Geography 3511 – Spring 2009

Exam 3 Study Guide

BRING A CALCULATOR!

Reading: Dingman Chpt. 7,9. Focus on the portions of the book that relate to what was covered in lecture…but class notes are most important.

See also the *lectures figures* presented in class (online).

There will be approximately 10 questions based primarily on the lecture notes, but you must understand, not just memorize the concepts, so the book can be useful in bringing things together. I realize that I have given you a lot of equations. Focus only on the equations discussed in class and make sure you understand the following things:
- what is the equation used for?
- what are the various terms in the equation, and what do they represent physically?
- what field data are needed to use a particular equation?

You don't need to memorize any complex equations; however, you should know simple equations, such as relative humidity. I will provide the more complex equations and either ask you what the terms represent, or ask you to calculate something.

Otherwise focus on the following information:

EVAPOTRANSPIRATION (chpt. 7; focus pp. 272-288; App. D has basic definitions of latent heat etc.) – The notes are from the lectures by Dr. Pitlick the week after spring break.

- Approaches for estimating ***Evaporation***: Water Balance, Mass Transfer, Energy Balance
- Lake Water Balance: Inputs-Outputs=Change in Storage (chpt. 7.3.1)

  $E = P+Qin+GWin-Qout-GWout-\Delta V$

  - What do these terms represent?

- Mass Transfer Approach: essentially a diffusion equation

  $E = K_e u_a(e_s-e_a)$ (eqn. 7-1)

  How do you estimate K_e, the mass transfer coefficient? Measure u_a, T_a, T_s, and RH and calculate e_s and e_a…Plot E versus $u_a(e_s-e_a)$…the slope of the line is K_e. Recall the calculation for question 5 on Exam 2, where knowing Temp, Relative humidity, and the equation for saturation vapor pressure (e_{sat}), we can calculate the surface vapor pressure (e_s) and the vapor pressure of the overlying air (e_a), thereby defining the vapor pressure gradient.

- Energy Balance Approach: Inputs-Outputs=Change in storage (chpt. 7.1.6; 7.3.4)

  Relies on the fact that $LE = \rho_w \lambda_v E$

  a) $LE = K + L + H + G - \Delta Q/\Delta t$

  b) Net Radiation, $R_n=K+L$; $G=0$

  c) Bowen Ratio: $B=H/LE$ (ratio of sensible to latent heat flux)

  Combine above equations…and compute evaporation

  d) $E = \frac{R_n - \Delta Q/\Delta t}{\rho_w \lambda_v (B+1)}$ -- Requires lots of measurements

  e) NOTE: High Rn, lots of evap, High Bowen Ratio, less evap.

- Combination Equation (mass balance + energy balance)

- Penman Equation (chpt. 7.3.5 – focus on class notes)
  a) Total Heat Content (of an air parcel over a lake) = Latent Heat Content + Sensible Heat Content
  b) Back to Bowen Ratio (eqn. 7-12) to describe changes in latent/sensible heat:
  $B = \gamma(T_a - T_{sat})/(e_{sat} - e_a)$ → we can interchange temperature and vapor pressure in the equations below because, for a given heat content, a change in latent heat must be accommodated by a change in sensible heat.
  c) As dry air moves over a lake (e_a below SVP curve), evaporation occurs (removing heat from air), thus cooling the air parcel and it moves toward saturation (Recall the SVP versus Temp curve! → e_a moves toward e_{sat})
  d) Rate of Evaporation can be described by combining $LE = \rho_w \lambda_v E$ with Bowen Ratio:
  $\lambda_v E = \frac{\rho_a c_a (T_a - T_{sat})}{r_a}$, where c_a is heat capacity, and r_a is the rate of heat exchange (which has all that velocity profile stuff embedded in it). This is the "diffusion" or mass transfer component of evaporation.
  e) Following saturation, evaporation can continue if the air parcel is warmed from incoming radiation
  f) Given that Δ is the slope of the SVP curve we can find that: $\lambda_v E = \frac{\Delta R_n}{\Delta + \gamma}$ → this is the radiative component of evaporation
  g) Combining the above two equations for a dry and saturated air parcel, and acknowledging that the temperature gradient can be related to the vapor pressure gradient via the Bowen Ratio and SVP curve, we arrive at the combined *PENMAN EQUATION*:
  $\lambda_v E = \frac{\Delta R_n + \rho_a c_a (e_{sat} - e_a)/r_a}{\Delta + \gamma}$ … know the terms in this equation.
  h) Note that if the parcel becomes saturated ($e_{sat} = e_a$), evaporation will be driven entirely by heat added due to net radiation. If the air parcel is dry, evaporation is a function of both vapor pressure gradient (and thus RH and temperature), and heating due to radiation. This is same as equation 7-33 in the book, written in a simpler way.

