
AC 2012-4511: WORK-IN-PROGRESS: AUTHENTIC DATA IN THE SCIENCE CLASSROOM USING GOOGLE MAPS (GRADES 9-16) - A MODEL AND EVALUATION

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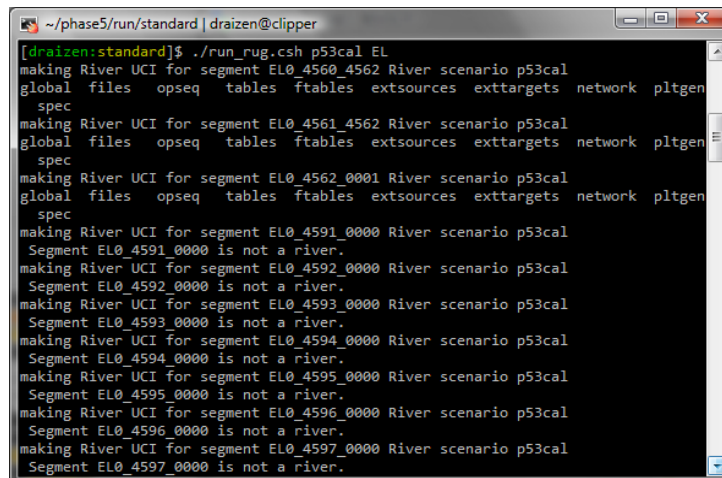
Dr. Madhumi Mitra Ph.D

Work in Progress: Authentic Data in the Science Classroom Using Google Maps (grades 9-16) - A Model and Evaluation

1. Introduction

The Chesapeake Bay is the largest estuary in North America, stretching nearly 300 km long and possessing a watershed spanning parts of six Mid-Atlantic States and more than 165,700 km³. It is a vital resource to more than 16 million people that live in its watershed and beyond, providing food, jobs, habitat, recreation, and other benefits. It is, however, a fragile resource made especially vulnerable to eutrophication (nutrient-enrichment) due to its long dendritic shoreline and the many human activities that are prevalent. These include high concentrations of agricultural activities as well as several major population centers^{3, 10}. Additionally, the Chesapeake Bay has a large ratio of watershed area to estuarine area, (14.3:1) which contributes to the eutrophication problem⁶.

Studying large and complicated structures such as environmental systems directly can be a daunting task however computer modeling can alleviate some of the problems associated with it. The Chesapeake Bay watershed is an extremely complex system, and many models and computer simulations of the Chesapeake Bay have been created to help study its various facets. Phase 5 Chesapeake Bay Community Watershed Model (subsequently called the Phase 5 Model,) (figure 1.) is one such resource for testing predictions about the response of the Chesapeake Bay to a variety of inputs. The Phase 5 Model consists of three submodels – a hydrologic submodel, a non-point source submodel, and a river submodel. These three systems work together to provide a picture of the water flow, soil erosion, and pollutant loading that the bay experiences when a wide range of meteorological, geophysical, agricultural and industrial variables are manipulated¹⁰. The software package mentioned above is the creation of the Chesapeake Bay Community Modeling Program, an organization dedicated to developing and advancing open-source environmental models of the Chesapeake Bay².



```
~/phase5/run/standard | draizen@clipper
[draizen:standard]$ ./run_rug.csh p53cal EL
making River UCI for segment EL0_4560_4562 River scenario p53cal
global files opseq tables ftables extsources exttargets network pltgen
spec
making River UCI for segment EL0_4561_4562 River scenario p53cal
global files opseq tables ftables extsources exttargets network pltgen
spec
making River UCI for segment EL0_4562_0001 River scenario p53cal
global files opseq tables ftables extsources exttargets network pltgen
spec
making River UCI for segment EL0_4591_0000 River scenario p53cal
Segment EL0_4591_0000 is not a river.
making River UCI for segment EL0_4592_0000 River scenario p53cal
Segment EL0_4592_0000 is not a river.
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Segment EL0_4593_0000 is not a river.
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Segment EL0_4594_0000 is not a river.
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Segment EL0_4595_0000 is not a river.
