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Computer-Based Instruction for Engineering Education in the Developing World

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COMPUTER-BASED INSTRUCTION FOR ENGINEERING EDUCATION IN THE DEVELOPING WORLD

by

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ABSTRACT

COMPUTER-BASED INSTRUCTION FOR ENGINEERING EDUCATION IN THE DEVELOPING WORLD

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Master of Science

Although civil engineers continually develop new ways to solve problems involving water, energy, infrastructure and environmental sustainability, these innovations can take years – or even decades – to reach developing countries. Computer-based instruction has the potential to dramatically decrease this lag time by improving engineering education in the developing world.

This paper discusses the development of instructional simulations, based on the theory of model-centered instruction. These simulations can serve as self-paced learning modules, which can be accessed for free over the Internet. A pilot learning module was developed for the United Nations Educational Scientific and Cultural Organization (UNESCO) on the topic of reservoir sedimentation. This pilot learning module is described in terms of widely-accepted instructional design principles.

Preliminary assessment of the pilot module demonstrated that instructional simulations can effectively teach engineering principles within the context of real-world problems. Students found this type of learning to be both challenging and engaging.

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1 Introduction

Civil engineers have always played an important role in improving the human condition through the advancement of natural sciences. These sciences have helped civil engineers develop creative ways to solve problems involving water, energy, infrastructure and environmental sustainability. Unfortunately, billions of people living in less economically developed countries have little or no access to these innovations. Instead of simply deferring this issue to social scientists and economists, engineers must realize their important role in solving this problem. The United Nations Educational, Scientific and Cultural Organization (UNESCO) has declared that engineering education has a primary role in promoting secure and sustainable development and addressing basic human needs (Marjoram 2003).

This paper discusses the use of computer-based instruction to improve engineering education in the developing world. Computer-based instruction is first compared to traditional education efforts, followed by a discussion of modern instructional theory. In order to assess the effectiveness of computer-based instruction, a self-paced learning module was developed. This pilot module is described in detail, followed by preliminary assessment results. Finally, future recommendations are presented.

2 Educational Approaches

Developing countries have, for the most part, understood the importance of investing in engineering education for sustainable development. Unfortunately, progress in this area has been slow due to the high costs of education.

2.1 Traditional Efforts

Because of scarce financial resources, most universities in developing countries have difficulty keeping up with changing technologies. Modern research equipment and laboratory facilities are typically out of reach for these schools. In addition, professors can rarely afford to travel to conferences to interact with the greater academic community (Siller et al. 2001). This disconnect from the academic community makes it difficult for these schools to provide instruction on specialized subjects.

Students who wish to pursue advanced engineering degrees must spend large sums of money to attend graduate school in developed countries. These engineers often return home having studied extremely narrow topics that have no practical application in the context of a developing country. This has caused some to question the value of such study-abroad programs (Uko 1987).

In addition to formal educational institutions, various non-governmental organizations have developed on-site training programs for engineers in developing countries. These programs allow engineers to interact with experts through seminars, technical courses, and workshops. Most importantly, this type of training enables the experts to tailor their instruction to the specific needs of each location. Although these sessions are extremely valuable, they only reach a small audience. There are simply not enough engineering experts in the world to make this form of instruction very time-efficient.

2.2 Computer-Based Instruction

Computer-based instruction has the potential to dramatically extend engineering education around the world. Over the past few years, UNESCO and other organizations have actively distributed computers to engineers in less economically developed countries. UNESCO has also worked to provide these engineers with greater access to the Internet. Not only do these computers provide a means for disseminating scholarly articles and electronic textbooks, they can also be used to deliver quality instruction. Computer-based instruction offers several advantages over traditional education programs.

Reduced delivery cost is the single greatest advantage of computer-based instruction. Internet-based or stand-alone learning modules can be distributed at little or no cost to the user. The two major costs associated with computer-based instruction are the development of instructional media, and the capital costs of the computers. Both of these costs are minimal when considering the cost per user.

Time efficiency is another significant advantage of computer-based instruction. Students can access learning modules at their own convenience instead of waiting for sporadic and infrequent training sessions. As new topics become critical for students, new modules can be added to the program and distributed instantly.

With computer-based instruction, the quality of instruction can also be carefully controlled. A central agency can maintain the consistency of the program to ensure that each learning module builds on previous instruction. Computer-based instruction reaches all students directly, as opposed to on-site efforts where training is often given to a few individuals and then relayed to others.

Computer-based instruction is not meant to replace face-to-face instruction. This type of instruction is meant to augment traditional education programs, particularly in specialized areas of civil engineering.

3 Instructional Theory

In the 1990s, “interactive” became the buzzword for describing computer-based learning tools (Galbraith 1992). Although multimedia elements such as video, graphics, animation, sound, and text have the potential to engage students in learning (Hotchkiss 1994), the mere use of multimedia elements does not ensure interactivity. For example, clicking a button to advance an online tutorial is not any more interactive than turning the page of a book (Hedberg et al. 1997). Truly interactive environments allow students to make critical decisions, receive feedback, continually refine their understanding, and build new knowledge (Bransford et al. 2000). Creating this type of learning environment requires much more than engineering and computer skills; it requires an understanding of modern instructional theory.

