**An evaluation of an online water quality simulator and its success at integrating curriculum**

The purpose of this paper is to evaluate the RiverWeb Water Quality Simulator (WQS) based on its success in integrating curricula from different disciplines. We will accomplish three tasks over the length of this paper: explain in detail the purpose and shape of the existing RiverWeb WQS program, evaluate RiverWeb WQS based on criteria we have set from our research of other programs that incorporate integrated curriculum, and set goals and recommendations for improvements than can be made.

The RiverWeb WQS, (http://mvhs1.mbhs.edu/ncsa/riverweb), is based on a STELLA model that simulates the effects of non-point source(NPS) pollution on a watershed. The simulated watershed includes monitoring stations at multiple land use areas including urban, suburban, agricultural, industrial/commercial, wetlands, and both pristine and working forests. It also includes a station at the river mouth that is a result of the collective outputs of all of the other 7 stations. Based on actual precipitation and air temperature data from the Baltimore-Washington International Airport in Maryland, water quality indicators and physical characteristics are simulated. Simulated indicators include: nitrogen, phosphorus, dissolved oxygen, biochemical oxygen demand, saturated dissolved oxygen, heavy metals, sediments, pH, and toxins. Physical characteristics modeled include: groundwater, runoff, total flow, and water temperature. The program provides an Internet-based interface for students to interact with the model. Through the interface students can view both line (Figure 1) and scatter plot (Figure 2) graphs of data from various indicators. Students can access a digital notepad which offers questions to answer and stores any additional observations the students have made . Through these questions students are asked to make connections between the data they find at the different land use areas. One additional aspect of the simulator is the ability to choose to improve the land use area in order to decrease pollution through the implementation of best management practices. Currently students are only able to implement the suggested improvement. Links explain what these changes are, and students can see how implementation of these improvements changes the NPS pollution in the area.

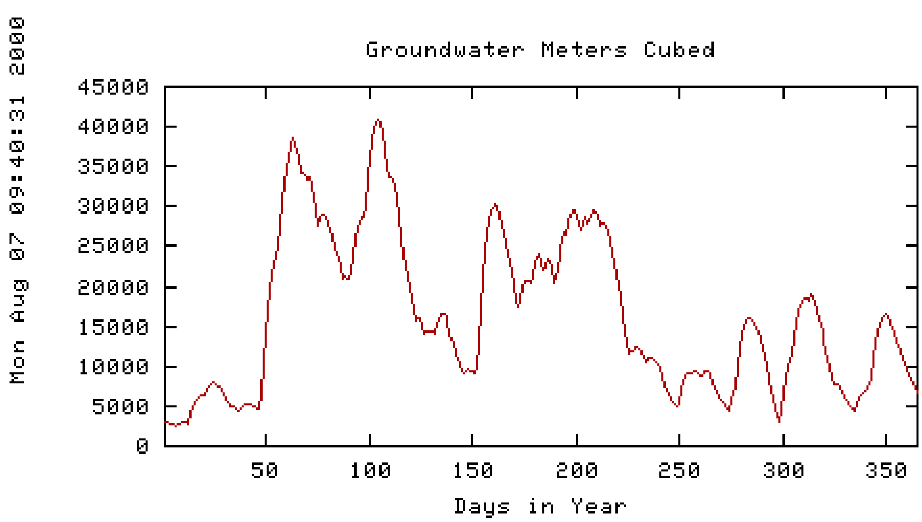



Figure 1: Groundwater levels over time

We designed the accompanying unit to RiverWeb to follow a modification of the jigsaw method. Students first familiarize themselves with the RiverWeb WQS interface and engage in a lesson tracing the path of water through a local watershed and the water cycle. Through this lesson, students are introduced to different land use areas and predict their possible effects on the water quality of their watershed. Students then break up into groups with each group being assigned a different land use area. In these groups they take the on-line tour where they become familiar with the interface and where they explore the pristine forest data and answer questions in the notepad. This is their exposure to the simulator and students will discover relationships between indicators through their exploration of station 0. The in these same groups, students explore the effect that their land use area has on the water quality of the river. Continuing to follow the jigsaw method, students then break into indicator expert groups where they study the effects and sources of an assigned indicator. For example a group of three students who were all exploring station 1 will now join different groups. One student in the station 1 group may join a new nitrogen group, one may join a phosphorus group, and anther may join BOD. These new groups will then explore their indicator in depth with the intent of sharing their discoveries with their original groups. The students then return to the land usage group and discuss pollution issues within their specific land use area, inputting the knowledge they have just acquired from their indicator groups. Finally, the class comes together as a whole and the different land use areas are compared and contrasted, bringing together all of the information learned throughout the project. Best management practices are implemented and the class as a whole discusses the results.