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Segment EL0_4596_0000 is not a river.
making River UCI for segment EL0_4597_0000 River scenario p53cal
Segment EL0_4597_0000 is not a river.
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figure 1. The Chesapeake Bay Phase 5 Community Model, running in a Linux command line environment

The Phase 5 Model is a large and complex piece of scientific simulation software, requiring considerable training or experience to properly install and utilize. In this paper, the authors describe the creation and testing of a web based interface to the Phase 5 Model (figure 2.). This interface was designed to enable easy access to output from the model by anyone possessing an internet connection and web browser, alleviating the need for complex software installation and configuration. The National Science Education Standards include a wide range of important goals and indicators that can be addressed using this system, including goals related to inquiry, systems, and personal and social perspectives, but this is only one potential use of this project¹. It is anticipated that this model would allow many users to experiment with a very important bio-physical system in a way that would not be possible otherwise.

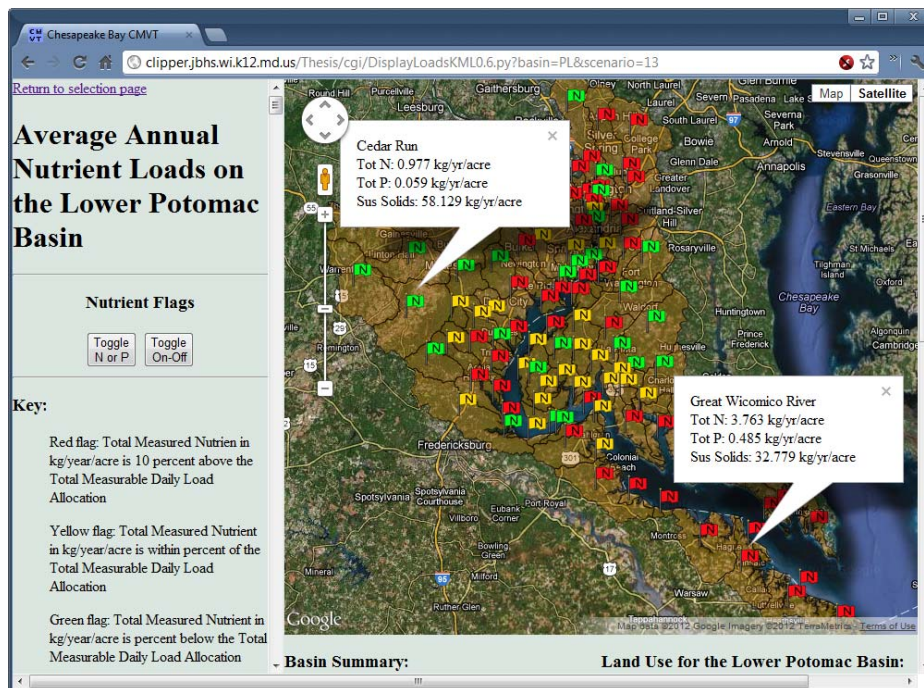


figure 2. The Chesapeake Bay Community Model Visualization Tool, displaying nitrogen data for the Lower Potomac River basin.

2.Methods - Creation of the Web Interface

To accomplish the goals of this project, the authors created a web-based interface to the Phase 5 Model. This software package runs on a Linux operating system, in a command line environment. Users input data into the model in the form of a large number of text files specifying the details of the watershed environment to be used in the run. Taken together these input files are referred to as a scenario. The model is then run by issuing a series of commands and the results are output as text files specifying daily flows, as well as sediment and nutrient loads¹⁰. These attributes make possible the creation of a web based front end to the Phase 5 Model. A graphic interface has been designed to run within a web page and allow the user to specify the geographic region and the particular scenario output to display. Model output files are then used to display a map using the Google Maps Application Programmer Interface (API).

This tool was created using a variety of standard internet technologies. Hypertext markup language (html), Cascading Style Sheets (CSS), and JavaScript were used to produce the first version, a static map of the Chesapeake Bay. Next, to enable the page to produce dynamic output, a custom Python script was created using Common Gateway Interface, (cgi) technology. The Python program responds to selections made by the user and generates the appropriate set of data to be displayed in the form of html output, which is presented to the user.