3.1 Model-Centered Instruction

The idea of using models as a basis for education is not new to engineering. As engineering professors attempt to explain difficult concepts to their students, they often use a wide variety of models. These models include drawings, lab demonstrations, physical prototypes, spreadsheets, verbal descriptions, computer simulations, etc. Models are valuable for learning because they help students experience realia while in the classroom (Mickleborough and Wareham 1994, Yarbrough and Gilbert 1999). Bridging the gap between abstract theory and real practice helps students develop engineering judgment and confidence (Lawson 2002). The theory of model-centered instruction describes the instructional psychology behind such an approach.

The central idea of model-centered instruction is that effective learning occurs when students interact with dynamic models that enable them to make expert-like decisions within cause-effect systems, or other environments that experience change (Gibbons 2001). Students are presented with a series of realistic problems, and are given the necessary tools and information they need to support them in solving those problems. Learning takes place as the students inquire of the model and receive helpful feedback about their performance with the presented problems (Gibbons et al. 1997).

This type of instruction redefines the concept of learning. Instead of viewing learning as the process of acquiring pieces of decontextualized information, model-centered instruction encourages instructors to consider the activities in which information is developed and deployed (Brown et al. 1989). The way humans learn is largely linked to recalling past experiences and making associations between those experiences and new knowledge (Gee 2003; Bransford et al. 2000). In this way, students learn how to use this knowledge as well as when to use it (Burton et al 1984). This concept of situated cognition is essential to the design of effective models.

As mentioned before, models used for educational purposes can take many different forms. Instructional simulations are one such form that is ideal for computer-based instruction.

3.2 Instructional Simulations

Simulations are already an integral part of the engineering field. Civil engineers use hundreds of simulation tools to emulate natural phenomena such as flooding, sediment transport, earthquakes, turbulent flow, and traffic patterns. Experts often run these simulations to help them make design decisions for engineering projects. Only recently have engineers begun using simulations as strictly instructional tools (Elgamal et al. 2005; Rafiq and Easterbrook 2005; Flora and Cooper 2005; Ribeiro and Mizukami 2005).

Effective instructional simulations contain the following five elements: (1) one or more dynamic models, (2) interactions resulting in state changes, (3) non-linear logic, (4) help structures to augment instruction, and (5) the pursuit of educational goals (Gibbons et al. 2003).

3.2.1 Dynamic Models

An effective instructional simulation contains one or more dynamic models. Students learn as they probe models, hypothesize, reprobe, and rethink until they can recognize patterns (Gee 2003). Gibbons (2001) describes three types of models used in instructional simulations: (1) environments; (2) cause-and-effect systems; and (3) expert behavior.

Environments are models that simulate real or imaginary physical locations. For example, an environment model may simulate a city, country, construction site, or office environment. The most important aspect of these models is the ability for students to obtain information from the model that will help them solve a problem. An example of an environment model – although not typically used for instruction – is the program

Google Earth. This program is an environment model of the earth. Google Earth allows users to adjust latitude, longitude, range, heading, and tilt of the viewing window in order to explore the simulated environment. With the model, users can measure distances, identify land use, and view topography. Such a model could easily be modified for instructional purposes.

The next type of model represents natural and manufactured *cause-and-effect systems*. These include systems such as the human circulatory system, open channel fluid flow, and economic systems. Each of these systems operates according to a unique set of laws. In the case of an economic system, as the supply of money decreases, interest rates rise. Cause-and-effect systems can also be governed by mathematical equations. Finite-element numerical models, for instance, are complex cause-and-effect system models.

Models of *expert behavior* are another way to encourage student learning. Students can learn a great deal from observing how experts make decisions and solve problems. According to Gibbons (2001), "expert behavior is structured in terms of goals, actions, motives, decision points, rationales, system-affordances, system indicators, system controls, and forces opposing action." As students observe these behaviors, they learn how to think and act as experts. A common type of expert behavior model is the "case study". Case studies allow students to see how experts solve real problems from beginning to end.

3.2.2 Interactions Resulting in State Changes

Associated with each model is a problem for the student to solve. To realistically solve problems within a model, a student must have the ability to interact with the environment. These interactions should result in appropriate state changes within the model that allow students to observe the consequences of their actions. After solving a problem, the student moves on to a more difficult problem and a more intricate model. These increasingly complex environments help the student to incrementally develop new skills (Burton et al. 1984). As students achieve success in solving realistic problems, they are compelled to try to solve more difficult problems (Gee 2003).