We are now going to evaluate RiverWeb WQS based on its successful integration of multiple disciplines. The integration of different disciplines is defined as the combination of more than one subject into a single curriculum in a meaningful way. Integration as a practice is effective because it provides multiple connections and real world applications for a subject matter, thereby increasing the probability of learning. Environmental education is well suited to such a concept and it easily integrates multiple subjects such as science, social studies, and math. The subject most commonly associated with environmental education is science, specifically biology. This is because environmental education and ecology both concentrate on the study of living things and how they interact with the abiotic environment around them. Social studies becomes an important subject within environmental education because humans live within the environment as well. Changes to the environment are created by humans and affect humans economically, politically, and socially. Mathematics plays an important role in environmental education through the analysis and interpretation of data.

In order to determine how effectively the RiverWeb WQS integrates the disciplines of mathematics, science and social studies we have adopted Ackerman's criteria for an effective integrated unit. Ackerman has developed two major categories of criteria for evaluation: intellectual criteria and practical criteria. The practical criteria measure whether or not the unit will be successful in a particular school. The practicality of the unit is based upon the political, economic, and physical necessities for the unit versus the political, economic, and physical resources of the school. The RiverWeb WQS was not developed with a particular school in mind, but has instead been developed with the hope that schools throughout Maryland would utilize it. It is therefore the responsibility of the individual teachers and administrators to determine the usefulness of the simulator for their classrooms and we will not be evaluating it with regards to the practical criteria.

Ackerman's intellectual criteria are used to determine the educational value of the unit. These criteria are as follows: validity within the disciplines, validity for the disciplines, validity beyond the disciplines, and contribution to broader outcomes. A unit that has **validity within the disciplines** covers topics that are significant to the existing school curriculum. Important topics in each discipline must be adequately represented within the unit in order to justify the use of the unit in that discipline. The teacher must feel that the unit is pertinent to his/her course of study. **Validity for a discipline** deals with whether or not the subjects being integrated are worth integrating. Given an integrated unit in social studies and math, the learning in both the math and the social studies courses must be enhanced by the linkages made to the other course in such a manner that they could not have been taught as effectively in isolation. For instance the topic taught in social studies may be the various waves of immigration throughout the history of the United States. The topic taught in math may be rates of change including immigration, emigration, birth and death rates. By teaching the two subjects in tandem, students not only gain a better understanding of the calculation of rates because they are using actual, meaningful data, but they also gain a greater appreciation for the effect that immigration had on the population dynamics of the U.S. through different time periods. a unit that has **validity beyond the disciplines** is one in which the theme for the unit itself is valuable and will alter the way students look at the world. **A unit that makes a contribution to broader outcomes** influences the learner's approach to knowledge. The unit develops desirable "habits of mind" in the students. These habits of mind are defined in <u>Benchmarks for Science Literacy</u> as values, attitudes, and skills that relate directly to a person's way of thinking and acting.