This version is called the Chesapeake Bay Community Model Visualization Tool (CMVT). To create the CMVT, the data from five different Phase 5 Model scenarios was stored on the web-server in the form of a large table of comma separated values (csv). When a user selects a scenario and river basin, a Python script parses the csv data and generates an associative array of load, geolocation, acreage, and land use data, which the script then passes to the Google Maps server through an intermediary JavaScript file using the Google Maps API causing a custom map to be created for display in the browser⁴. The map includes colored markers for each Chesapeake Bay segment based on compliance with the 2010 TMDL's (figure 3.); a green flag represents nutrients more than 10% below the TMDL for that segment, a yellow flag represents nutrients between 10% below and 10% above the TMDL for it and a red flag represents nutrient loads greater than 10% above the TMDL.

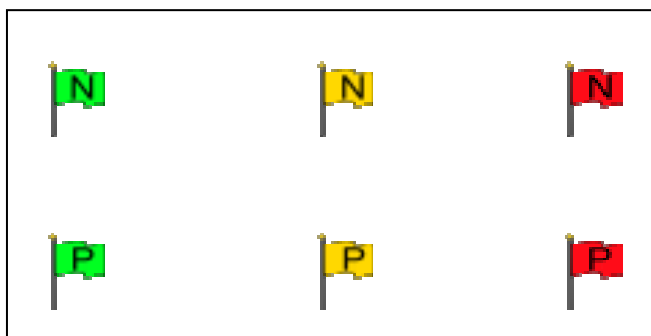


figure 3. The colored flags created for the display of nutrient pollution data in the CMVT

In addition to the interactive custom map, the script displays summary data for the river basin selected. This data includes total nitrogen, phosphorus, and sediment for the basin in units of kilogram per year per acre and land use area in percentage of total land for the basin in three categories: agricultural land uses, urban land uses, and undeveloped forest land uses.

The data displayed by the CMVT was provided by the Chesapeake Community Modeling Program and produced by five different Phase 5 Model scenarios. These are high value, well documented scenarios and were chosen based on their importance in the creation of the United States Environmental Protection Agency's Total Maximum Daily Loads (TMDL) which describe the limits to nitrogen, phosphorus, and suspended sediment pollution that the bay can tolerate in order to meet water quality standards¹¹. The Phase 5 Model was used in developing the TMDL's to help set the upper and lower bounds for pollutants. Several key scenarios were created to model a variety of environmental, technological, and legislative conditions relating to the highest and lowest historic pollutant loads to the bay.

It is data from these scenarios that the authors choose when creating the CMVT, including the 1985 High Historic load scenario, the 2010 No Action scenario, the 2010 Tributary Strategy scenario and the Everyone, Everything, Everywhere (E3) scenario. The 1985 High Historic Load scenario is based on the land uses, nutrient pollutant loading, and other inputs from 1985, extended to the total temporal length of the modeling run and estimates the upper bounds of nutrient pollution the Bay has experienced in recent history. The E3 scenario, on the other hand, represents the fullest possible extent of nutrient management practices, extended over the entire watershed, hence the name Everyone, Everything, Everywhere. It represents the maximum practicable level of controls for all sources of input to the Bay, and was used in conjunction with the 2010 No Action scenario to define controllable loads – i.e. the difference between the two scenarios. The 2010 No Action scenario represents an estimate of all nutrient loads using 2010 land use and population figures along with the minimum possible pollution reduction controls. Finally, the Tributary Strategy scenario is an estimate of nutrient loads based on full implementation of the seven management jurisdictions' 2004-2005 tributary strategies, including stated best management practices, as well as 2010 land use, population, permitted point-source loads, and updated State laws and policies¹⁰.

These scenarios were selected to use as the input configurations for the CMVT for several reasons. First, they are thorough and well-documented scenarios. Created by the Chesapeake Bay Program, they represent extensive study and scholarship and include detailed explanations of the scientific reasoning that was used to set each variable. Second, they represent a wide variety of conditions in the Chesapeake Bay watershed and can be therefore useful in illustrating how the bay responds to these diverse levels of management. Finally, because they were used in the creation of the TMDL's these scenarios are excellent examples of the kind of data scientists use when making decisions that impact the entire watershed population and can help users of the tool to gain a better understanding of how these decisions are made.