3.2.3 Non-linear Logic

As mentioned before, effective learning occurs as students draw connections between past experiences and newly acquired knowledge. The learning strategies that students employ are largely a function of their past experiences (Bransford et al. 2000). Learning environments must be dynamic enough to accommodate a wide range of learning strategies.

Instructional designers must also recognize that not all students have the same level of skill and experience. To compensate for this disparity, a non-linear approach customizes the learning process for each student's proficiency. An experienced student may take a more direct route to solve a problem than an inexperienced student (Bransford et al. 2000).

3.2.4 Help Structures to Augment Instruction

Allowing students to explore without any guidance is not only an inefficient use of time, it may also cause them to arrive at incorrect conclusions. Help structures, therefore, are essential in augmenting self-directed learning. These help structures may consist of multiple layers or tools including live coaching, expert feedback, visual demonstrations, databases, books, progress reports, and tutorials (Gibbons 2001). Help structures can bridge the gap between models and reality. In a situation where a model places a student in an unfamiliar environment, the companion can help the student to gain confidence in interacting with that environment. For example, a student performing a laboratory experiment may need to consult a laboratory manual or ask a lab assistant for help.

3.2.5 Pursuit of Educational Goals

Instructional simulations must lead the student in the pursuit of educational goals. What should the student learn? In answering this question, the instructional designer must recognize how experts differ from novices. Experts have a rich understanding of subject matter as a result of years of situated learning. This deep understanding of subject matter allows them to easily isolate and organize the most pertinent facts of the subject matter. Unfortunately, experts often fail at teaching when they attempt to present these isolated facts to their students (Bransford et al. 2000). Educational goals, therefore, should not be identified in terms of content, but rather in terms of skills (Beder 2000). These might include broad skills such as critical thinking, decision-making, recognizing data trends, or they might include specific skills such as taking measurements or writing reports. Whether the skills are broad or specific, they help students to situate new knowledge within a realistic environment.

4 Pilot Learning Module

In an effort to evaluate the effectiveness of instructional simulations for engineering education, a pilot learning module was developed. This pilot module was created for UNESCO's International Sediment Initiative (ISI) to provide training for effective sediment management practices.

4.1 Background Information

Approximately two-thirds of the world's large dams exist in developing countries (World Commission on Dams, 2000). These countries rely on dams and reservoirs for energy, agriculture, flood control, and drinking water. It is estimated that reservoir sedimentation depletes worldwide reservoir storage by one percent per year (Mahmood 1987). Sedimentation can also have long-lasting impacts that extend far upstream and downstream from the reservoir (Hotchkiss and Bollman, 1996). Due to economic shortsightedness, very few dams in developing countries have facilities for managing sedimentation (Hotchkiss 1995). A computer-based distance learning program could provide training on this specialized subject and thus contribute to more sustainable dams in the future.

The pilot learning module is based on an actual problem that occurred at the Guanting Reservoir near Beijing, China. Over time, sediment from the Yongding River created a depositional delta that steadily moved toward the dam (Zhang et al. 1996). This accumulation of sediment corresponded with a decrease in the energy slope upstream from the dam. As a result, the water elevation upstream increased. The rising water levels saturated the agricultural land upstream, rendering the land useless for agricultural production. This case study provides students with an opportunity to use problem-solving skills to learn about sediment processes.

4.2 Description of Learning Module

The following description uses the pronouns "you" and "your" to emphasize the first-person nature of the simulation. Before the simulation begins, you are prompted to enter your name and email address into two blank text fields (these will be used for correspondence after completion of the module). After pressing the "submit" button, you may choose to watch a short introductory video, which explains how to navigate through the simulated environment.

The simulation begins with a first-person view of a jeep driving down a dirt road (See Figure 4-1). The jeep stops in front of a small building with a placard which reads, "Benua Department of Water Resources: Valkea Reservoir." You open the door and enter a small office. On top of a desk in the back of the room is a letter with your name on it (See Figure 4-2). The letter congratulates you on accepting a job with the Benua Department of Water Resources and informs you of your first assignment: you must determine why the agricultural land upstream from the reservoir has failed to produce crops for the past three years. To solve this problem, you may look for clues in the office and in the field. Attached to the letter is a final report form for you to complete when you have solved the problem. The report follows a standard scientific report format. From this point on, you are free to navigate through the environment on your own.

