UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: December 2015

Module Number: CE6303 **Module Name: Engineering Hydrology**

[Three Hours]

[Answer **all questions**, each question carries 12 marks]

Q1 Figure Q1 illustrates Gin river basin and its sub-basins. Areas of each sub-basin are given in Table Q1.1. Department of Meteorology maintains two rain gages at Anninkanda and Thawalama whereas Department of Irrigation maintains a discharge gage at Thawalama.

a) The basin-average rainfall data given in Table Q1.2 were obtained by taking Thiessen-weighted average of the rainfall data from two rainfall gages in the upper Gin river (Anninkanda and Thawalama) for a storm during May-June, 2015.

(i) Explain how the Thiessen-weighted average method is used in determining the basin average areal precipitation.

(ii) Briefly discuss two other alternative methods to determine basin average areal precipitation from point measurements highlighting their strengths and weaknesses compared to Thiessen method.

[02 + 02 Marks]

b) (i) Using the straight line method and a constant base flow of 12 m^3/s, confirm that the direct runoff hydrograph (DRH) ordinates are as given in the Table Q1.2.

(ii) Show that the phi-index for the basin is 10 *mm/day*.

(iii) Show that the effective rainfall hyetograph (ERH) is having only three pulses and their numerical values are as given in Table Q1.2.

Direct runoff r_d, in *mm* is given by;

$$r_d = \sum_{m=1}^{M} (R_m - \Phi \Delta t)$$

where;
R_m - observed rainfall (*mm*)
Δt - time interval length (*days*)
Φ - phi index (*mm/day*).

[01 + 03 + 04 Marks]

Q2 The unit hydrograph of a watershed is defined as a direct runoff hydrograph (DRH) resulting from 1-cm of excess rainfall generated uniformly over the drainage area at a constant rate for an effective duration.

a) (i) Briefly explain the two basic principles that follow the theory of unit hydrograph.

(ii) Find the one-day unit hydrograph using the effective rainfall hyetograph (ERH) and direct runoff hydrograph (DRH) given in Table Q1.2.

[02 + 04 Marks]

b) (i) Calculate the discharge hydrograph for a storm of 15 *cm* areal average effective rainfall, with 5 *cm* in the first day, 7.5 *cm* in the second day and 2.5 *cm* in the third day. Use the one-day unit hydrograph computed in above part a)(ii) and a constant base flow of 12 m^3/s.

(ii) Confirm that the total depth of direct runoff is equal to the total effective rainfall.

[04 +02 Marks]

Q3 A hydrological model is a simplified mathematical representation of processes involved in precipitation-runoff transformation at the basin scale. Starting from precipitations that are the main drivers of flow, a hydrological model simulates the runoff at the basin/sub-basin outlet.

a) (i) What are the different types of hydrological models? State advantages and limitations of each type. Briefly explain influencing factors that govern the selection of a model.

(ii) Explain briefly the use of consistency checks of rainfall records before inputting to hydrological models. Suggest a correction technique to rectify such inconsistencies?

[03 + 02 Marks]

b) Figure Q3 illustrates hydrological model calibration results generated in two independent parameter optimization trials.
(i) Briefly discuss WHY and HOW the calibration and validation processes are performed in hydrological modeling. Illustrate parameter optimization procedure adopted in a hydrological model.

(ii) "*Optimization-A is better and able to capture most of the observed discharge*" Comment on the above statement.

(iii) Suggest an alternative approach to improve the Optimization-B results.

[03 + 02 + 02 Marks]

Q4

a) Using clearly labeled sketches describe the following terms related to groundwater:
(i) Confined/unconfined aquifers
(ii) Groundwater recharge
(iii) Saturated/unsaturated zone

[03 Marks]

b) (i) Show that the governing equation of unconfined groundwater flow with a horizontal impervious base and recharge from the top ground surface into the aquifer at a rate of R (m^3/s per m^2 of horizontal area) is given by;

$$\frac{\partial^2 h^2}{\partial x^2}+\frac{\partial^2 h^2}{\partial y^2}=-\frac{2R}{K}$$ (All the notations have their usual meanings)

(ii) Using the equation of above part b) (i), deduce the governing equation for groundwater flow in an unconfined aquifer with a horizontal impermeable base and of length L, with uniform recharge per unit area R between two constant head boundaries H_0 and H_L.

(iii) Two parallel streams with a horizontal separation of 0.5 *km* positioned on a horizontal base of impermeable clay. The hydraulic conductivity of the soil of this strip of land is 8.0 *m/day*. The constant heads in the two streams are 2.5 *m* and 1.5 *m* above the base. Calculate the maximum height of water table above the impermeable base when there is a steady recharge of 3.0 *mm/day*.

[03 + 02 + 04 Marks]

Q5

a) (i) Using first principles show that the governing equation for pumping rate from a well in an unconfined aquifer is given by;

$$Q=\frac{\pi K\left(h_1^2-h_2^2\right)}{\ln {r_1}/{r_2}}$$ (All the notations have their usual meanings)

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

[04 + 01 Marks]

b) A 0.4 *m* diameter well fully penetrates an unconfined aquifer whose bottom is 80 *m* below the undisturbed ground water table. When pumped at a steady rate of 1.5 m^3/min, the drawdown observed in two observation wells at radial distance of 5 *m* and 15 *m* are, 4 *m* and 2 *m* respectively.

(i) Determine the drawdown in the well.

(ii) At the boundary of the well, the governing equation of above part a)(i) reduced to $Q=\frac{\pi K\left(H^2-h_w^2\right)}{\ln {R}/{r_w}}$. Can this equation be used to determine hydraulic conductivity K of the area? Explain.