3. Methods - Testing the CMVT in Science Classrooms

The stated goals of this project include enhancing secondary and post-secondary education through dissemination efforts. One important possible use of this software could be to enhance environmental science coursework relating to the Chesapeake Bay, as well as topics such as scientific inquiry and responsible stewardship. This software can be used effectively to present several important indicators in both the National Science Education Standards and the Maryland Science Education Core Learning Goals. In addition, efforts such as these can help to meet NASA's goals of Enhancing Environmental Stewardship and Educating the Next Generation and Creating a World-class Workforce, as stated in their 2010 Science Plan document⁸.

To test the effectiveness of this software for this purpose, the authors devised and presented a lesson plan to students in several secondary and post-secondary classes including tenth grade biology, tenth, eleventh, and twelfth grade computer science, eleventh and twelfth grade environmental science, and undergraduate marine botany. Prior to participating in the lesson, each student was asked to respond to a survey containing twenty-two items assessing environmental behavior on a scale of one to five. The students then completed the inquiry-based lesson and took the survey a second time. In this way, the authors measured the influence on the

students of the CMVT and the lesson designed around it. All educational materials such as the survey, lesson plan and student hand-out are included in the Appendices.

The authors created the survey tool to measure a variety of indicators of Environmentally Responsible Behavior (ERB). The questions (table 1) assessed students’ feelings regarding the use of computer models for making decisions, the importance of the Chesapeake bay as a shared resource, the impact various human activities have on the bay, including agriculture and urban activities, the relative importance of nutrient pollution to the overall bay health, and the importance use of scientific data in making sound decisions. The authors create the survey as a form using the Google Docs website. This allowed them to embed the survey in a web page. As students completed the survey, the form automatically populated a spreadsheet, also in Google Docs. The authors then analyzed the survey results to determine the effectiveness of the lesson and tool.

Survey Items

Item #	Item
1	Computer models can help people to make informed decisions about environmental issues.
2	Nutrient pollution is a problem for the Chesapeake Bay
3	Agricultural activities have a great impact on the Chesapeake Bay
4	It is important for people all across the Chesapeake Bay watershed to help protect the Bay
5	I understand how scientific data is used to make decisions about the Chesapeake Bay
6	Restoring the Chesapeake Bay is important to people where I live
7	My activities have an impact on water quality in the Chesapeake Bay
8	Computer models are useful scientific tools
9	I consume food or other products that come from the Chesapeake Bay at least occasionally
10	Urban activities can harm the Chesapeake Bay
11	Many diverse living things can be found in the Chesapeake Bay watershed
12	Scientific data is important for making decisions about our environment
13	Human activities on the Chesapeake Bay can be controlled better so they are less harmful to the Bay
14	Excess nutrients in the Chesapeake Bay can harm its water quality
15	Nitrogen and Phosphorus are important agricultural resources that should be controlled
16	There are many uses for computer models
17	Computer models can provide accurate descriptions of our world
18	The Chesapeake Bay watershed is a very complex system
19	I can use scientific data to understand important environmental issues
20	Nutrient pollution is a problem for the Chesapeake Bay that can be addressed by everyone
21	Nutrient pollution is a problem for the Chesapeake Bay that should be addressed by everyone
22	The Chesapeake Bay is important to people in many parts of the country

table 1. Survey items administered to students both before and after completion of the model lesson involving the CMVT

4.Results

Results of the application of the model lesson using the CMVT with several groups of students in grades 9 through 16 were very positive and encouraging. The overall response mean across all groups of increased by 9.9%, from a mean response of 4.1319 to a mean response of 4.5418 (table 2). This result is highly significant when analyzed using a two-sample T test. When survey items were broken into categories based on content, results were similar, as summarized below.