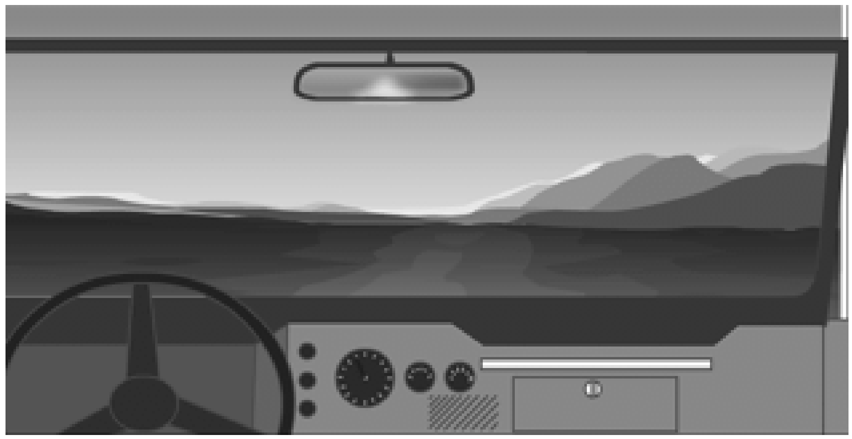

Figure 4-1 Approaching the Office from the Jeep

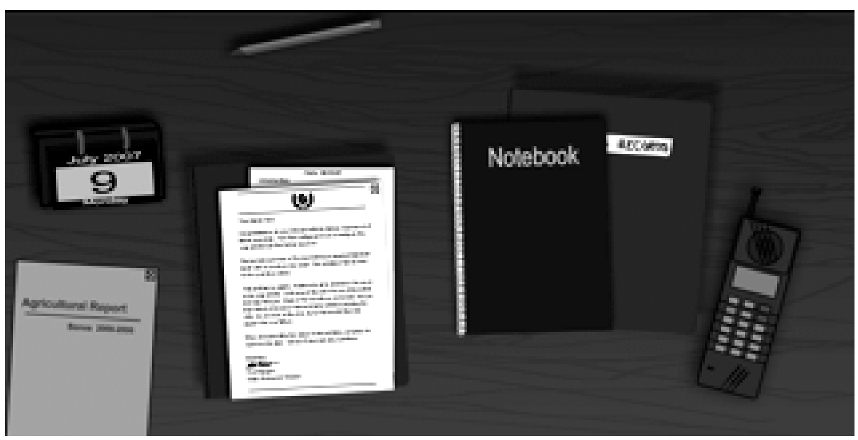

Figure 4-2 Desk Items in the Office

As you look around the office, you discover a few items that you can take with you wherever you go. These include a cellular phone, a notebook, a measuring tape, and a sounding rope. The simulated cellular phone allows you to call your supervisor to ask questions (See Figure 4-3). The phone serves as a standard “help” document.

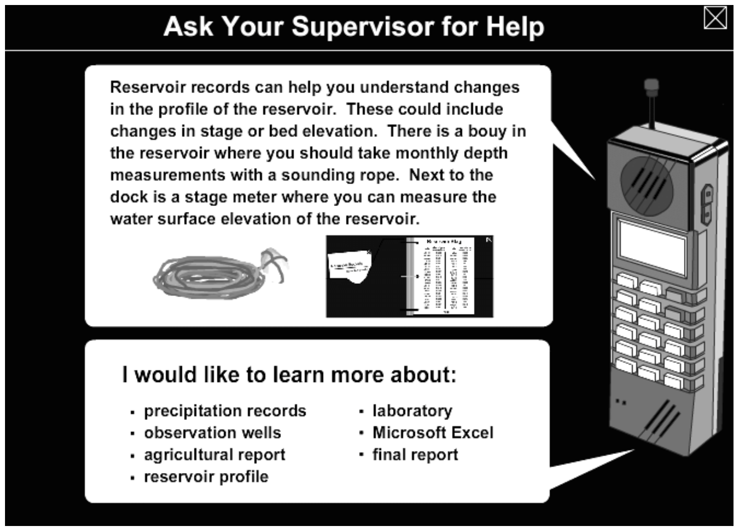

Figure 4-3 Simulated Cellular Phone

If you exit the building, you can drive the jeep to various locations around the reservoir. You can take measurements at observation wells with the measuring tape (See Figure 4-4), and you can take depth measurements for the reservoir from a small boat using the sounding rope (See Figure 4-5). You can record the measurements in the notebook at any time.

