CEE 577 14 May 2009

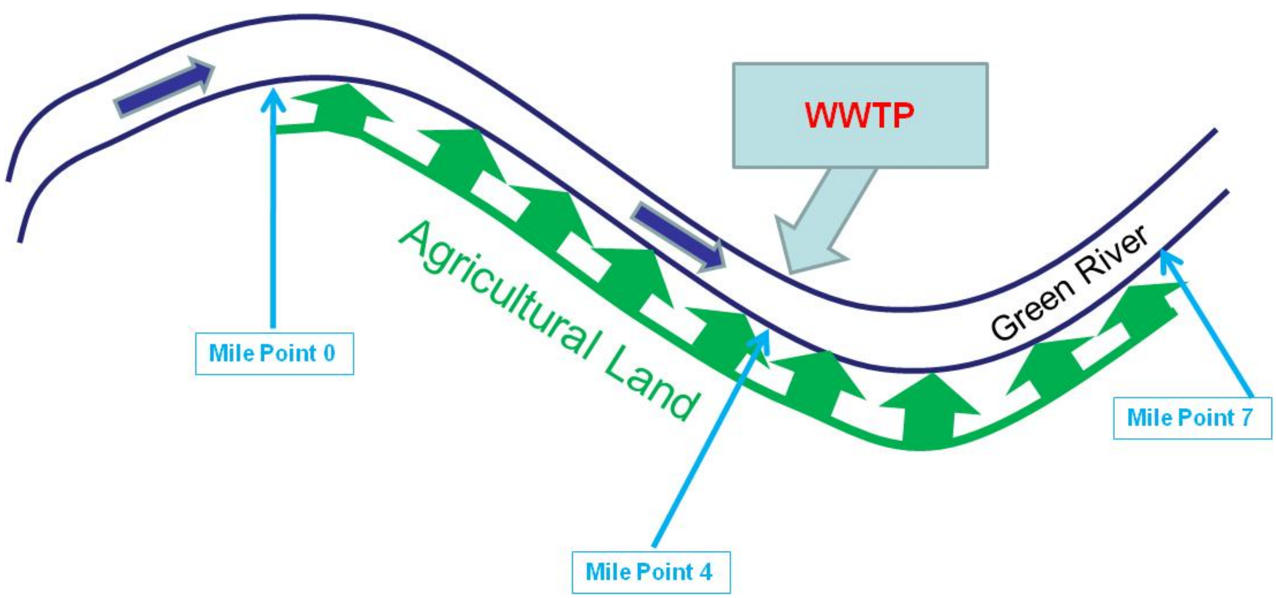
FINAL EXAM

Closed book, 2 sheets of notes allowed.
Answer 2 of the following 3 questions. Please state any additional assumptions you made, and show all work.

1. (50%) The Snake River emerges from pristine headwaters and runs through an agricultural region. Four miles into this agricultural region is a municipal wastewater discharge (from the city of Lackawana). The BOD of the headwaters is 3 mg/L, and the dissolved oxygen is 8.2 mg/L (saturation is 9.1 mg/L for 20^{o}C). Starting at mile point zero, there is a significant non-point agricultural runoff of BOD amounting to 35 kg/mile/day. At mile point 4 is the Lackawana WWTP outfall. Here a fully nitrified WW flow of 5 cfs is discharged with a CBOD of 30 mg/L and a DO of 6 mg/L. Immediately past this outfall is 3 more miles of agricultural land.

- **A) Calculate the dissolved oxygen concentration immediately above the WWTP outfall (i.e. at MP 3.999999)**
- **B) Calculate the dissolved oxygen concentration immediately below the WWTP outfall (i.e. at MP 4.000001)**
- **C) Calculate the dissolved oxygen concentration at the end of the agricultural land (i.e. at MP 7**

Assume complete mixing across the stream in cross section. Assume also a temperature of 20^{o}C, a flow of 40 cfs from the headwaters and no incremental flow downstream except for flow from the WWTP. You may also assume an SOD downstream of the WWTP outfall of 1.5 g/m^2/d.