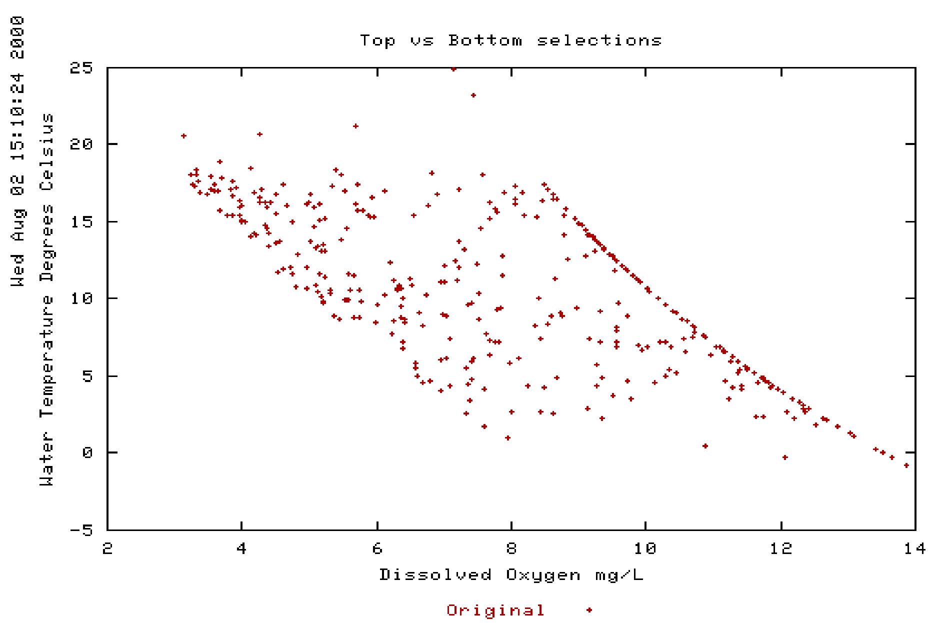
<u>Validity Within the Disciplines</u>

Validity within the disciplines refers to a unit or lesson's usefulness to a particular discipline. Since RiverWeb WQS was designed with Maryland high school classes in mind the validity of the unit was determined using the Maryland State Core Learning Goals (CLGs). Through this analysis RiverWeb WQS was determined to have validity within the science disciplines of Biology and Earth and Space Science as well as fulfilling much of CLG #1: Skills and Processes which is relevant for all sciences(Table 1). RiverWeb WQS does not, however, validity within mathematics or social studies because it does not fulfill any CLGs in those subject areas. In order to understand out analysis using the CLGs, you must first understand the organization of the Maryland State Core Learning Goals. The first division of the CLGs is into Goals. These goals divide the CLGs into broad areas within a discipline such as dividing science into, Skills and Processes, Physics, Earth and Space Science, Biology, and Chemistry. The goals are then divided into expectations. These expectations state what a student should know at the completion of a course within that goal. For example, at the end of a course in biology a student should be able to explain the correlation between structure and function of biologically important macromolecules. The indicators of learning are the ways in which students demonstrate that they have accomplished the expectations. In other words, the indicators of learning suggest a product as proof of learning. Finally, the CLGs are divided into assessment limits. These assessment limits are intended to be a guide to the specific topics that will be covered on the state mandated assessments. We have used them, however, as an aide in narrowing the expectations and the indicators of learning. For instance, the expectation that students can correlate structure of a biologically important molecule with its function can be limited through the assessment limits to their ability to correlate the structure of water with its function and unique properties.

The WQS meets most goals through the type of notepad questions asked. Two examples of the use of the notepad to fulfill CLGs are Science Goal #1, Expectation #4, Indicator of Learning #2 which states that the student will analyze data to make predictions, decisions, or draw conclusions and Science Goal #1, Expectation #2, Indicator #3 which states that the student will form a working hypothesis. Through the notepad program, students are asked to compare the same indicators at two different stations or different indicators at the same station. Based on the line graphs and the scatter plots, students are asked to interpret the data shown on the graphs and hypothesize relationships between indicators and causes for discrepancies between stations, thus fulfilling the above learning goals. One example is the scatter plot produced by comparing water temperature and dissolved oxygen at station 0 (Figure 2). When students access the notepad at this station, the following question appears: "What type of relationship exists between water temperature and dissolved oxygen? Why?" This question requires students to look at the data presented by the line graphs and the scatter plot and draw conclusions about the type of relationship that exists between the two indicators, thus fulfilling the first of the above mentioned CLGs. The second part of the question asks "Why?" This part of the question asks students to form a hypothesis as to what is causing the observed relationship between the two indicators, thus fulfilling the second of the above CLGs.

Maryland State CLG #2, Expectation #5, Indicator #1 expects students to be familiar with the water cycle. The introductory lesson is the major vehicle though which the water cycle is reviewed. This lesson asks students to trace the path of water as it flows from the school through the local watershed including what materials it may pick up along the way. Finally the water is evaporated and enters the cycle again. During this lesson, students are expected to apply their knowledge of the water cycle to the problem of pollution caused by different land usages.