Survey Response Difference Pre to Post

Variable	Mean	N	SD	SE
Total Post-Survey	4.5418e	1100	0.7826	0.0236
Total Pre-Survey	4.1319e	1584	1.0064	0.0253
Percent Difference	9.9203%			
Models Post-Survey	4.5833a	300	0.7244	0.0418
Models Pre-Survey	4.0810a	432	0.9539	0.0459
Percent Difference	12.3082%			
Eutrophication Post-	4.5029b	350	0.8249	0.0441
Eutrophication Pre-	4.1508b	504	0.9610	0.0428
Percent Difference	8.4827%			
ERB Post-Survey	4.5480c	250	0.7655	0.0484
ERB Pre-Survey	4.1361c	360	1.0613	0.0559
Percent Difference	9.9586%			
Chesapeake Post-	4.5400d	200	0.8135	0.0575
Chesapeake Pre-Survey	4.1701d	288	1.0895	0.0642
Percent Difference	8.8702%			

table 2. Analysis of student responses to the pre and post lesson surveys. Matching letters indicate significant difference, $p < 0.0001$

A total 72 pre-surveys and 50 post-surveys were collected. The surveys were not paired, and no identifying information was collected, therefore the two-sample T test was chosen to analyze them. Both surveys contained 22 identical items, for a total of 1584 pre-survey items and 1100 post-survey items.

The survey items can be arranged into groups based on content for analysis, with items placed into one of four categories: computer modeling content knowledge, eutrophication content knowledge, environmentally responsible behavior knowledge, and Chesapeake Bay knowledge (table 3). The strongest effect was found in the “Computer Models content knowledge” category, with a significant improvement in the mean of 12.3%. The results were similar for the other categories, with significant improvements ranging from 8.48% to 9.96%, (figure 1.).

Survey Question Domain Groups

Grouping	Question Numbers
Models	1, 5, 8, 12, 16, 17
Eutrophication	2, 3, 10, 14, 15, 20, 21
ERB	4, 6, 7, 13, 19
Chesapeake	9, 11, 18, 22

table 3. Survey item groupings

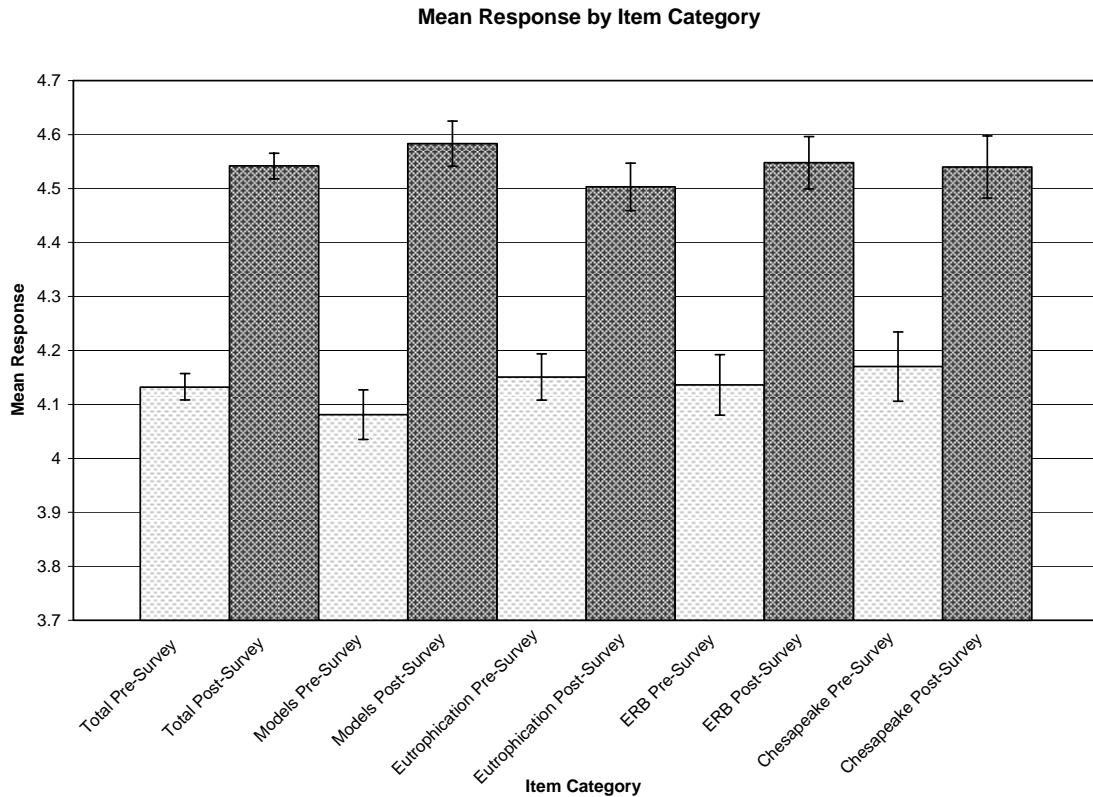


figure 4. Mean responses to survey items by group and in total. Bars indicate standard error

These results indicate the overall effectiveness of the model lesson utilizing the CMVT. Significant gains are observed in all item groups, even though initial survey responses were generally high, leaving less room for improvement.

