**Utah State University**
**Department of Civil and Environmental Engineering**
**CEE 3430 Engineering Hydrology**

Test 1 Solution — Date: 2/18/2011
D.G. Tarboton — Time: 50 min
30 Points

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1. A lake with a surface area of 525 acres was monitored for a one month period. The inflow was 30 cfs, the outflow was 27 cfs. There is negligible seepage loss. The total precipitation was 4.25 in. Evaporation loss was estimated as 6.0 in. Estimate the **change in lake level** during the month. Assume 30 days for this month. [Note 1 acre = 43560 $ft^2$] [10 points]

   Lake water balance

   Change in storage = Inputs – Outputs

   Care needs to be taken to express all quantities in equivalent units. It is easiest, because it gets directly to the answer to express all quantities in depth units over a month. I used inches:

   Inputs

   Precipitation, P=4.25 in

   Inflow

   $$Q_{in} = \frac{30\ ft^3 s^{-1}}{525\ acre\ \times\ 43560\ ft^2 acre^{-1}} 30\ day\ mon^{-1} \times 3600\ \times 24\ s\ day^{-1} 12\ in\ ft^{-1}$$
   $$= 40.80\ in$$

   Outputs

   Evaporation, E = 6 in

   Outflow

   $$Q_{out} = \frac{27\ ft^3 s^{-1}}{525\ acre\ \times\ 43560\ ft^2 acre^{-1}} 30\ day\ mon^{-1} \times 3600\ \times 24\ s\ day^{-1} 12\ in\ ft^{-1}$$
   $$= 36.72\ in$$

   Change in level

   $$\Delta z\ = P + Q_{in}\ - E - Q_{out} = 4.25 + 40.8 - 6 - 36.72 = 2.33$$

   The lake will **increase in level by 2.33 inches** over the month

2. At a weather station near a lake the following measurements are made
    - Air pressure: 850 mb
    - Air temperature 17 $^oC$
    - Relative humidity 60 %
    - Net radiation 350 cal $cm^{-2}$ $day^{-1}$
    - Water temperature 18 $^oC$

    a) Calculate the **dew point** [5 points]

    b) Calculate the **evaporation** from the lake using the energy balance approach with Bowen ratio. Neglect stored and advected energy. [5 points]
    [Note, Latent heat of vaporization = 587 cal $g^{-1}$]

a) Saturation vapor pressure is the following function of temperature

$$e_s(T) = 2.7489 \times 10^8 exp\left(-\frac{4278.6}{T+242.79}\right) \qquad (1)$$

Therefore at air temperature $T_a$ = 17 C

$e_{sa}$ = 19.34 mb

With RH = 0.6, actual air vapor pressure is

$e_a$ = 19.34*0.6 = 11.61 mb

Dew point temperature is the temperature at which this is the saturation vapor pressure.
Inverting equation (1)

$$T = -242.79 + \frac{4278.6}{\ln(2.7489 \times 10^8/e_s)}$$

Put $e_s$=11.61 mb into this equation to obtain dew point

**$T_d$ = 9.19 $^oC$**

Note that dew point temperature, relative humidity and air vapor pressure are properties of the air, so when calculating them the air temperature is used.

b) The Bowen Ratio is

$$R = \frac{0.66P}{1000}\left(\frac{T_s - T_a}{e_s - e_a}\right)$$

$$e_s = e_s(T_w = 18) = 20.61\ mb$$

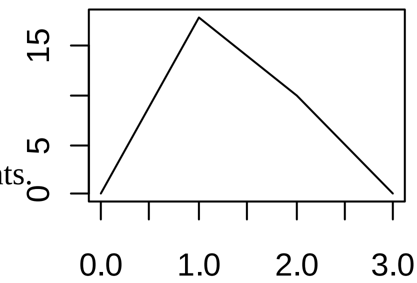
$$\therefore R = \frac{0.66 \times 850}{1000}\left(\frac{18-17}{20.61-11.61}\right) = 0.0623$$

With advected and stored energy neglected

$$E = \frac{Q_N}{\rho L_e(1+R)} = \frac{350}{1 \times 587 \times (1+0.0623)} \frac{cal\ cm^{-2}\ day^{-1}}{g\ cm^{-3}\ cal\ g^{-1}} = \mathbf{0.561\ cm/day}$$

3. The 1 hr Unit Hydrograph following was recorded for a watershed.

| Time (hr) | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Discharge (cfs $in^{-1}$) | 0 | 18 | 10 | 0 |




Consider a 3 hour storm with the following precipitation amounts.

| Time (hr) | 1 | 2 | 3 |
|---|---|---|---|
| Precipitation (in) | 1 | 2 | 1.5 |

Assume infiltration of 0.8 in. in the first hour, 0.6 in. in the second hour and 0.5 in. in the 3rd hour. Determine the **peak flow** and **volume of runoff** from this storm. [10 points]

Subtracting infiltration losses, the excess precipitation in each time step is

| Time (hr) | 1 | 2 | 3 |
|---|---|---|---|
| Excess Precipitation (in) | 1-0.8 = 0.2 | 2-0.6 = 1.4 | 1.5-0.5 = 1 |

Multiply each of these by the unit hydrograph values. Lag the second and third hours by 1 and 2 hours respectively and add up to get the response hydrograph

| Time | Unit Hydrograph cfs $in^{-1}$ | Direct response to first hour excess precipitation of 0.2 in cfs | Direct response to second hour excess precipitation of 1.4 in cfs | Direct response to third hour excess precipitation of 1 in cfs | Total response (sum of 3 columns to left) cfs |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | |
| 2 | 18 | 18*0.2=3.6 | 0 | 0 | 3.6 |
| 3 | 10 | 10*0.2=2 | 18*1.4=25.2 | 0 | 2+25.2=27.2 |
| 4 | 0 | 0 | 10*1.4=14 | 18*1=18 | 18+14=32 |
| 5 | | | 0 | 10*1=10 | 10 |
| 6 | | | | 0 | 0 |

The peak flow occurs at the end of the 4th hour and is **32 cfs**.

The sum of the total response gives the volume of runoff. This is:
3.6+27.2+32+10 = 72.8 cfs. Hour = 72.8 x 3600 = **262080 $ft^3$**.