Final Examination Land Surface Hydrology
Tuesday, 9 November 2010
Duration: 9.00 to 12.00

The use of pocket calculators is allowed. The back of this page is the sheet with formulas.

At the end of the session hand in your answer sheet, graded paper and this exam. Write your student number on all the sheets you eventually hand in.

This exam consists of large number of questions. Do not loose too much time on a specific question but continue with the next. If you skip a question or answer it later on, please indicate this.

If you think you need to know the answer to a previous question to answer the next, assume a value yourself and state this clearly in your answer and continue.

Motivate your answers but be as concise as possible. You are allowed to answer in English or in Dutch. Please write clearly! Unreadable answers are incorrect.

Good luck!

Rens van Beek

Equations LSH examination:

Reynolds number $$Re = \frac{v \cdot L}{\nu}$$

Froude number $$Fr = \frac{v}{\sqrt{gD}}$$

Bernoulli's equation: $$\frac{\overline{v^2}}{2g} + \frac{P}{\rho g} + z = \text{constant}$$

Manning: $$Q = A \cdot V_{avg} = \frac{A \cdot R^{2/3} \cdot S^{0.5}}{n}$$

Chezy: $$Q = A \cdot V_{avg} = A \cdot C \cdot (R \cdot S)^{0.5}$$

Muskingum

$$O_2 = c_0 I_2 + c_1 I_1 + c_2 O_1$$
$$c_0 = (-KX + 0.5{*}\Delta T) / (K - KX + 0.5{*}\Delta T)$$
$$c1 = (KX + 0.5{*}\Delta T) / (K - KX + 0.5{*}\Delta T)$$
$$c2 = (K - KX - 0.5{*}\Delta T) / (K - KX + 0.5{*}\Delta T)$$

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$$c = m{*}v$$
$$K = \Delta x / c$$
$$X = 0.5 * [1 - Q_0 / (S_0 {*} B_0 {*} c {*} \Delta x)]$$

St. Venant $$S_f = S - \frac{\partial y}{\partial x} - \frac{v}{g}\frac{\partial v}{\partial x} - \frac{1}{g}\frac{\partial v}{\partial t}$$

Linear reservoir $$Q_t = Q_{t-1} \cdot e^{-dt/k} + I_t \cdot \left(1 - e^{-dt/k}\right)$$

$$Q_t = \frac{k - \frac{1}{2}\Delta t}{k + \frac{1}{2}\Delta t} Q_{t-1} + \frac{\Delta t}{k + \frac{1}{2}\Delta t} I_t$$

Curve Number $$Q = \frac{P^2}{P + S},$$

$$CN(II) = 1000 / (10 + S)$$

$$CN(I) = \frac{4.2CN(II)}{10 - 0.058CN(II)}, \quad CN(III) = \frac{23CN(II)}{10 + 0.13CN(II)}$$

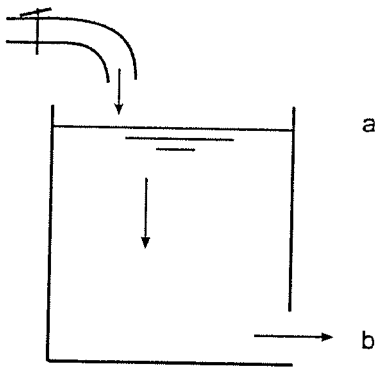
where I corresponds to dry, II to normal and III to wet conditions.

Question 1: Right or Wrong? (15 points in total, equally divided)
EXPLAIN; WITHOUT A CONCISE EXPLANATION NO POINTS

a) The classification by means of the Froude number distinguishes flow state based on viscosity.
b) A flow duration curve (*FDC*) contains information on the sequence of events.
c) In Muskingum's hydrologic routing scheme the equation reduces to a linear store when the travel time K becomes zero.
d) The Geomorphologic Instantaneous Unit Hydrograph (*GIUH*) uses catchment information to divide the upstream area into isochrones.
e) Prior to ponding, propagation of the wetting front in the Green-and-Ampt formula depends on the saturated hydraulic conductivity and sorptivity only.

Question 2: Bernoulli's equation (10 points in total, a= 2, b= 4, c= 4)

a) In your own words, explain the difference between the total energy head and specific energy head (both in units of [L]).
b) List the basic assumptions of the Bernoulli equation.
c) Shown here is Torricelli's vessel. A vessel has an outlet at *b*, where a constant outflow is maintained by keeping the water level at *a* constant. Bernoulli is valid. Use this formula to find an expression for the flow velocity at *b* in terms of the water level at *a* and indicate which simplifying assumptions you have to make.



Question 3: New Orleans revisited (after Tarboton in Bras, 1990; 15 points in total; a= 3, b= 3, c= 4, d= 5)

You are asked to make a preliminary design of a flood-control channel in New Orleans. The channel is to be built as an equilateral triangular channel of depth *d*. The material is concrete with a Manning's n of 0.01 and the channel must have a slope of 0.004. The channel is to carry the outflow resulting from a historic rainfall event of cyclonic tropical origin. The maximum total precipitation recorded for the 18-hour long event was 12.8 inch with a maximum intensity that was twice that of any other 6-hr period (rainfall depths of 3.2, 6.4 and 3.2 inches respectively). Total losses during the storm were 3.6 inch and proportional to the total rainfall. You are given the following unit hydrograph:

For those of you not familiar with imperial units: 1 inch= 25.4 mm, 1 foot= 0.3048 m and a mile is 1609 m.