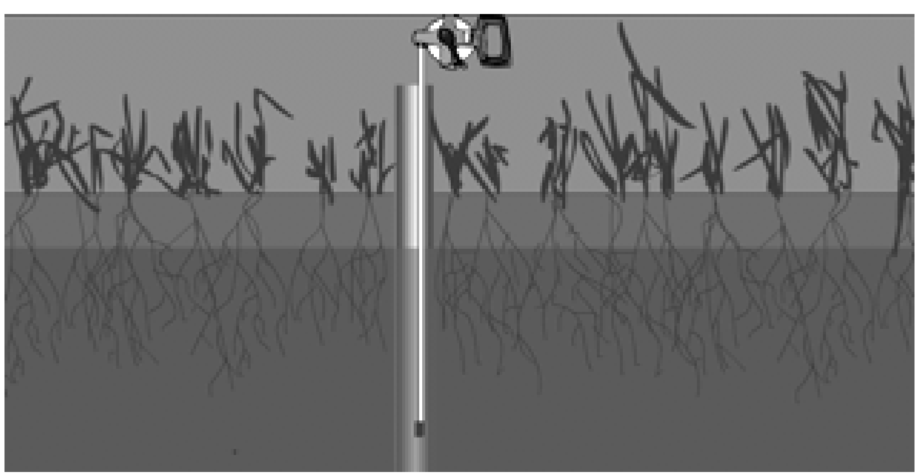

Figure 4-4 Taking Measurements at an Observation Well

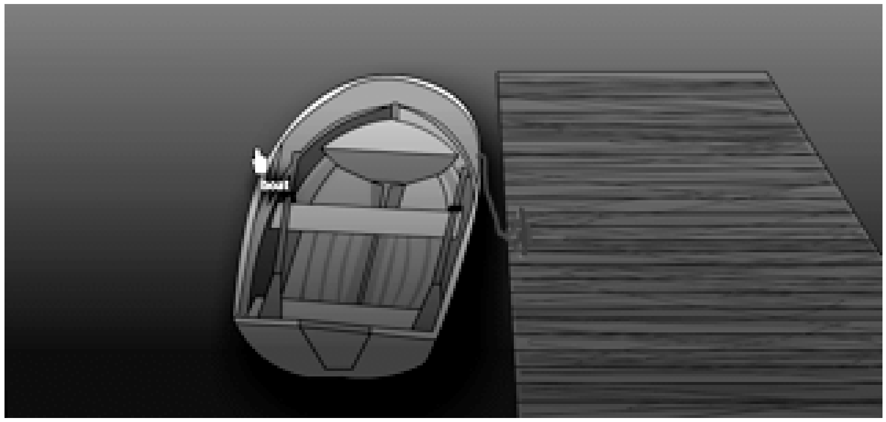

Figure 4-5 Boat Tied to a Small Dock at the Reservoir

Back in the office, there are several folders containing historical records. These include irrigation records, precipitation records, observation well records, reservoir depth records, and reservoir stage elevation records. Along with each set of records is an instructional pamphlet explaining how the records are obtained and how to interpret trends. These pamphlets operate like traditional computer tutorials; however, the students are not required to view them. The pamphlets show short animations and give instruction from engineering textbooks (See Figure 4-6).

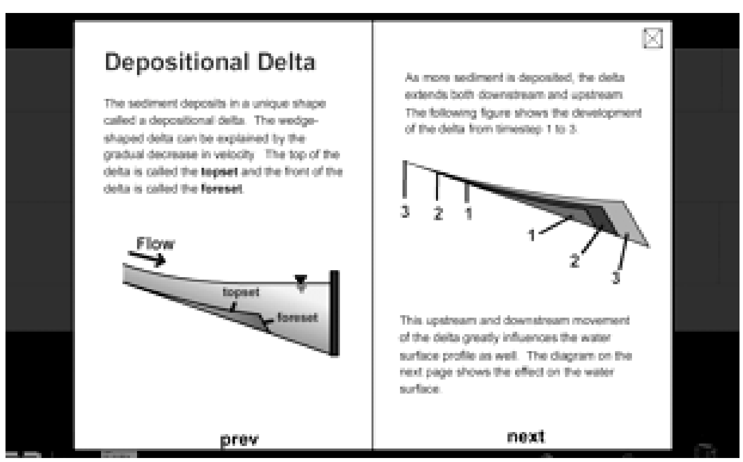

Figure 4-6 Instructional Pamphlet with Animation

At the end of each historical records folder there is an "export" button, which copies the data to the clipboard. You may then paste the data into Microsoft Excel. By plotting the data you can look for unusual trends that may explain the crop failure.

There is also a small laboratory with an experimental flume located near the office (See Figure 4-7). In the flume is a scale model of the Valkea Reservoir and dam. By pressing a button above the flume, a hopper drops sediment into the flume. A depositional delta forms and the water level upstream slowly rises. An instructional pamphlet in the laboratory discusses the consequences of reservoir sedimentation along with common mitigation methods such as flushing, sluicing, and storing.

