Gx706

OLLSCOIL NA hÉIREANN, GAILLIMH
THE NATIONAL UNIVERSITY OF IRELAND, GALWAY

International Postgraduate Hydrology Courses

M.Appl. Science - Summer Examinations, 1999

APPLIED HYDROLOGY V

Examiners: Professor P.E. O'Connell
Professor C. Cunnane
Professor K.M. O'Connor

Time allowed is *three* hours. Attempt *any five* questions.

1. (a) In the context of a continuous linear time-invariant system, initially relaxed, **demonstrate *graphically* the operation of the "convolution"** of two time functions.

(b) Does the operation of **convolution** imply that the system is **conservative?** (Yes or no!)

(c) Is the application of the **convolution integral** generally a **practical option** in the hydrological context? (Explain your answer in *one* sentence!)

(d) For a system defined by the **convolution integral, derive relations** between

(i) **the unit step response function** S(t) and the **unit impulse response function** h(o,t).

(ii) the **unit pulse** (of duration T) **response function** h(T,t) and the **unit impulse response function** h(o,t).

(iii) the **unit pulse response function** h(T,t) and the **unit step response** function S(t).

(e) Demonstrate that the **convolution summation relation**

$$y_m = \sum_{r=0}^{m} x_r h_{m-r} \qquad \text{for} \quad m = 0,1,2,3,.....,$$

is discretely coincident with the assumed relation

$$y(t) = \int_0^t x(\tau).h(0,t-\tau).d\tau$$

between the **effective rainfall blocks** and the **storm-runoff component of the discharge hydrograph.**

2. (a) What do you understand by the term **flood routing** ?

(b) Distinguish clearly between **reservoir routing** and **channel routing.**

(c) What *simplification* is implied in **linear routing** ?

(d) Demonstrate that the **Muskingum channel routing model** is a ***linear*** one?

Question 2 continued overleaf ..../

(e) Outline the derivation of the expressions for the coefficients C_0, C_1, and C_2 of the **classic finite-difference form of the Muskingum channel routing model,** having the general form

$$Q_m = C_0 Q_{m-1} + C_1 I_m + C_2 I_{m-1}, \quad \text{for } m = 0,1,2, \ldots.$$

and discuss *briefly* the **restrictions** (if any) **on the model parameters K and X** and on the data interval **T.**

(f) Show that, for the routing system to be **conservative,** the **coefficients** of the above **Muskingum** equation must satisfy the relation

$$(C_0 + C_1 + C_2) = 1$$

(g) Indicate *briefly* the physically unrealistic characteristic of the unit impulse response function of the Muskingum model and its implication in the application of the method.

3. (a) Explain, *very briefly,* why the **Linear Transfer (LTF) model,** defined by

$$(1 + \phi_1 B + \phi_2 B^2 + \ldots + \phi_n B^n) y_m = (\theta_0 + \theta_1 B + \theta_2 B^2 + \ldots + \theta_k B^k) x_m, \quad \text{for} \quad m = 0,1,2,3,\ldots,$$

where B is the *backward shift* operator and n > k, is still widely used in deterministic hydrological modeling, particularly in the context of real-time river flow forecasting.

(b) Show that the **Gain Factor** (G) of the **LTF model** is given by

$$G = \frac{\theta_0 + \theta_1 + \theta_2 + \ldots + \theta_k}{1 + \phi_1 + \phi_2 + \ldots + \phi_n}$$

(c) For the **discrete cascade model of two unequal discrete linear reservoirs,** defined by

$$(1 + K_1 \nabla)(1 + K_2 \nabla) y_m = x_m \;, \quad \text{for} \quad m = 0,1,2,3,\ldots.$$

where ∇ is the *backward difference* operator, with $\nabla = (1-B)$, show that

(i) the model is **conservative,**

(ii) it's **unit impulse response series is given by**

$$h_m = \frac{(1-q_1)(1-q_2)}{(q_1 - q_2)} \left[q_1^{m+1} - q_2^{m+1} \right], \quad \text{for } m = 0,1,2,3,\ldots,$$

where $q_1 = \dfrac{K_1}{1+K_1}$ and $q_2 = \dfrac{K_2}{1+K_2}$,

(iii) it's **lag** (i.e. the **1st moment** about the origin) is $M_1' = (K_1 + K_2)$.

(d) If **only two isolated blocks of effective rainfall,** 2cm and 1cm in depth, each of duration T = 2 hours, fall on a catchment of area A = 360 km^2, **determine the first five ordinates of the storm runoff,** at 2-hour intervals, assuming that the form of LTF model in part (c) above is appropriate, with $K_1 = 4$ and $K_2 = 2$, using *either* the **linear difference equation** *or* **convolution summation.**

4. (a) An annual maximum flood population has the following values of Probability Weighted Moments (PWMs)

M_{100}=166.2495 M_{110} = 101.0709 M_{120} = 75.17723
M_{101} = 65.1786 M_{102} = 39.2800

Assuming that the flood magnitudes follow a GEV distribution determine

(i) the magnitude of the 50 year return period flood *[6 marks]*

(ii) the magnitude of the flood which has a risk of 0.25 of being exceeded at least once in 20 years *[6 marks]*

(b) What are the relative advantages/disadvantages of the GEV distribution relative to the EV1 distribution in the context of flood hydrology?

(c) What is understood by the standard error of a flood quantile estimate. *[4 marks]*

5. The following flood peaks over a threshold of 80 m^3/s occurred over a 7 year period.

(a) Extract a series of peaks corresponding a reate parameter of 1.4 peaks/year, rounding off the number of required peaks to the nearest integer. *[2 marks]*

(b) Prepare a probability plot of the extracted data on rectangular graph paper on an exponential base *(A table of exponential plotting positions is provided).* *[6 marks]*

(c) Show on the plot a return period scale *[2 marks]*

(d) Show on the plot the exponential distribution relation estimated by the method of moments. *[10 marks]*

Year	Flood Peak m^3/s	Year	Flood Peak m^3/s
1992-93	115 83 139	1995-96	90 105 165
1993-94	87 94	1996-97 1997-98	84 97
1994-95	115 110	1999-99	140 82

continued overleaf..../

6. (a) Explain briefly what role(s) simulation can play in hydrological frequency analysis *[4 marks]*

(b) What advantages, if any, does parameter estimation by the method of Probability Weighted moments have over other methods in the context of hydrological frequency analysis. *[4 marks]*

(c) See the attached sheet labelled "Data for Question 6" which contains the results of two regression analyses of log mean annual flood on log of specified catchment characteristics.

(i) Is there a significant relationship between log (Q bar) and log (Area)? If yes, explain why in terms of all the relevant information in the table. *[6 marks]*

(ii) Show how the ANOVA data can be used to decide whether the variable of S explains a significant extra amount of the variability of log (Q bar) over and above what can be explained by log A alone. *[6 marks]*

7. Explain the basic principles of the electrical resistivity method, and compare and contrast profiling and mapping, with vertical electrical sounding. *[10 marks]*

What aspects of the electrical resistivity method make it particularly suitable for hydrological applications? Illustrate your answer with examples which you know directly or which you have studied in the literature. *[10 marks]*

8. Define

(a) the erosivity of rain
(b) the erodibility of soil. *[5 marks]*

Describe the physical appearance of the following three types of erosion, and for each of them, explain the principal hydraulic processes that cause it.

(c) sheet erosion
(d) rill erosion
(e) mass erosion. *[5 marks each]*