# FACULTY OF FISHERIES AND MARINE SCIENCES & TECHNOLOGY

## Bachelor of Science Honors in Fisheries and Marine Sciences Degree/ Bachelor of Science Honors in Marine and Freshwater Sciences Degree

**Level III, Semester II Examination -2023/2024**

**LIM 3213: Principles and Applications of Hydrology** **Time: 2 hours**

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Answer only 4 (four) questions.

1. Stable isotopes of water, such as oxygen-18 and deuterium, serve as powerful tools in hydrological studies, enabling researchers to trace water sources, track movement within the hydrological cycle, and better understand water dynamics in various environmental contexts.

   **(a)** How are stable isotopes of water (e.g., oxygen-18 and deuterium) used in hydrological studies, and why are they important for understanding the water cycle and tracking water movement? **[8 marks]**

   **(b)** How can stable isotopes be used to trace water sources and determine the origin and flow paths of water within a catchment or aquifer? **[9 marks]**

   **(c)** What are the main advantages and challenges of using stable isotopes in hydrological research, considering both their tracer capabilities and practical limitations? **[8 marks]**

2. The formation of raindrops involves a sequence of intricate physical processes within the atmosphere. It begins with the condensation of water vapour onto microscopic particles and continues through droplet growth by various mechanisms, ultimately leading to precipitation.

   **(a)** How does condensation of water vapour lead to the formation of cloud droplets, and what role do cloud condensation nuclei (CCN) play in this process? **[8 marks]**

   **(b)** How do cloud droplets grow into raindrops through collision and coalescence, and what enables them to reach a size sufficient for precipitation? **[9 marks]**

   **(c)** What factors influence the descent of raindrops from clouds to the ground, particularly the roles of droplet size and air resistance? **[8 marks]**

3. A drainage network is a fundamental component of a watershed, governing the movement of water across the landscape. Quantifying its characteristics provides valuable insights into hydrological behavior and supports effective watershed management and flood risk assessment.

   **(a)** Define the key quantifiable characteristics of a drainage network—such as number of streams, stream length, stream density, and drainage density—and how is each defined? **[10 marks]**

   **(b)** How do drainage network characteristics like stream density and drainage density influence hydrological responses such as runoff and infiltration in a watershed? **[8 marks]**

   **(c)** How can quantified drainage network characteristics be used in watershed management and flood prediction? **[7 marks]**

4. Runoff generation is a key component of the hydrological cycle and is influenced by a range of climatic and physical factors. Understanding these influences is critical for predicting water flow, managing watersheds, and mitigating flood risks.

   **(a)** What are the major factors influencing runoff generations such as storm characteristics, meteorological conditions, and basin properties—and how does each factor affect runoff? **[10 marks]**

   **(b)** How do the interactions among storm characteristics, meteorological conditions, and basin properties affect the timing and magnitude of runoff in a watershed? **[8 marks]**

   **(c)** What are the implications of these factor interactions for watershed management and hydrological modelling? **[7 marks]**

5. Porosity is a fundamental property of earth materials that directly influences the storage and movement of groundwater. A clear understanding of porosity and its relationship to other hydrogeological properties is essential for assessing aquifer performance and groundwater availability.

   **(a)** What is porosity, and why is it important for groundwater storage and movement? Explain the difference between total and effective porosity, and how porosity affects water retention and flow. **[8 marks]**

(b) What are the main factors that influence the porosity of earth materials, including grain size, sorting, and compaction across different geological formations? **[9 marks]**

(c) How do variations in porosity affect aquifer characteristics such as permeability, water retention, and the ability to store and transmit groundwater? **[8 marks]**

6. Urbanization significantly affects the natural hydrological cycle, influencing water movement and distribution within the catchment. Hydrological modelling plays a key role in understanding these changes and informing sustainable water resource management. In this context, students enrolled in the *Principles and Applications of Hydrology* module are required to conduct a hydrological assessment to evaluate the effects of urbanization on surface runoff using hydrological modelling techniques.

a) Explain the role and importance of hydrological models in the planning, development, and management of water resources. **[05 marks]**

b) Explain the procedure for calibrating and validating a hydrological model in HEC-HMS using observed streamflow data. Your answer should outline the key steps involved and important considerations during the modelling process. **[07 marks]**

c) An urban catchment of 50,000 m² has the following land cover distribution:

- 20,000 m² : commercial area (Hydrologic Soil Group C)
- 10,000 m² : residential area (1/4-acre lots, Hydrologic Soil Group B)
- 10,000 m² : grassland in good condition (Hydrologic Soil Group A)
- 10,000 m² : paved parking lots (impervious surface)

A rainfall event of five inches occurs over the area. Assume that the initial abstraction is given by $I_a$=0.2S, where S is the potential maximum retention.

i. Determine the weighted Curve Number (CN) for the entire area using the provided land cover information. (Refer to the provided Table 1 for appropriate CN values.). **[04 marks]**

ii. Using the SCS Curve Number (CN) method, calculate the effective rainfall and resulting surface runoff for the given precipitation event. **[06 marks]**

iii. Discuss how urbanization influences surface runoff generation and its effects on key components of the hydrological cycle, including infiltration, evapotranspiration, and groundwater recharge. **[03 marks]**

**Note**: Use the following equations where applicable:

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

Table 1. Runoff curve numbers for selected agricultural, suburban, and urban land uses (antecedent moisture condition II, $I_a = 0.2S$)

| | Hydrologic Soil Group | | | |
|---|---|---|---|---|
| **Land Use Description** | **A** | **B** | **C** | **D** |
| Cultivated land: 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 | 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: | | | | |
| Average lot size — Average % impervious | | | | |
| 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. | 98 | 98 | 98 | 98 |
| Streets and roads: | | | | |
| paved with curbs and storm sewers | 98 | 98 | 98 | 98 |
| gravel | 76 | 85 | 89 | 91 |
| dirt | 72 | 82 | 87 | 89 |