Additional Information:

$U = 0.200$ ft/sec = 3.27 miles/day — $T = 20^oC$

DO_{sat} or C_S = 9.1 mg/L (at 20^oC) — $H = 6$ ft = 1.83 m

BOD deoxygenation rate ($k_N = k_d$) = 0.8 day^{-1} (at 20^oC) — for k_N and k_d, θ=1.047

CBOD settling rate (k_s) = 0.080 day^{-1} (at 20^oC) — for reareation, θ=1.024

2. (50%) The Mill river parallels an interstate highway. Methyl t-Butyl Ether (MtBE), a consituent of gasoline, enters the river though runoff from the pavement (see table of MtBE properties from previous problem). This runoff enters the river at two points via storm overflows. These are located 33.2 Km and 15.8 Km upstream of the river's eventual dicharge into the Monongahoopla river. Assume that these two are the only significant sources of MtBE and that they can be represented by a characteristic incremental drainage area (750 ha for the most upstream discharge, and 1550 ha for the other). You may also assume an MtBE export coefficient for these drainage areas of 10 g/ha/yr.

   A. **What is the expected concentration of MtBE at the end of the Mill River (i.e., confluence with the Monongahoopla) under average flow conditions?**
   B. **What percentage of MtBE loss is due to volatilization?**

Assume that particulate forms of this compound biodegrade at 0.02 d^{-1} as opposed to 0.001 d^{-1} for the dissolved form. (universal gas constant, $R=8.206\times10^{-5}$ atm m^3/°K mole).

Characteristics of Mill River

Characteristic	Value
Mean Width	20 m
Average Flow	50,000 m^3/day
Mean Depth	1 m
Mean Wind Speed	2.5 m/sec
Solids Settling Rate	0.2 m/d
Solids Burial Rate	0.000027 m/d
Sediment:Water Diffusive Exchange Rate	0.01 m/d
Water Column Suspended Solids	2.2 mg/L
Mixed Sediments Suspended Solids	12,000 mg/L
Thickness of Mixed Sediments	0.2 meters
Fraction of Organic Carbon in Solids	0.2
Density of Suspended Solids	1.55 g/mL

Selected Physical and Chemical Properties of MtBE

Property	**Value**	**Special Conditions**	**Reference**
Molecular Weight	88.15		
Melting Point	-109°C		Weast, 2000
Boiling Point	55.2°C		Weast, 2000
Density	0.7405 g/mL	20°C	Weast, 2000
Aqueous Solubility	4-5%	20°C	Gilbert & Calabrese, 1992
Log K_{ow}	1.05		Gilbert & Calabrese, 1992
Vapor Pressure	$2.45 \times 10^{+2}$ mm Hg	20°C	Merck, 2000
Henry's Law Constant	5.87×10^{-4} atm-m^3/mol		HSDB, 1994
Log K_{oc}	2.7		Davidson et al., 1980
Diffusivity in Water	4×10^{-6} cm^2/s		Estimated
Biodegradation Rate	0.001 d^{-1}	Dissolved	Estimated
Photolysis Rate	0.0041 d^{-1}		Estimated
Hydrolysis Rate	0.0071 d^{-1}	25°C, neutral only	Estimated

3. (50%) On a separate sheet of paper, answer any five (5) of the following questions.

   A. Describe and contrast one mechanistic and one empirical approach to modeling THM precursors in surface waters.
   B. Explain what the light and dark bottle method measures and how it works
   C. Describe the factors that determine gas transfer of toxics in rivers, and contrast this with the factors that determine gas transfer in lakes. In your description, relate micro-scale processes (molecules) to macro-scale (bulk water or air)
   D. Describe how you might model the impact of a seasonal load (e.g., canning operation) on two lakes in series when the direct loading is occurring to each lake.
   E. Describe the various steps involved in photolysis of toxics in surface waters. Include some discussion on how these steps are modeled.
   F. Discuss the ultimate fate of PCBs in the Great Lakes. Where do they end up, and why?
   G. Describe why sorption of many trace organic compounds has been found to be poorly described by conventional sorption models (simple hydrophobic partitioning) in surface waters.
   H. Why does the Streeter-Phelps equation sometimes predict negative concentrations of dissolved oxygen, despite the fact that this is physically impossible? How can one correct this problem?