UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: February 2020

Module Number: CE 6303 Module Name: Engineering Hydrology

[Three Hours]

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

Q1. a) Sketch typical storm hydrograph and mark the following on the hydrograph.

i) Time to peak

ii) Lag time

[1.0+1.0 Marks]

b) i) Briefly explain the factors that affect the shape of a streamflow hydrograph.

[1.0 Mark]

ii) Explain the procedure of derivation of a unit hydrograph from an isolated storm hydrograph.

[2.0 Marks]

iii) Explain three limitations associated with the Unit Hydrograph theory emphasizing suggestions to overcome each of them.

[2.0 Marks]

c) Calculate the streamflow hydrograph for a storm over a watershed having excess rainfall of 3 cm for the first six-hour and 2 cm for the second six-hour. Assume a constant baseflow of 20 m^3/s.
The six-hour unit hydrograph of the watershed is given in Table Q1.

Table Q1

Time (h)	6	12	18	24	30	36	42
Unit Hydrograph ($m^3/s.cm$)	5.1	15.7	33.5	28.7	20.3	5.2	2.4

[3.0 Marks]

Q2. a) Using clearly labeled sketches, describe the following terms related to groundwater:

i) Confined/unconfined aquifer.

ii) Saturated/unsaturated zone.

[1.0+1.0 Marks]

b) Show that the one-dimensional Dupuit's flow with recharge is given by $\frac{\partial^2 h^2}{\partial x^2} = -\frac{2R}{K}$ with standard notations. Use first principles for the derivation.

[4.0 Marks]

c) There are two canals separated by a strip of land 1200 m wide, of permeability k = 10 m/day. One canal is 2 m higher than the other and the depth of the aquifer is 20 m below the lower canal to an impermeable base. Assume that the annual rainfall is 2.0 m and 50% of that would infiltrate to the aquifer.

i) Find the inflow into, or abstraction from, each canal per metre length.

ii) Calculate the water divide for the above two canals.

[2.0+2.0 Marks]

Q3. a) i) An extract of a set of maximum annual daily precipitation data for a meteorological station between 1962 to 2012 is given in Table Q3.1 (ranked in descending order).
Estimate the probability of exceedence and return period of precipitation of 202.7 mm (year 2000 value) using the California formula.

Table Q3.1

Year	1965	1971	2000	1963	1985	1973		2002
Rainfall (mm)	312.7	236.3	202.7	188.7	179.1	154.4		61.9
Rank	1	2	3	4	5	6		50

[2.0 Marks]

ii) A one-day rainfall of 100 mm at a station was found to have a return period of 50 years. Determine the probability that a one-day rainfall of this or larger magnitude will occur at least once in 20 successive years.

[2.0 Marks]

b) i) Briefly explain the necessity of performing consistency checks with rainfall data in preparation for hydrologic statistics analysis.

[2.0 Marks]

ii) Square shaped land area (4 km x 4 km) is having x,y coordinates of (0,0), (4,0), (0,4) and (4,4) at its four corners (given in km). Four rain gauges (A, B, C, and D) are located inside this area. The x,y coordinates of their locations and the rainfall amounts measured by them are given in Table Q3.2. Determine areal average rainfall for the area by:

i) Arithmetic mean method.

ii) Thiessen method.

Table Q3.2

Rain gauge	x,y coordinates (km)	Rainfall amount measured (mm)
A	(1,1)	50
B	(1,3)	100
C	(3,3)	80
D	(3,1)	120

[2.0+2.0 Marks]

Q4. a) i) Explain how 'effective rainfall' and 'direct runoff' are extracted from streamflow observations.

[2.0 Marks]

ii) Evaporation from water surfaces are estimated through water and energy budget concepts. Briefly explain each method highlighting their associated limitations.

[2.0 Marks]

b) Rational formula is a widely used method to estimate the peak streamflow using the peak rainfall intensity. What are the assumptions and limitations associated with this method?

[2.0 Marks]

c) A catchment area of 1500 acres comprises of equal proportions of sandy loam and soils usually high in clay. The land use of the entire catchment is identified as poor cover forest land. Calculate the runoff from 38 cm rainfall, assuming antecedent moisture condition II.

The catchment is expected to undergo large scale development and the projected land use is;
50% residential area that is 30% impervious
14% residential area that is 65% impervious
6% paved roads with curbs and storm sewers
16% open land with 50% fair grass cover and 50% good grass cover
14% parking lots, schools and so on (all impervious)

Estimate additional runoff that would be generated as a result of the proposed development. State all the assumptions.
The excess precipitation or direct runoff from a storm with usual notations is given by $P_e = \frac{(P-0.2S)^2}{P+0.8S}$ where $S = \frac{1000}{CN} - 10$. Runoff curve numbers and Soil type classification are given in Table Q4.1 and Table Q4.2, respectively.

[4.0 Marks]

Table Q4.1: Runoff curve numbers (antecedent moisture condition II, Ia = 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 agricultural 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 computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.

[4]The remaining pervious 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 used.

Table Q4.2: Soil type classification by SCS

Group	Soil characteristics
A	Deep sand, deep loess, and aggregated silts
B	Shallow loess and sandy loam
C	Clay loams, shallow sandy loam, soils in organic content, and soils usually high in clay
D	Soils that swell upon wetting, heavy plastic clays, and certain saline soils