- Penman-Monteith Equation for Evapotranspiration (eqn. 7-56 – focus on class notes)
- Basically add a term accounting for stomatal resistance, r_s, which regulates transpiration:
  $\lambda_v E = \frac{\Delta R_n + \rho_a c_a (e_{sat} - e_a)/r_a}{\Delta + \gamma(1 + r_s/r_a)}$. Focus your attention on the Penman Eq.

SURFACE WATER (chpt. 9 – focus on class notes)

- Streamflow Measurement: Continuity equation: Q=WxHxU
  - We can develop a stage-discharge relation at a gauging station
- Runoff producing mechanisms (pp. 407-413)
  - Infiltration Excess (Horton Overland Flow) "Saturation from above"
  - Saturation Excess (Dunne Overland Flow) "Saturation from below"
  - Subsurface Storm Flow
  - What are the conditions under which these different types of runoff producing mechanisms may occur?
  - There could also be a combination of these mechanisms during a precipitation event depending on the watershed characteristics
  - How might hydrograph shape reflect these different mechanisms?
  - TOPMODEL (BOX 9-3, p. 414) – Know the topographic index; Where is it high? Where is it low?
  - Hydrogeomorphology - What is the relation between drainage density, runoff processes and peak discharge of flood flows.

- Flood frequency analysis (*not really in the book - see lecture diagrams link for some images*)
    - Floods = random events
    - What is the relation between return period and probability?
    - A normal distribution can be defined by a z-score: $z = \frac{x-\bar{x}}{s}$, where x is a discharge value, $\bar{x}$ is the mean discharge, and s is the standard deviation. Because z is related to probability, if we know the mean discharge and standard deviation (from a gauge record), we can calculate the exceedance probability of a given flow. For example, a flow exceeded 16% of the time has a z-score of 1, thus $x_{16}=\bar{x}+sz = \bar{x} + s(1)$.
    - What is the difference between a normal and log-normal distribution? Can we apply the same statistics as above?
    - What is skewness?
    - Sometimes flood distributions are characterized by mixed populations (e.g. rain vs. snowmelt based flood events) which may have their own unique probability distributions (e.g. Front Range).

- Flood Wave – see review on pp. 425-427, in particular equations 9-21 through 9-24 which allow solution for flood wave velocity through combination with the continuity and Manning's equations.
- What are some effects of dams on river systems?
- How might we calculate the discharge necessary to move sediment…
    - If sediment begins to move when $\tau^* = \frac{\rho g H S}{(\rho_s-\rho) g D}$ where H is depth, S is slope, D is grain size, and the rest are various constants. If sediment begins moving when $\tau^* = 0.03$, then we can rearrange the equation and solve for depth (given a known slope and grain size). We can put that depth into Manning's equation, and solve for velocity. If we know how wide the channel is, we can now calculate the discharge necessary to move sediment from Q=WxHxU.
- The last couple lectures we discussed how stream channel morphology is related to water discharge and sediment transport.
    - Hydraulic Geometry: empirical power-law relations describing downstream changes in width, depth, and velocity; but does not account for sediment transport
    - Rational Method: Use physics to determine stable channel form.
    - Gary Parker (1979) solved the "stable channel paradox" which allows for sediment transport (such that $\tau^* = 1.2\tau_c^*$) where τ_c^* is 0.03 as defined above. Thus channel geometry is directly tied to the physics of sediment transport.

FINAL THOUGHTS:

If you've been to all the lectures, and have the notes, focus your attention on those. The book does not cover many of the things we covered in class, so don't get hung up trying to navigate through all of the text. I've tried to focus you in on the pertinent sections in the book above.

Good luck!