ENGS-43 Spring 2007
ENVIRONMENTAL TRANSPORT & FATE

HOMEWORK #5

Assigned: Friday 22 February 2008
Due: 11:15 a.m., Wednesday 27 February 2008

1. (10 points) Consider a lake with 10^5 m^2 of surface area, an average depth of 3.5 m, a temperature of 18^oC and for which the only source of BOD is the effluent from a wastewater treatment plant. The effluent flow rate is 40,000 m^3/day, its BOD concentration is 20.0 mg/L and its dissolved oxygen is nil. The lake is also fed by a fully oxygenated stream discharging 150,000 m^3/day, while evaporation removes water at a rate that corresponds to a removal of 5 cm of water per day across the entire surface. The reaeration coefficient is estimated to be 0.30 per day at 20^oC, while the decay constant of the treated sewage is 0.20 per day at 20^oC. What are the BOD and dissolved oxygen concentrations in the stream that drains the lake? (Assume steady state.)

2. (10 points) In mid autumn, just before the onset of seasonal convection under surface cooling, a 15-m deep lake is stably stratified with temperature decreasing linearly with depth from 18^oC at the surface to 6^oC at the bottom. At that time, the dissolved-oxygen concentration at the bottom is 7.50 mg/L and is gradually consumed at the rate of 0.01 per day. If winter cooling persists at 24 W/m^2, how low will the dissolved-oxygen concentration fall before the renewal of bottom waters by convection?

3. (10 points) Lake Mascoma in New Hampshire is typical in the sense that in its middle part, which is most subject to the atmosphere, a wind generates a surface current with speed equal to 2% of the wind speed. Now, consider this scenario.

On a nice summer day, the water of Lake Mascoma exhibits a two-layer structure with a 1.5-m thick warmer layer at 15^oC lying on top of a colder layer at 12^oC. This second layer extends all the way to the bottom, which is uneven but is at least 12 m deep in the area of interest. A gusty evening wind of 28 miles/hour generates a current that fills the top layer but leaves the lower layer unmoving. This current does not persist, of course, because mixing occurs between the two layers.

a. (5 points) Which depth interval is engulfed in the mixing and what are the resulting surface temperature and velocity in the mixed zone?
b. (5 points) If sediments at the bottom of Lake Mascoma are known to be contaminated, is there any chance that a stronger but still realistic wind would mix the waters all the way from the surface down to the bottom at 12 meters and bring contamination up to the surface?

4. (10 points) The following atmospheric data have been collected:

Altitude (m):	0	100	200	300	400	500	600
Temperature (^oC):	20	18	16	15	16	17	18

What is the mixing height in that situation? How high would you expect ventilation exhaust from a building to rise if it is released at 21^oC from a 100-m high roof? (Assume that the exhaust rises at the dry adiabatic lapse rate and furthermore without any mixing along the way.)

Then, reconsider the rise of warm air and now assume (with greater realism) that during its ascent it dilutes with surrounding air such that its temperature excess (= temperature of ascending air to ambient air at same level) is reduced by 10% every 20 meters. How high will the exhaust now reach?