5. Conclusion

A highly significant and positive response to the survey items is a desired outcome of this study. It can be considered, therefore, a successful test of the CMVT, based on the results above. Michaela Zint, et. al. state in their 2002 paper that, “Changing human behavior is difficult.”¹³. One goal of this project was to influence students toward more Environmentally Responsible Behaviors, and while it is impossible to say that that goal was realized based on the data that were collected, the gains on the ERB survey items do suggest that students who took part in this activity now possess a greater understanding of some specific behaviors that could have a positive influence on the health of the bay.

In addition to influencing ERB, another goal of this project is to foster a greater understanding of computer modeling. Computer simulations and models are important tools to many environmental scientists, as predicted by meteorological pioneer L. F. Richardson in 1922, while describing a method for predicting weather through the use of a theater full of human computers, solving the partial differential equations underpinning the most advanced (at the time) statistical models of the atmosphere, and generating predictions of upcoming weather conditions across the

globe⁹. Modern computers have advanced almost immeasurably from this fanciful imagining and have become central to our understanding of the massive systems we study in environmental science. Computer models play an ever increasing role in the lives of American citizens. The highest post-survey response mean was found in the category of Computer Model Knowledge. This is a good indicator that this project can help students to understand that very important topic. Also, the Computer Models Knowledge category had the lowest pre-survey mean response, indicating that this is a topic that students were not nearly as comfortable with prior to the experience of the lesson.

There are a number of important improvements that could be made regarding this study in the area of experimental design and data collection. First, survey responses could have been analyzed with more validity had they been paired, with each pre-survey matched to a post-survey. The surveys were conducted without pairing in the interest of ease of administration and personal privacy for the minor students involved, however in future studies it would be helpful to match response, possibly by assigning a unique random number to each participant and requiring that they use that number in both surveys. The problem of assigning the numbers and ensuring that they are unique is one that can be worked out at a later date.

The next improvement is in the area of analysis as well. For this study, all the responses were lumped together with no way to separate the different classes from each other. It might be interesting, however to determine if there was a difference in mean response between University students and high school students, for instance, or between Biology students and Computer Science students. This could be accomplished by running just one class at a time through the survey and clearing the data out of online table for each run. Due to time constraints, however, this was not possible for the current study.

Finally, this test of the CMVT could be improved by including two additional control groups. One would take the pre- and post-surveys without experiencing any of the segments of the model lesson, while the other would take both surveys and participate only in the web-quest portion of lesson. In this way it could be determined if the use of the CMVT itself was the factor that caused the improvement in the response means, or if the front loading of content knowledge through the use of the web quest sections was the more important factor in improving responses. This strategy would require a substantially larger number of students, however, which were not available to the researchers at the time of the current study.

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Appendix A

Lesson Plan

Introduction

This lesson is designed to give your students experience with computer modeling of the environment, as well as teach them about the challenges of nutrient pollution on the Chesapeake Bay. Note the table of contents in the sidebar at the left - it is always visible and will enable you to easily navigate this site. This page, however, is not included, so if you want to get back to it, you may need to use you back button or create a bookmark for it. The project includes two web quest sections where students will strengthen their background knowledge of the Chesapeake Bay in general, nutrient pollution, computer modeling, and how these things can be tied together. It also includes a research section, where students will be required to formulate a valid scientific question about nutrient pollution in the Chesapeake Bay watershed, use the provided computer model to collect data about their question and formulate a conclusion. The project culminates with a lab report in the style of a journal article. It is recommended that you read through the content of this site before using it with your students. If you have any questions, comments or problems please feel free to contact me at draizen@wcboe.org

Thanks!