Figure 2



## Validity for the Disciplines

A unit that has validity for the disciplines is one in which the two subjects that are taught in tandem with each other are taught in such a way that they would not be taught as effectively separately. The CLGs that RiverWeb WQS currently fulfills are heavily concentrated in the first science goal: Skills and Processes. The RiverWeb WQS does not have validity outside of the sciences meaning it does not fulfill any CLGs in math or social studies, but because of its fulfillment of many of the CLGs for Skills and Processes it has validity for the disciplines within the sciences. These skills can only be taught effectively through scientific study. The Science CLG Expectation #5 and Indicator #1 within the the second goal, Concepts of Earth and Space Science, requires students to investigate various cycles in the natural world including the water cycle. Science CLG Expectation #1, Indicator #1, in the third goal, Concepts of Biology, asks students to be able to describe the unique characteristics of macromolecules utilized by living systems one of which is water. These two CLGs go hand-in-hand with each other. Knowing the characteristics of a water molecule increases the students understanding of how it behaves during the water cycle and observing how it behaves in the water cycle can strengthen the knowledge of a water molecule's properties. The RiverWeb WQS combines these two goals in the introductory lesson and the notepad questions.

## Validity Beyond the Disciplines

A unit or lesson that has validity beyond the disciplines has a theme that in and of itself is valuable to the students and alters their perception of the world. The RiverWeb WQS's theme is that of water quality. This theme does have validity beyond the disciplines because it relates to the broader theme of ecology. After using RiverWeb WQS, the students should understand that decisions such as land use have consequences for the health of the body of water. Students should also be able to see that with the implementation of best management practices pollution can be mitigated, but not eliminated. The RiverWeb WQS introduces students to the idea that water bodies do not exist in isolation of the human population and that the students have a responsibility to protect them.

## Contribution to Broader Outcomes

A lesson or unit that contributes to broader outcomes not only presents students with new material, but also develops their thinking skills. The RiverWeb WQS contributes to broader outcomes by expanding students' "habits of mind", especially their scientific communication skills. The RiverWeb WQS asks students to analyze data generated by the model, thus developing students' skills in receiving and interpreting communications from another source. Students are then asked to develop clear, understandable answers to questions posed in the notepad. This develops students' skills in producing communications, written or oral, that are useful to others.

| ***Subject*** | ***Goal*** | ***Expectation*** | ***Indicators of Learning*** | ***Assessment Limits*** |
|---|---|---|---|---|
| Science | 1. Skills and | 2. The student will pose | 2. The student will pose | N/A |

| Subject | Goal | Expectation | Indicators of Learning | Assessment Limits |
|---|---|---|---|---|
| | Processes | scientific questions and suggest experimental approaches to provide answers to questions. | meaningful, answerable scientific questions. | |
| Science | 1. Skills and Processes | 2. The student will pose scientific questions and suggest experimental approaches to provide answers to questions. | 3. The student will formulate a working hypothesis. | N/A |
| Science | 1. Skills and Processes | 4. The student will demonstrate that data analysis is a vital aspect of the process of scientific inquiry and communication. | 2. The student will analyze data to make predictions, decisions, or draw conclusions. | N/A |
| Science | 1. Skills and Processes | 4. The student will demonstrate that data analysis is a vital aspect of the process of scientific inquiry and communication. | 6. The student will describe trends revealed by data. | N/A |
| Science | 1. Skills and Processes | 4. The student will demonstrate that data analysis is a vital aspect of the process of scientific inquiry and communication. | 8. The student will use models and computer simulations to extend his/her understanding of scientific concepts. | N/A |
| Science | 1. Skills and Processes | 5. The student will use appropriate methods for communicating in writing and orally the processes and results of scientific investigation. | 9. The student will communicate conclusions derived through a synthesis of ideas. | N/A |
| Science | 1. Skills and Processes | 7. The student will show that connections exist both within the various field of science and other disciplines including mathematics, social studies, language arts, fine arts, and technology. | 1. The student will apply the skills, processes, and concepts of Biology, Chemistry, Physics, and Earth Science to societal issues. | N/A |
| Science | 2. Concepts of Earth and Space Science | 5. The student will know how to connect prior understanding and new experiences to evaluate natural cycles. | 1. The student will investigate various physical cycles found in the natural world. | The Water Cycle |
| Science | 3. Concepts of Biology | 1. The student will be able to explain the correlation between the structure and function of biologically important molecules and their relationship to cell processes. | 1. The student will be able to describe the unique characteristics of chemical compounds and macromolecules utilized by living systems. | Water |

**Table 1: Maryland State Core Learning Goals that RiverWeb WQS currently fulfills.**

Our analysis of the existing RiverWeb WQS shows that it does not currently integrate science, mathematic, and social studies well. In order to make RiverWeb WQS more integrated we suggest a few changes to the model. These include adding biological and economic/political indicators to the simulator itself, adding more best management practices and having a choice of which ones to implement, adding links to the interface, and adding a culminating activity.