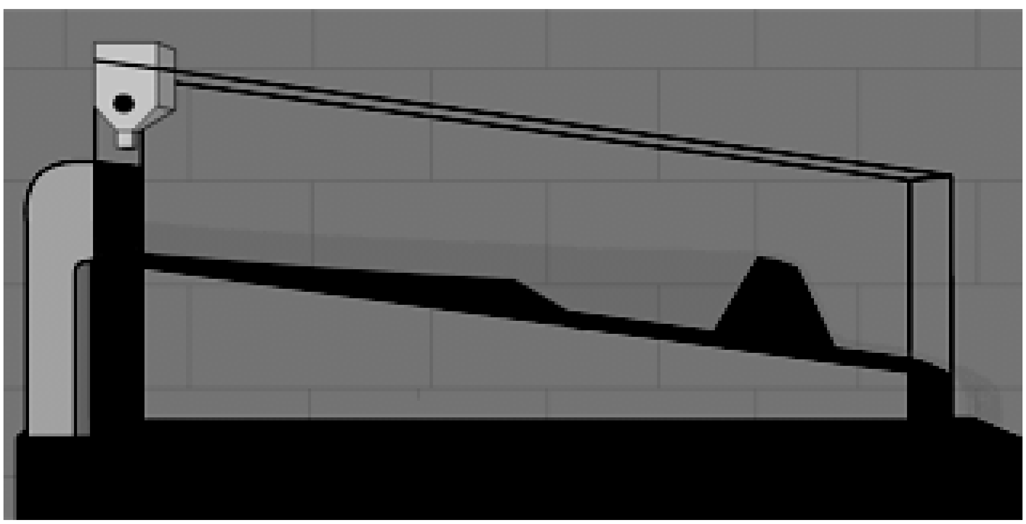

Figure 4-7 Experimental Flume in Field Laboratory

The simulated environment allows you develop and test multiple hypotheses about the mysterious crop failure. You may have initially guessed that the crop failure was a result of precipitation irregularities or a problem with irrigation, but the data did not support those hypotheses.

You may have determined the real cause of the crop failure from the following clues:

- The observation well data showed that the water table rose near the mouth of the reservoir.
- A visit to the field showed that the roots of the crops were completely saturated with water.
- The reservoir stage elevation remained fairly constant over the past several years, but the depth of the reservoir crops suddenly decreased three years ago. This means that the bed elevation rose suddenly.
- The flume experiment showed that sediment deposits progress relatively quickly toward the dam (this caused the sudden rise in bed elevation).
- The flume experiment showed a slight rise in the headwater upstream from the reservoir (near the agricultural land).

These clues lead you to conclude that sedimentation in the reservoir caused the water table to rise upstream. The crops cannot survive in the water-saturated soil. According to the pamphlet in the laboratory, the best way to solve the problem would be to use sluicing techniques to flush sediment out of the reservoir through low-level outlets during the runoff season.

At this point, you can finish the final report and submit it to your “supervisor” over the Internet. The final report is actually sent to a central agency, which is responsible for evaluating the reports. After evaluation, the report is returned with appropriate feedback to the email address entered at the beginning of the simulation.

4.3 Instructional Simulation Characteristics

As mentioned before, there are five characteristics of effective instructional simulations. These characteristics provide the foundation for the instructional design of the pilot learning module.

4.3.1 Dynamic Models

The pilot learning module described in the previous section utilizes all three types of models described by Gibbons. The module is primarily an environment module, consisting of several locations. The interactions within the environment simulate natural interactions in an office or field environment. Students can turn around to look in different directions, pick up objects, write down notes, take measurements, move to new locations, use tools, ask for help, etc.

The module also contains a cause-and-effect system. The experimental flume demonstrates a few of the effects of reservoir sedimentation. These principles can then be applied to the reservoir and agricultural lands. The historical data also represents several systems. As students observe trends in Excel, they must think about what could cause the data to fluctuate.

The module is also models expert behavior. Although the module does not demonstrate expert behavior as explicitly as a case study, the module aids the student to think and act as an expert. The final report helps students to immediately think about the problem in terms of the scientific method. In addition, the options available to the student reflect the hypotheses of an expert.

4.3.2 Interactions Resulting in State Changes

Since this pilot learning module is mainly for diagnosing a problem, there are not any dramatic state changes that occur. The next learning module would likely involve major state changes involving flushing the sediment out of the reservoir. There are, however, subtle and important changes that occur in this module. For example, traveling out to the middle of the lake in the boat is useless if the student has not picked up the rope and rock to measure the depth of the water. The experimental flume also demonstrated some important state changes as sediment was added to the water.

4.3.3 Non-linear Logic

The non-linear nature of the module allows students to customize their own learning strategy. As mentioned before, some students may want to spend more time getting a general feel of the environment before analyzing data; others may want to immediately analyze data. All paths should ultimately lead participants to make the same conclusion. Experienced students should be able to move through the simulation much faster than inexperienced students.

4.3.4 Help Structures to Augment Instruction

This description of the pilot learning module identified three help structures to assist the student in solving the main problem. These include the instructional pamphlets, the simulated cellular phone, and the report feedback. These structures ensure that the students are reaching acceptable conclusions for the problem, and learning the proper terminology, formulas, and other technical information they will need to solve similar problems in the real world.

4.3.5 Pursuit of Educational Goals

The educational goals of this module are as follows: (1) foster problem-solving skills in students; (2) teach students how to recognize and interpret trends; (3) inform students about simple and high-tech methods to collect reservoir data; (4) help students learn to write technical reports; and (5) teach hydraulic principles associated with reservoir sedimentation. The advantage of the simulation is that these goals can be achieved in the context of a real-world problem.

