STELLA EXERCISE #5

Part 1.
It is possible to solve problem #2 in homework set #4 using STELLA. In STELLA Exercise #3, you created a model for DO and BOD in a plug flow reactor. To modify this model to represent a CSTR, all you have to do is to add a new flow in and a new flow out to both the BOD and DO stocks. These flows will account for the mass transport in and out of the CSTR reactor, and the stock values for BOD and DO become the reactor concentrations. Since the reactor stocks have the units of concentration, flow in and flow out are calculated as:

\[(C)*(Q/V) \text{ units: mass/volume*time}\]

where C for inputs is the concentration of BOD and DO in the reactor feed, and C for outputs is the DO and BOD concentration in the reactor itself. You will need to add converters for V and Q so STELLA can calculate the input and output for you. [Note, all converters from the diagram in STELLA exercise #3 pertaining to the plant and river are not needed for this problem. You can also eliminate the nonpoint source of BOD. Use the dynamite to erase unnecessary elements from the model.]

Use the answer determined in part a of problem #2 of homework #4 for your input value for BOD_L and remember the input value of D.O. to the CSTR is 4 mg/L. Make sure all the rate constants (k_1 & k_2) are as given in that problem, and that C* is 10.0 mg/L. Assume the initial BOD and D.O. in the CSTR are 5 mg/L and 10 mg/L, respectively.

Run your STELLA simulation with a time step of 0.01 day for a time period of 35 days. [Note: DT for the simulation is different from the report interval that you use in your table. A one day report interval should be used.] A 35 day run length should be long enough for the model to get close to the steady-state solution. If your STELLA model is correct, the steady-state DO in the reactor will be \(\approx 2.00 \text{ mg/L}\).

Note that the STELLA simulation allows you to examine the transient behavior of the CSTR reactor. This is new information since our analytical solution only gave us the steady-state value and did not show us what happened in the reactor prior to this time. Please turn in a printout of your STELLA diagram, equations, graph, and a table of BOD and DO values in the CSTR (at one day intervals). Since your initial BOD concentration was 5 mg/L you should also be able to use STELLA to check your answer to Problem 2b in homework #4. Do the 3 day values agree?

Part 2.
In STELLA exercise #3 you used STELLA to simulate the oxygen sag curve in a stream. A key assumption in this simulation was that the stream behaved as a plug flow reactor with uniform flow velocity.

Real streams often have non-uniform geometry resulting in variable rates of flow. One approach to simulation of this problem is to describe the stream as a series of interconnected reaches, each of which is modeled as a completely mixed reactor (CSTR). An example of this approach is illustrated on pages 274-276 in your recommended text Water Quality by Tchobanoglous and Schroeder (a copy of the relevant text is attached).
This type of model is very easy to create with STELLA. Let’s recreate the problem described in the text. [Please note that in this exercise we are interested in modeling the pollutant concentration, not the D.O. concentration.] We will use STELLA to model the first three stream segments which have volumes of $8.64 \times 10^5$ m$^3$, $25.92 \times 10^5$ m$^3$ and $17.28 \times 10^5$ m$^3$, respectively. The first reactor in the series is fed a flow of 5 m$^3$/sec containing a pollutant concentration of 30 g/m$^3$. The pollutant obeys first order decay kinetics with $k_1 = 0.2$/day.

Let each reactor's concentration of pollutant be a stock in your STELLA model. Each stock will have a flow in and flow out of pollutant as the water enters and leaves. Each stock must have an additional flow out to account for decay. Remember the pollutant concentration entering a downstream stock must be that of the stream segment (stock) which precedes it. [However, the mass/volume*time out of one segment will not equal the mass/volume*time into the next segment if their volumes are different.]

a) Construct your STELLA model to represent these interdependencies and run your simulation for a period of 30 days (don't forget to change the units of the water flow rate). Use a time step of 0.01 day. Assume the initial concentration of pollutant in each reach of the stream is zero. Have STELLA make a graph of the reservoir concentrations (use a vertical scale for the graph equal to the maximum feed concentration). As time proceeds, each reservoir should approach a steady-state value. Check your 30 day values against the steady-state concentrations determined by Tchobanoglous and Schroeder. They should be close; if they are not, your STELLA model is probably in error. Make a print out of your STELLA diagram, equations and graph to turn in. Also have STELLA prepare a table showing concentration in each segment (at one day intervals, and show concentrations to at least two decimal places). Please turn the table in also.

b) Rerun your STELLA model for the same conditions except set the initial concentration in segment 2 at 30 g/m$^3$. Print out the graph and table for this simulation. How does the initial concentration in segment 2 affect the steady-state concentration in this and the downstream segment?

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### Summary of STELLA output you should turn in.

<table>
<thead>
<tr>
<th>CASE</th>
<th>Diagram</th>
<th>Equations</th>
<th>Graph</th>
<th>Table</th>
<th>Answers to questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1 CSTR</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓ Comment on steady state D.O., and compare BOD to problem 2b in Problem set #4.</td>
</tr>
<tr>
<td>Part 2. (a) segment #1 inflow = 30 g/m$^3$</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓ (compare with Tchobanoglous and Schroeder)</td>
</tr>
<tr>
<td>Part 2. (b) same as above but with initial conc.= 30 g/m$^3$ in segment #2</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓ (compare with Tchobanoglous and Schroeder)</td>
</tr>
</tbody>
</table>