We suggest adding biological indicators to the model output. The purpose of these biological indicators would be to allow students to study the effect that pollution has on living organisms. These biological indicators would include the number of fish species present, the number of reptile and amphibian species present, the number of plant species present, and the number of benthic species present. This will make the relationships that they discover more concrete and useful. A student who discovers a body of water with a pH of 4.0 will appreciate the discovery more if he or she has also discovered that a pH of this level will stress the fish and other aquatic life in the body of water. Addition of biological indicators will also expose students to more ways of representing data. Currently all indicators are graphed against a daily time scale. Biological indicators cannot be graphed in this manner because daily data points are not available and are not useful. The most beneficial representation of this data would then be a bar graph and students would have to learn to interpret these as well as the line graphs and scatter plots.

We also suggest that the model have an economic/political indicator. This indicator would take into account the economic benefits of land use types, the economic costs of best management practices, and the recreational benefits of land use types. This would allow students to explore how decisions to use and improve the environment have an effect on humans. Students should understand that implementing best management practices such as forbidding clear cutting will have an effect on the human population that may financially rely on profits from clear cutting. We suggest that students, therefore, have a choice of which best management practice to implement. They would have to take into account political and economic, not just ecological concerns in their decisions. This will give students the chance to make decisions that are most beneficial to both the environment and to humans.

In addition to the current best management practice, students should be able to adjust the area taken up by each type of land usage. We feel that this would make the model more realistic and will provide students with a better understanding of which types of land usages cause the greatest effect on the stream. We suggest adding links to RiverWeb WQS where students can research indicators, land usage types, and best management practices. This will not only allow students to become more familiar with Internet technologies, it will also allow for a deeper understanding of the material if the students must do the research themselves and allow for a greater flexibility of use as determined by the teacher.

We have also made recommendations for making the accompanying RiverWeb WQS unit more integrated. We suggest that a cumulative activity be added to the unit. After students identify the issues at our simulated river and develop a best management practice plan they must inform the authorities of their discoveries. This requires that students research existing laws, possible government agencies to be contacted, and how to go about letting their concerns be known to the proper authorities. Their final product would be a persuasive letter to the EPA or other government agency or an appropriate government official such as a congressman presenting the problems discovered at each station, what the causes are, and what their plans for betterment are. All claims in the letter must be backed up by evidence and data taken from the RiverWeb WQS and the analysis of the data must reflect the scientific concepts learned through the simulator. Table 2 shows those Maryland State Core Learning Goals that an improved RiverWeb WQS would fulfill with the suggested changes in addition to those that it already fulfills (Table 1).

| ***Subject*** | ***Goal*** | ***Expectation*** | ***Indicators of Learning*** | ***Assessment Limits*** |
|---|---|---|---|---|
| Math | 1. Functions and Algebra | 1.1 The student will analyze a variety of patterns and functional relationships using the language of mathematics and appropriate technology. | 1.1.4 The student will describe the graphs of a non-linear function and discuss its appearance in terms of the basic concepts of maxima and minima, roots, limits, rates of change, and continuity . | Given the graph of a non-linear function, the student will identify maxima/minima, roots, rate of change, continuity, or domain and range. |
| Math | 3. Data Analysis and Probability | 3.1 The student will apply the basic concepts of statistics and probability to predict possible outcomes of real world situations. | 3.2.2 The student will interpret data and/or make predictions by finding and using a line of best fit and by using a given curve of best fit. | N/A |
| Science | 1. Skills and Processes | 1. The student will explain why curiosity, honesty, openness, and skepticism are highly regarded in science. | 1. The student will recognize that real problems have more than one solution and decisions to accept one solution over another are made on the basis of many issues. | N/A |
| Science | 1. Skills and Processes | 4. The student will demonstrate that data analysis is a vital aspect of the process of scientific inquiry and communication. | 4. The student will determine the relationships between quantities and develop the mathematical model that describes these relationships. | N/A |
| Science | 1. Skills and Processes | 5. The Student will use appropriate methods for communicating in writing and orally the processes and results of scientific investigations. | 2. The student will explain scientific concepts and processes through drawing, writing, and/or oral communication. | N/A |
| Science | 1. Skills and Processes | 7. The student will show that connections exist both within the various fields of science and other disciplines including mathematics, social studies, language arts, fine arts, and technology. | 4. The student will recognize mathematics as an integral part of the scientific process. | N/A |
| Science | 3. Concepts of Biology | 1. The student will be able to explain the correlation between the the correlation between the structure and function of biologically important molecules and their | 3. The student will describe the flow of matter and energy between living systems and the physical environment. | The water and Nitrogen Cycles |