Time (hr)	UH ($ft^3 s^{-1} in.^{-1}$)
6	80
12	150
18	100
24	90
30	0

a) Calculate the catchment area (either in km^2 or mi^2).
b) Verify that, to express Manning's formula in imperial units, a conversion factor of 1.49 is needed:

$$v = Q/A = 1.49\frac{R^{2/3}\sqrt{S}}{n}.$$

c) What is the time and height of the peak flood for this design storm?

d) What is the required depth of the channel (in *feet*) so that no overflow occurs during the storm?

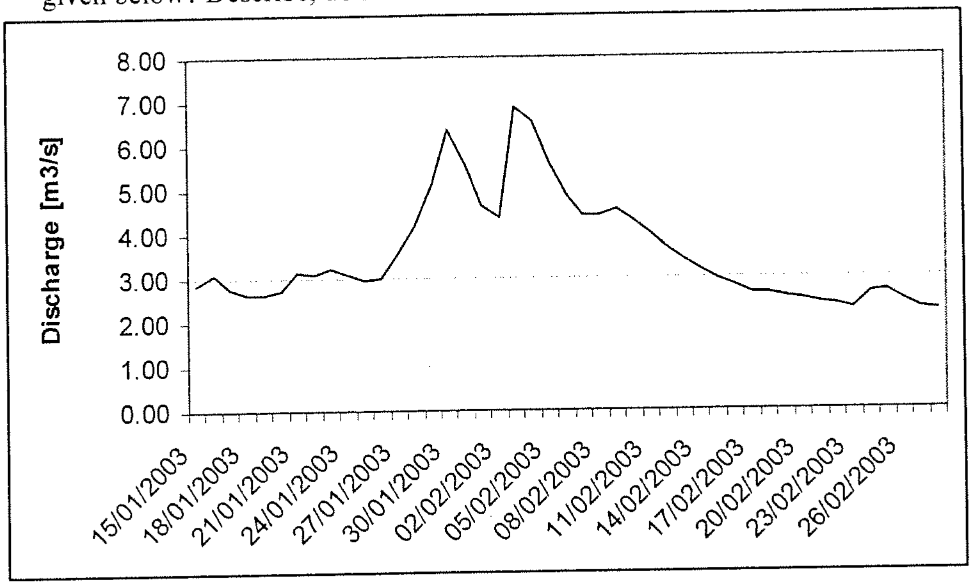
Question 4: Rainfall-runoff relationships (10 points in total: a= 3, b= 4, c= 3)

Give a short explanation in addition to your graphs for *a* and *b*.

a) Starting from a deep, uniform soil profile with saturated hydraulic conductivity K_s, sketch distribution of soil moisture with depth for two separate rainfall events of uniform intensity I for which 1) $I << K_s$, $I >> K_s$, at regular time intervals (say, at six time steps).

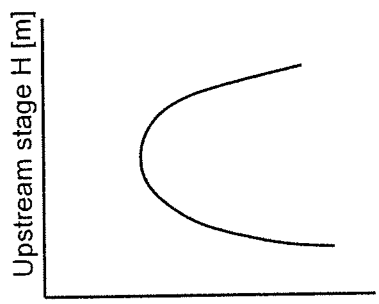
b) Once rain ceases and assuming negligible evaporation, draw for both cases the profiles of soil moisture redistribution (again for six time steps).

c) How would you determine the unit hydrograph if you would only have the hydrograph as given below? Describe, do not calculate!



Question 5: Routing (15 points in total: a= 3, b= 5, c= 2, d= 3, e= 2)

a) Shown here is the typical non-linear response in travel time for peak discharge as a function of stage. Copy this on your answer sheet and explain under which conditions the travel time is at its lowest and which factors contribute to increasing travel times in case of rising and falling water levels.



b) Give the continuity equation employed in hydraulic routing schemes and list which forces form the basis of the momentum equation and the underlying assumptions made.

c) Starting from Chezy's equation, explain why only the kinematic wave solution exhibits no hysteresis:

$$S_f = \frac{v^2}{C^2 R}.$$

d) Starting from Manning's equation and ignoring lateral inflow, show that, under kinematic conditions in which the momentum equation can be written as $Q = bA^m$, the kinematic wave celerity is approximately $5/3$ times the flow velocity, v.

e) Two observers are located along a deep, rectangular channel, at equal distances (30 m) from an inflow point but at opposite directions (up- & downstream). At the inflow point, a discharge of 142 $m^3 \cdot s^{-1}$ enters the channel. This water flows downstream with a velocity of 2.65 $m \cdot s^{-1}$ and the water depth belonging to the new flow rate is 0.88 m. At what time – if at all- do the observers see the dynamic wave pass?