent moisture condition II. The land use of the entire catchment is identified as poor cover forestland. Calculate the direct runoff volume over the catchment due to 10 mm rainfall. (1 ha = 1×10^4 m^2)

[2.0 Marks]

ii) This catchment is expected to undergo large scale development with projected land use pattern of 50% industrial area (72% impervious); 15% paved parking lots; 20% paved roads with curbs and storm sewers; 15% gravel streets. Estimate the additional direct runoff volume generated due to the proposed development.

(Direct runoff depth from a storm with usual notations is given by

$$P_e = \frac{(P-I_a)^2}{(P-I_a)+S} \text{ where } I_a = 0.2\,S \text{ and } S = \frac{1000}{CN} - 10$$

Runoff curve numbers are given in Table Q3.2)

[4.0 Marks]

Q4. a) i) Two successive storms A and B, each of 4-h duration produced a rainfall excess of 2.0 cm and 3.0 cm, respectively, where A was followed by B. The flood hydrograph ordinates generated from these storms are given in Table Q4.1. Considering a constant baseflow at 5 m^3/s, derive the **first 5 ordinates** of a 4-h unit hydrograph (UH).

[3.0 Marks]

ii) Derive the corresponding 8-h UH ordinates from the above 4-h UH ordinates for the same catchment using the S-curve lagging method (*Guide*: Complete columns 2 to 7 of Table Q4.2 for this part).

[4.0 Marks]

b) The average annual precipitations at four stations of Gin River basin are: A-225.8 mm; B-218.2 mm; C-254.2 mm; D- 210.4 mm. In the year 2018, stations A, B, and D recorded annual precipitations of 232.5 mm, 221.6 mm, and 194.8 mm respectively, while station C was inoperative. Estimate the precipitation at C in that year.

[1.0 Mark]

c) The maximum annual rainfall data for Anuradhapura meteorological station from 1954 to 2004 (50 hydrological years) were ranked in descending order. The 4th highest rainfall was found 165.0 mm. What is the probability that this event will occur at least once within a 25-year period? Use the Weibúll formula with usual notations, $p = \frac{m}{N+1}$

[2.0 Marks]

d) A bridge has an expected life of 50 years. There is an acceptable 10% risk of failure for the bridge to be flooded during its lifetime. Determine the design return period for the bridge.

[2.5 Marks]

Table Q1: Isohyetal Data

Isohyetals (intervals) (mm)	150-120	120-90	90-60	60-30	30-10
Inter-isohyetal area (km^2)	70	101	103	160	66

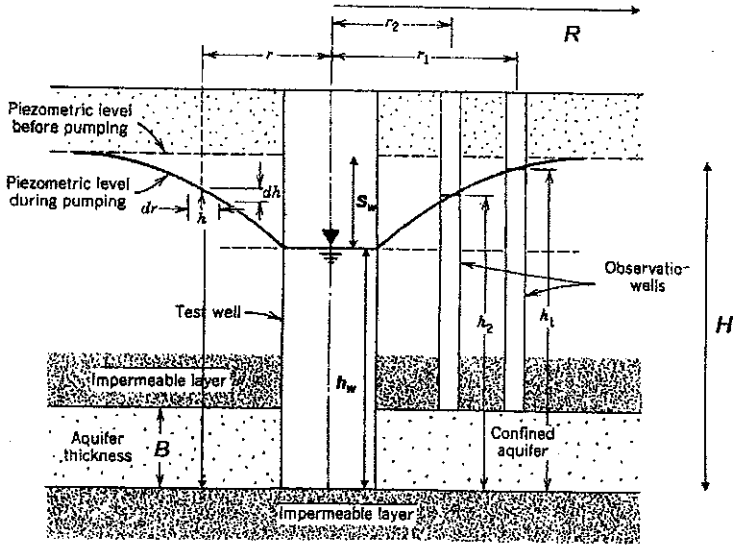

Figure Q2: Well operating in a confined aquifer

Table Q3.1: Flow measured at the catchment outlet

Time from start of rainfall (h)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Discharge (m^3/s)	4	3	5	8	15	22	28	32	28	22	16	10	5	3	2

Table Q3.2: United States Soil Conservation Service runoff curve numbers for agricultural, suburban, and urban land uses (Antecedent moisture condition II, I_a=0.2S)

Land Use Description		Hydrologic Soil Group			
		A	B	C	D
Cultivated land[1]:					
without conservation treatment		72	81	88	91
with conservation treatment		62	71	78	81
Pasture or range land:					
poor condition		68	79	86	89
good condition		39	61	74	80
Meadow: good condition		30	58	71	78
Wood or forest land:					
thin stand, poor cover, no mulch		45	66	77	83
good cover[2]		25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.					
Good condition: grass cover on 75% or more of the area		39	61	74	80
Fair condition: grass cover on 50% to 75% of the area		49	69	79	84
Commercial and business areas (85% impervious)		89	92	94	95
Industrial districts (72% impervious)		81	88	91	93
Residential[3]:					
Average lot size	Average % impervious[4]				
1/8 acre or less	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.[5]		98	98	98	98
Streets and roads:					
paved with curbs and storm sewers[5]		98	98	98	98
gravel		76	85	89	91
dirt		72	82	87	89

1. For a more detailed description of land use curve numbers, refer to Soil Conservation Service 1972, Chap. 9.
2. Good cover is protected from grazing and litter and brush cover soil.
3. Curve numbers are calculated assuming the runoff from the house and driveways is directed towards street with a minimum of roof water directed to lawns where additional infiltration could occur.
4. The remaining previous areas (lawn) are considered to be in good pasture condition for these curve numbers.
5. In some warmer climates of the country a curve number of 95 may be assumed.

Table Q4.1: Flood hydrograph ordinates due to A and B storms

Time from start of rainfall (h)	0	4	8	12	16	20	24	28
Flood hydrograph ordinate (m^3/s)	5	20	45	55	50	25	15	8

Table Q4.2: Derivation of 8-h UH ordinates (first 5 ordinates)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
Time (h)	4-h UH ordinate (m^3/s)	S-curve addition (m^3/s)	S-curve ordinate (S_4) (m^3/s)	S-curve lagged by 8-h (S_8) (m^3/s)	$S_4 - S_8$ (m^3/s)	8-h UH ordinate (m^3/s)
0						
4						
8						
12						
16						