ENV 4001: ENVIRONMENTAL SYSTEMS ENGINEERING

Fall 2021 | University of South Florida
Problem set #5 | Civil & Environmental Engineering
Complete by Wednesday, October 13 | Prof. J.A. Cunningham

This problem set will not be collected or graded. Your reward for completing this problem set is that it is essential for learning the course material and passing the tests and final exam.

1. Look up two of the Sustainable Development Goals that seem like they would be particularly relevant for ENV 4001. Write down the number and the title (e.g., Goal 4, “Quality Education”) of these two SDGs. Then, look up the brief description of these two goals and write those down too (e.g., “Ensure inclusive and quality education for all and promote lifelong learning”). Finally, for one of the goals, look up the <u>*targets*</u> and write down two of the targets.

2. Answer any five of these seven problems from your text book: 7.28, 7.32, 7.33, 7.36, 7.38, 7.40, and 7.42.

Questions 3-9 all refer to the town of Nastyville and its wastewater discharge.
The town of Nastyville dumps its municipal wastewater (sewage) into the Ohio River. The wastewater has undergone primary treatment but not secondary treatment; we’ll learn later in the semester what that means. Just upstream of where the wastewater is dumped in, the river has the following properties during the summer:

volumetric flow rate, Q_{up} = 56.6 m^3/sec
average flow velocity, u = 0.122 m/sec
river depth, h = 1.83 m
river width, w = 254 m
concentration of dissolved oxygen = 9.17 mg/L
BOD_5 (at 20 °C) = 5.0 mg/L
BOD decay coefficient, k_L (at 20 °C) = 0.20/day

The wastewater stream has the following properties:

volumetric flow rate, Q_w = 6.6 m^3/sec
concentration of dissolved oxygen = 0.00 mg/L
BOD_5 (at 20 °C) = 165 mg/L
BOD decay coefficient, k_L (at 20 °C) = 0.20/day

Just downstream of where the wastewater mixes into the river, the river has the following properties:

volumetric flow rate, Q_{down} = (56.6 m^3/sec + 6.6 m^3/sec) = 63.2 m^3/sec
average flow velocity, u = 0.128 m/sec [a little faster than it was upstream]
river depth, h = 1.94 m [a little deeper than it was upstream]
river width, w = 254 m
concentration of dissolved oxygen = ??? mg/L
oxygen deficit = ??? mg/L
BOD_5 (at 20 °C) = ??? mg/L
BOD decay coefficient, k_L (at 20 °C) = 0.20/day
bed activity coefficient, $\eta = 3.7 \times 10^{-6}$

Given this information, answer the following questions.

3. a. Find L_0 for the river upstream of the mixing point. Describe in words what L_0 is.
   b. Find L_0 for the wastewater stream entering the river.
   c. Find L_0 for the river just downstream of the mixing point. Hint: use a mass balance.
   d. Find BOD_5 for the river just downstream of the mixing point.

4. a. Find the concentration of dissolved oxygen just downstream of the mixing point. Hint: use a mass balance.
   b. Find the oxygen deficit just downstream of the mixing point. Hint: use a table of saturation concentrations to look up the saturation concentration at the proper temperature. I will try to post such a table on Canvas.

5. a. Find the reaeration rate coefficient, k_2, for the river just downstream of the mixing point. Report your answer in units of d^{-1}. Use the following formula, and *watch your units*:

$$k_2 = \sqrt{\frac{\left(2.1\times10^{-9}\,\text{m}^2/\text{sec}\right)u}{h^3}}$$

   b. Find the deoxygenation rate constant, k_1, for the river just downstream of the mixing point. Report your answer in units of d^{-1}. The deoxygenation rate constant k_1 is almost the same as the BOD decay coefficient, which in this problem I have called k_L. If you assumed that $k_1 = k_L$, you would probably be pretty close. However, some people recommend that you account for additional deoxygenation processes in the river, using a "bed activity coefficient." Thus you can use the following formula, but *watch your units*:

$$k_1 = k_L + \eta\frac{u}{h}$$

6. Use the Streeter-Phelps equation (7.16 in your text book) to graph the *oxygen deficit* in the river. Plot oxygen deficit on the ordinate (y-axis) and plot distance downstream on the abscissa (x-axis). Graph it for a river length (distance) of 160 km. You probably want to use Excel or MatLab. (I did mine in Matlab, but you can use whatever tool you like.) You may assume a temperature of 20 °C. If you did problems 3–5 (above), then you know everything you need for equation 7.16.

7. On the same graph, plot the oxygen *concentration* in the river as a function of distance. Thus your graph should have two lines on it, one for oxygen concentration, and the other for oxygen deficit. Hint: think about the relationship between oxygen deficit and oxygen concentration. You probably want to use Excel or MatLab.

8. a. From your graph, identify the distance at which the oxygen deficit is the most severe, i.e., the critical point. What is the value of the oxygen deficit at that distance?
   b. Compare your answers from part (a) to those predicted by equations 7.16 and 7.17. Does your graph agree with the equations in terms of the location and severity of the critical point? (If not, something has gone wrong!)

9. Suppose that healthy fish need at least 5 mg/L of dissolved oxygen to survive. Are there any stretches of the river where we would expect the fish to disappear as a result of Nastyville's wastewater? Based on this, do you think Nastyville should continue their existing practices, or should they consider secondary treatment for their wastewater?