CE4505 SURFACE WATER QUALITY
PROJECT 2E. TORCH LAKE RECOVERY MODEL
Final installment: Due Tuesday, November 8

Only parts A and B are due on 11/8; part C may be handed in as part of the final report.

A. You have already built your model into a spreadsheet. To run the model for a 100-year period requires a few thousand rows of spreadsheet. If one were running a program with hourly time steps, it would become impractical to have a row for each time step. To obviate the need for huge spreadsheets, we write the program into computer code; each calculated number now occupies “space” only in the computer’s memory. You are to use the sample macro sent to you via e-mail together with the instructions below to write a macro for your model of Torch Lake. Verify that the macro is working by comparing the output with that calculated in your spreadsheet version of the model. You are to send to me the excel file with your embedded macro once it is working properly. You may use either the spreadsheet or the macro version for part B below.

B. You have modeled the lake as a completely mixed body of water. Now you are to introduce stratification. The easiest way to accomplish this is to break the lake into two (vertical) compartments for the entire time sequence. This requires that you create separate mass balance equations for the epilimnion and hypolimnion. Because dispersion across the thermocline is a feedback process, the mass balance for copper in the epilimnion will be a function of copper concentration in the hypolimnion and vice versa. Rather than worrying about changing the depth or thickness of the thermocline over time, you will simply vary the value of the dispersion coefficient across the thermocline in each season. For the period January – March you should set the dispersion coefficient to a value of 0.1 cm²/sec; for April-May and October-December you should use a value of $10^4$ cm²/sec to simulate well-mixed conditions. For June-September, you should use the value of the dispersion coefficient that you determined in part 3 of the project. You may use either a spreadsheet or Macro-based model to run this simulation.

Model the lake for the period of historical record (1968-2005). Compare your results graphically with those obtained using the 1-box model. Do you think that it is important to include stratification in the model?

C. The whole purpose of creating the model was to evaluate whether or not Torch Lake will recover on its own. Your initial conclusion should be that the lake will not reach the state’s water quality criterion for copper. With the model, however, you have the power to examine different management options. Would cleaning up the sources of contamination to the Traprock River clean the lake? Would capping all or some fraction of the littoral (zone 1) sediments lead to successful recovery? Would fertilizing the lake with sewage and enhancing primary production lead to increased copper burial in the sediments? You are to use the model to examine 2 scenarios for remediation of the lake. Report on these scenarios (provide all details of your modeling) in your final report.
Macro Instructions

Microsoft Excel uses a condensed version of Visual Basic as the language for writing Macros. A Macro is a short program that automates calculations within a spreadsheet. We will only scratch the surface of what is possible with Macros.

I have attached a spreadsheet (PondMacro.xls) that illustrates everything that is discussed below. I have used a model of phosphorus in a stormwater detention pond (Project 1) for the demonstration. The macro inside the spreadsheet is called pond. You may want to go back and forth between the spreadsheet and the Visual Basic Code as you read the instructions below to better understand what is being described. In order to see the Visual Basic code for the macro, you simply go the toolbar, select Tools-Macro-pond and then press the EDIT button.

You should have the Excel file containing your model for Project 2 (i.e., the spreadsheet model that you made last week for all processes in Torch Lake) open on the computer. To create a macro in Excel, go to the toolbar and select Tools-Macro and press Return; you will then be asked to enter a name for the macro. After entering a name, a basic page will open with two programming lines

Sub macroname
End Sub

that indicate the beginning and ending of a subroutine. You will fill in the programming lines in between these two lines. After you understand how the pond macro operates, I would suggest that you copy the lines of text from the macro pond into the macro that you create in your own spreadsheet.

The macro is going to do all of the calculations that you have done previously in the spreadsheet. It will do the calculations at each successive time step just as is done in each row of your spreadsheet. Then, you will have the macro print a subset of the results into the spreadsheet so that you can see and graph them. Thus, there are two nested loops within the macro; one loop is going from i = 0 to the maximum number of intervals that you will have (i.e., the duration of the modeling period in years times the number of output data points that you want per year), and the loop inside this is counting down the "extra" timesteps that you do not want in your spreadsheet and printing into the spreadsheet just the values that you do want there. For instance, if the modeling period was six years and the timestep was 1 day, there would be a total of 2190 timesteps. If you wanted to print out only a single value at the end of each month, you would have 72 intervals, and your macro would look something like this:

for i = 1 to 72
    for j = 1 to 30
        perform a single calculation
    next j
    Print value(j=30) to spreadsheet
This nesting of loops allows you to select just a small fraction of the calculated results to put into the spreadsheet and graph. (Note that the example above assumed that all months have 30 days.)

The first section of your program will be the dimensioning of variables. You will define a variable for each column in the spreadsheet (i.e., each process contributing to the change in mass in your modeled system); each of these variables can be an array. It is best to dimension the array to be much larger than you are ever likely to make it in practice. In the sample program that I sent, I arbitrarily chose to allow the array to have up to 10,000 members.

The next step is the defining of variables; every variable that you used as input in the spreadsheet must be defined and given a value in the program. This is easily accomplished by putting the values in the spreadsheet as you did before, and then simply telling the macro where in the spreadsheet they are located. It is helpful to name your variables in a way that will identify what they represent.

Now you are ready to define secondary variables, variables that are calculated from the primary input variables that you provide in the spreadsheet. Variables such as lake volume (area times mean depth) can be calculated here as can a number of "dummy variables" that are used further in the program. For instance, it will be necessary to calculate items such as the number of time steps, the number of intervals, the number of time steps per interval.

The next step is to initialize some of the variables. This simply means that you tell the program what are the initial conditions (e.g., starting date and initial concentration). Some of these variables will be defined in cells in the spreadsheet. Some counting variables also have to be given an initial value.

When that has been done, you are ready to construct the two nested loops. Each loop is initiated with a programming statement

For countingvariable = 1 to upperlimit

The letters i,j,k,l,m as well as x,y,z are commonly used as counters. All of the calculations are performed within the second (or inner) of the two loops. The only thing that must be done in the first loop is to print the calculated values into the spreadsheet.

When you use arrays, the hardest part of the program is choosing the right counter variable (i,j,k,l) with which to index your array. Often it is not necessary to use arrays; if, outside of the inner loop, you only use the last values of the variables that are calculated within the inner loop then you do not need to save the previous values in an array. In that case, it is adequate to use a simple variable that does not need to be dimensioned.

In the sample macro that I provided, there is the additional complication of reading in the monthly values of precipitation and evaporation. I chose to read these into an array, but other options would have worked as well. In printing out the results, you can choose which variables you wish to print out. Often it is helpful to print out intermediate results to help you to debug your program.