5 Preliminary Module Assessment

Preliminary assessment of the pilot learning module was performed to determine the module's effectiveness in achieving the instructional goals mentioned in Section 4.3.5. The broad objective of the assessment was to determine whether the learning module can facilitate student learning in the area of reservoir sedimentation. This section describes two separate usability studies and a formal assessment of the learning module.

5.1 Usability Studies

In order to discover potential problems with the usability of the learning module, two separate studies were conducted. The first usability study consisted of 30 students enrolled in an undergraduate hydraulics course at Brigham Young University. These students accessed the learning module over the Internet. Each student was required to submit a list of suggested improvements for the module. The students identified multiple broken links, typos, and unclear directions. These issues were promptly fixed.

For the second usability study, five international students were chosen to determine the usability for non-native English speakers. For this usability study, the students were asked to verbally describe any problems they encountered as they used the module. A web cam and microphone were attached to a computer to record these reactions. A screen-capture program also recorded the students' screen in real-time to determine where they spent the most of their time (See Figure 5-1). The students identified several words and phrases in the module that were difficult to understand. One of the students had difficulty navigating through the environment. A brief instructional video was added to the beginning of the simulation to clarify some of the navigation logistics.

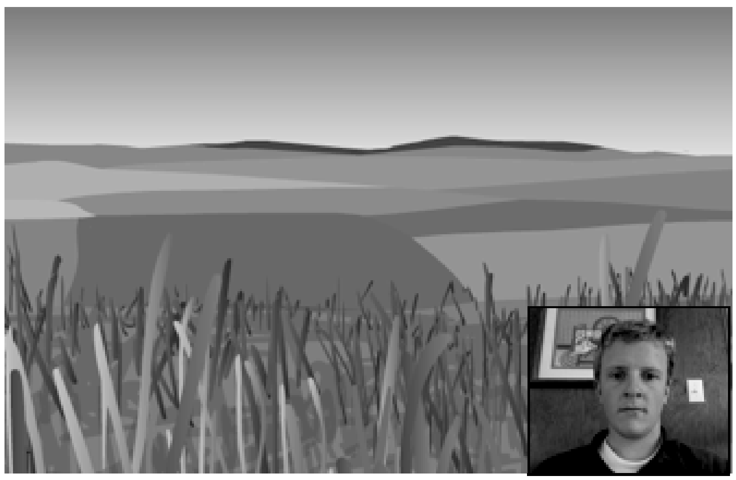

Figure 5-1 Usability Study Screen Capture

5.2 Formal Assessment

A formal assessment of the learning module was conducted to evaluate student learning as well as student enjoyment.

5.2.1 Methods and Procedures

The formal assessment involved 20 additional students enrolled in an undergraduate hydraulics course at Brigham Young University. The students were given extra credit points as incentive to complete the module. Each submitted final report was evaluated. The students then completed a short survey and participated in focus groups to determine their proclivity toward this type of learning. The 20 students were divided into 3 focus groups. They were videotaped as they discussed what they liked and disliked about the learning module.

5.2.2 Results and Discussion

In order to assess student learning, the final reports were carefully evaluated. 90% of the students correctly identified rising water levels as the cause of the crop failure. These students also correctly correlated the rising water levels with the sedimentation processes in the reservoir. Unfortunately, only 65% correctly identified sediment sluicing as an effective method for managing this problem. This is primarily a design flaw, since sediment sluicing was only mentioned in one of the instructional pamphlets. As a result, those who didn't access the pamphlet didn't arrive at the correct conclusion for managing sediment. Several of these students did, however, suggest other creative ways to manage the problem.

On average, the students reported spending a little over an hour on the module. The students were surveyed to determine how much they agreed or disagreed with several statements. Some of these results are shown in Figures 5-2 through 5-4.

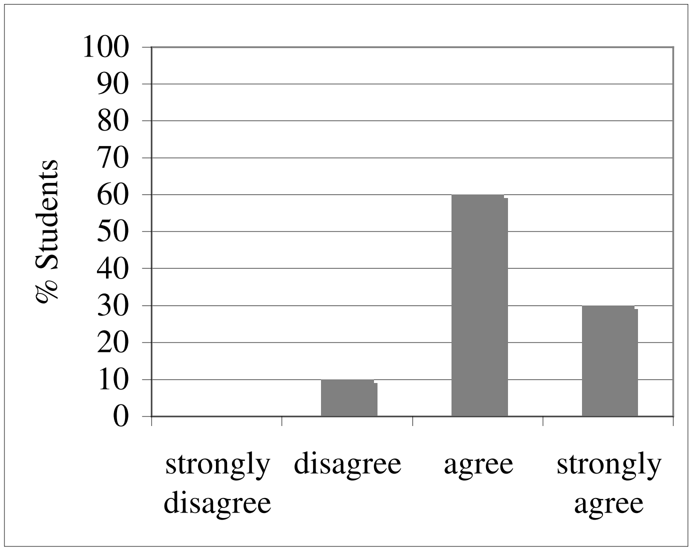

Figure 5-1 "I Learned Something New About Reservoir Sedimentation"