| Subject | Goal | Expectation | Indicators of Learning | Assessment Limits |
|---|---|---|---|---|
| | | relationship to cell processes. | | |
| Science | 3. Concepts of Biology | 2. The student will demonstrate an understanding that all organisms are composed of cells which can function independently or as part of multicellular organisms. | 2. The student will conclude that cells exist within a narrow range of environmental conditions and changes to that environment, either naturally occurring or induced, may cause death of the cell or organism. | Temperature, pH, oxygen, toxins |
| Science | 3. Concepts of Biology | 5. The student will investigate the interdependence of diverse living organisms and their interactions with the components of the biosphere. | 1. The student will analyze the relationships among organisms and between organisms and abiotic factors. | Abiotic/biotic Factors: Water, temperature |
| Science | 3. Concepts of Biology | 5. The student will investigate the interdependence of diverse living organisms and their interactions with the components of the biosphere. | 3. The student will investigate how natural and man-made changes in environmental conditions will affect individual organisms and the dynamics of populations. | Destruction of habitats, Pollution, Urbanization |
| Social Studies | 1. Political Systems | 1. The student will demonstrate an understanding of the structure and functions of government and politics in the United States. | 3. The student will evaluate roles and policies the government has assumed regarding public issues. | Public Issues |
| Social Studies | 1. Political Systems | 1. The student will demonstrate an understanding of the structure and functions of government and politics in the United States. | 4. The student will explain roles and analyze strategies individuals or groups may use to initiate change in governmental policy and institutions. | Political Parties, interest groups, lobbyists, citizens, and the impact of media on public opinion and the behavior of the electorate. |
| Social Studies | 3. Geography | 1. The students will demonstrate an understanding of the relationship of cultural and physical geographic factors in the development of government policy. | 2. The student will evaluate the role of government in addressing land use and other environmental issues. | International, national, state and/or regional issues. |
| Social Studies | 4.Economics | 1. The student will demonstrate an understanding of economic principles, institutions, and processes required to formulate government policy. | 2. The student will utilize the principles of economic costs and benefits and opportunity cost to analyze the effectiveness of government policy in achieving socio-economic goals. | Competing socio-economic goals. |
| Social Studies | 4.Economics | 1. The student will demonstrate an | 3. The student will examine regulatory agencies and their | EPA |

| Subject | Goal | Expectation | Indicators of Learning | Assessment Limits |
|---|---|---|---|---|
| | | understanding of economic principles, institutions, and processes required to formulate government policy. | social, economic, and political impact on the country, a region, or within a state. | |

**Table 2: Maryland State Core Learning Goals that RiverWeb WQS will potentially fulfill after implementation of our recommendations.**

Our first step in the process of developing an integrated unit was to look at the existing unit and decide how well it currently integrates multiple subject areas. To accomplish this we used the Maryland State Core Learning Goals to establish how well different subjects are represented in the unit (Table 1). Next we had to redesign the existing unit to accommodate more subject areas. To do this we had to determine which subject areas would be most conducive to using an environmental simulator. The simulator had originally been designed for use in a Biology classroom, therefore science was an obvious choice. Math was another logical choice due to the simulator's reliance on graphs for communicating data to the user. Finally we decided on social studies because environmentalism and ecology are currently hot topics in the political and economic worlds. We used the Maryland State Core Learning Goals for these subjects as a guide to determine how well these subjects have the potential of being integrated into the unit. We decided on the persuasive letter as the best mode to add the social studies component. We had discussed before with the modelers about adding in some Biological and economic indicators and we thought that the letter would be a good avenue for discussing connections between these types of indicators. While we found the notepad questions very useful in discussing connections between two indicators we found it limiting when looking at multiple indicators, therefore we thought another writing activity might be more useful. We then re-examined the CLGs that we thought the RiverWeb WQS might cover and determined which ones the new design did cover (Table 2). In designing the activity we were careful to ensure that it followed Ackerman's criteria for an integrated unit.