[05 + 02 Marks]

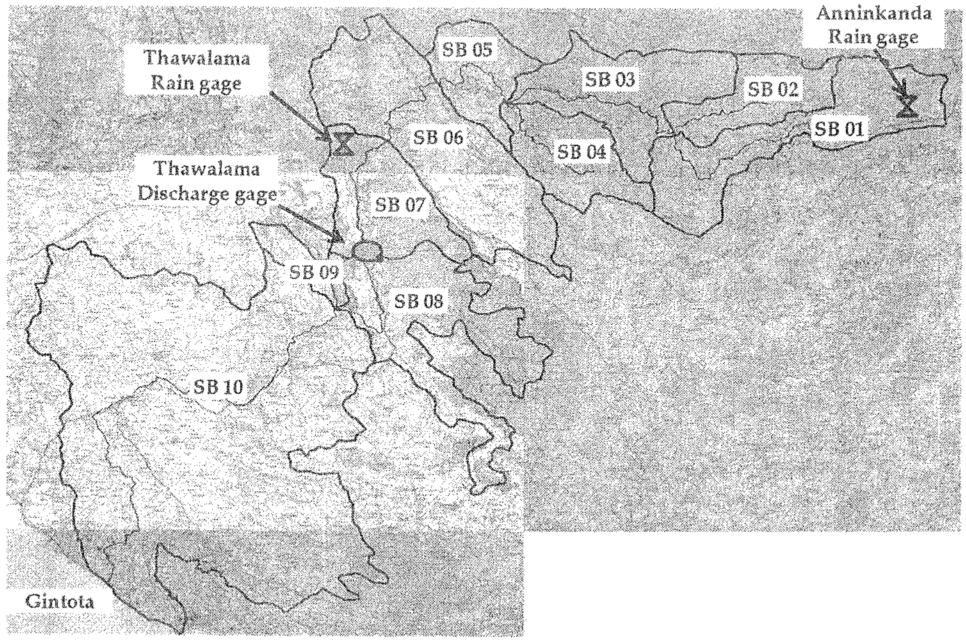


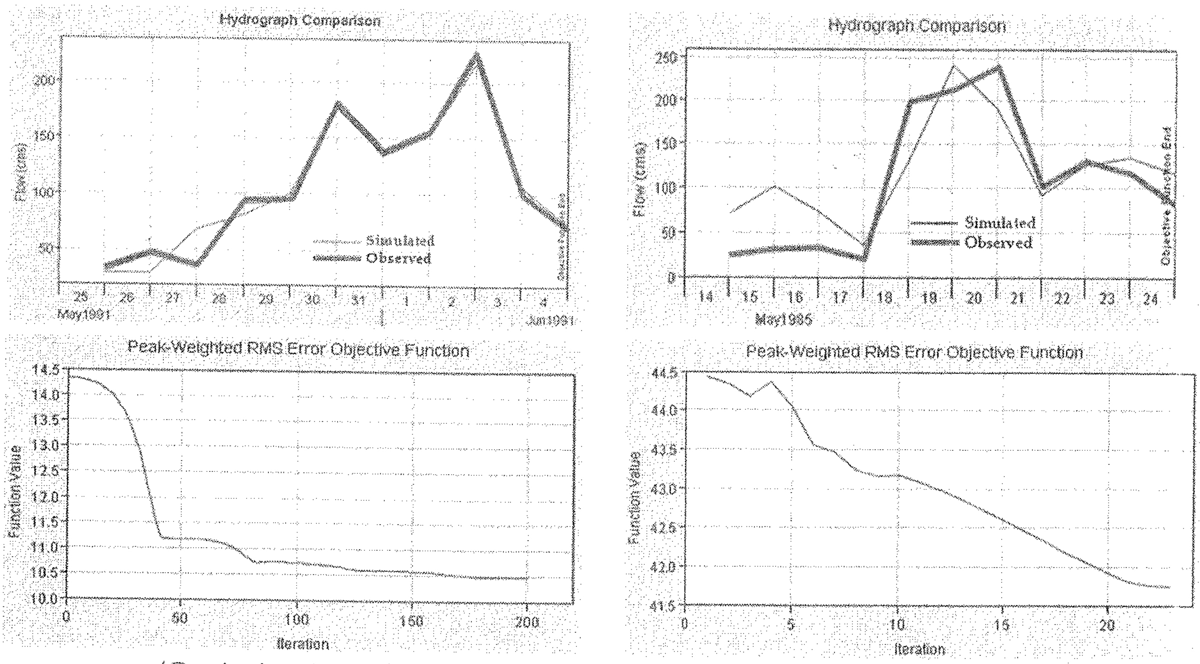
Figure Q1: Gin river, its sub-basins and location of rainfall/discharge gages.

Table Q1.1: Sub-Basin areas

Sub Basin	Area (Km^2)
SB1	82.4
SB2	40.0
SB3	68.0
SB4	45.0
SB5	37.0
SB6	117.5
SB7	56.5
SB8	86.0
SB9	14.5
SB10	405.0

Table Q1.2: Rainfall and Discharge data at upper Gin-river basin.

Month	Day	Observed Rainfall (mm)	Observed Discharge (m^3/s)	Effective rainfall hyetograph (ERH) (mm)	Direct runoff hydrograph (DRH) (m^3/s)
May	28		6.5		
	29	4.5	7.0		
	30	7.0	8.0		
	31	34.0	23.0	24.0	11.0
June	1	62.0	48.0	52.0	36.0
	2	49.0	80.0	39.0	68.0
	3	8.5	136.0		124.0
	4	3.5	182.0		170.0
	5		142.0		130.0
	6		53.0		41.0
	7		26.5		14.5
	8		11.0		
	9		9.5		
	10		7.5		



(Optimization A) (Optimization B)

Figure Q3: Hydrological model calibration results