Materials/ Methods

Computers with Internet access - one for each team of students (I recommend 1 - 3 students per team) This site is best viewed using Firefox 3 or greater, however most modern browsers should work fine.

Printer (only needed if final reports are to be printed not emailed)

Procedure

Begin by introducing the concept of computer modeling of environmental systems, ask about weather prediction, etc. Then direct students to the [Welcome](https://sites.google.com/site/chesapeakebaycmvt/) page (<https://sites.google.com/site/chesapeakebaycmvt/>) of this site and allow them to complete the two web-quest sections. This should take most of one 45 min period. Next, the students should move on to the Phase 5 Model page. The students should proceed through the informational pages of the site, paying special attention to the Scenarios page, as this describes the various models that can be investigated in this project. The main research section of this project involves formulating a question about the Chesapeake Bay watershed that can be studied using this site. Some sample questions include:

- Which scenario reduces Nitrogen (or Phosphorus or Sediment) the most in the Patuxent (or any other interesting) basin?
- What is the difference between the Tributary Strategy scenario and the E3 scenario in terms of sediment (or other nutrient) in the (whatever) basin?
- Which basin has the lowest (or highest) impact on the bay in the (whichever) scenario?
- Compare nitrogen (or other) levels for all five scenarios in (whichever) basin.

Feel free to share any of these with your students if they are having trouble coming up with good questions on their own.

To create the lab report, the students should describe their question in the Introduction section, describe how they will investigate it in the Methods section, present their data (using charts or graphs if appropriate) in the Results section and report on their conclusion in the Conclusion section. This file can be created using whatever word processor software is available. There are several free web based options available, a quick internet search will reveal them. Below in the attachments section, you will find a link to a worksheet that can be used with this lesson to explain the steps to your students.

Appendix B

Student Hand-out

Chesapeake Bay Research Project

In this project you will complete an inquiry investigation of nutrient pollution in the Chesapeake Bay. To receive full credit, please complete each of the following steps in order. All of the information you need can be found at <http://sites.google.com/site/chesapeakebaycmvt>

1. Bay health web-quest (5 points) – answer each question using the links provided
2. Computer Models web-quest (5 points) – answer each question using the links provided
3. Phase 5 Model and Scenarios (5 points) – read the Phase 5 Model and Scenarios pages to get a full understanding of the model, then experiment with the model to try to understand what sorts of questions it can be used to investigate. I will assign points for this section based on how well you apply the model to your question.
4. Lab Report (20 points) – conduct an investigation of nutrient pollution in the Chesapeake Bay using the CMVT and write a lab report based on your investigation. Follow the format below:

Chesapeake Bay Investigation Lab Report

Introduction (5 points) – Explain the question that you are trying to answer with your investigation, and why it is important and useful. Some sample questions include:

“Which river basin has the largest impact on the bay when comparing the 1985 Highest Historical Load Scenario and the 2010 Tributary Strategy Scenario?”

“Which scenario reduces Nitrogen the most in the Patuxent basin?”

“Compare sediment levels for all five scenarios in the Lower Eastern shore basin.”

“How does the amount of undeveloped land effect the amount of sediment, nitrogen and phosphorus, and which basins have the most and least forest?”

“Which basin has the best nitrogen levels under the *Tributary Strategy* scenario? Which has the worst?”

You may use one of these questions, or come up with one of your own.

Methods (5points) – Explain the steps you took to answer your question using the CMVT. Give enough detail so that someone else would be able to conduct the same investigation that you did.

Results (5 points) – Present the results of your investigation – what is the answer to your question? Use graphs and charts if possible to present the information.

Conclusion (5 points) – Summarize your investigation. What did you learn? What might you do differently if you did the experiment again? What questions do the results of you study raise that could be investigated at a later date?

Please type your report and turn it in at the end of this activity.