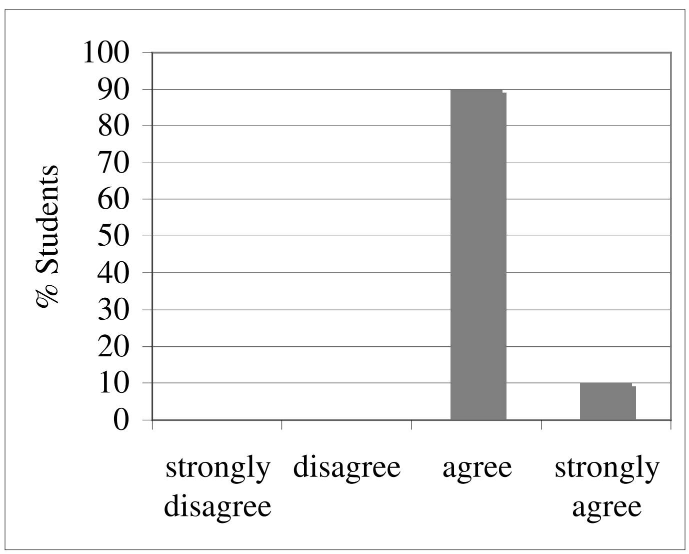

Figure 5-2 "The Module Demonstrated the Connection Between Historical Data and Natural Processes"

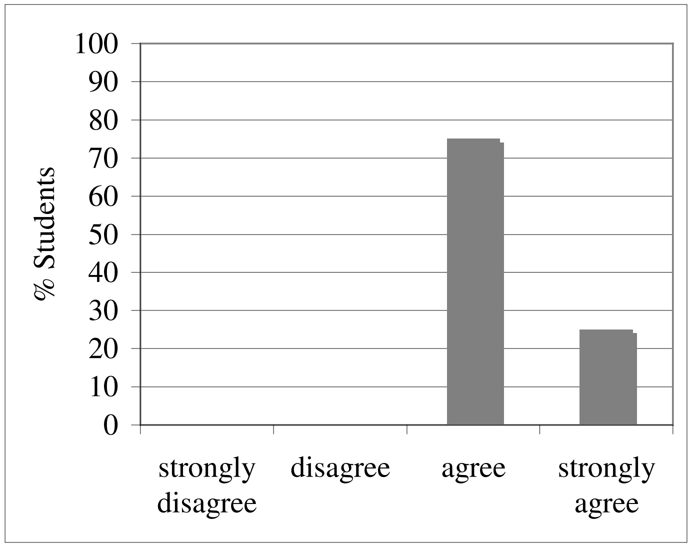

Figure 5-3 "The Module Helped Me Develop Problem-Solving Skills"

The consensus from the three focus groups was that the students generally enjoyed learning from the module. Although the students agreed that the module was challenging, they felt like they had adequate resources to solve the problem. Some of the students expressed some initial frustration with the usability of the simulation, but they quickly learned how to navigate through the environment. In comparison to traditional lectures and homework problems, the students felt like the module allowed them to use problem-solving skills more. One student remarked, "we started with a problem, and we sorted through information to find a solution, rather than plugging numbers into a formula." When asked how the learning module compared to textbook homework problems, one student said, "It felt a little more hands-on. You can actually visualize what you're dealing with."

5.2.3 Assessment Limitations

Despite the positive results of the assessment, the students who participated in the study were not part of the eventual target population. They were all juniors and seniors in a civil engineering undergraduate program in the United States. Even with a basic usability test for non-native English speakers, this assessment did not take into account the cultural considerations that would be required to distribute the module worldwide. Also unlike the eventual target population, the students involved in the study had strong computer proficiency. Despite these limitations, the study showed that the learning module effectively facilitated student learning.

6 Summary and Recommendations

In order to improve engineering education in the developing world, this paper discussed the use of computer-based instruction. Computer-based instruction cannot be viewed simply as a digital representation of facts and figures. Effective computer-based instruction allows students to interact with complex models to solve realistic problems. A pilot learning module was developed to evaluate the effectiveness of computer-based instruction in civil engineering. The results of preliminary assessment showed that the module successfully promoted problem-solving skills, helped students learn about a technical engineering topic, and demonstrated the importance of recognizing trends in data. Students found the module both challenging and interesting.

This research focused primarily on learning effectiveness. This is only one aspect of effective educational tools. Future studies should address the issues of cost-effectiveness and accessibility.

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Appendix A. Pilot Module Screen Captures

The pilot learning module was created using Adobe Flash, Version 8. The following images were taken from individual "keyframes" on the Flash timeline. For a copy of the source files or the published shockwave files, contact Brad Singley at bradsingley@gmail.com. The learning module can also be exported as an executable file for Windows operating systems.

Figure A-4 Introduction Page

Figure A-5 Name and Email Submission

Figure A-6 Dirt Road

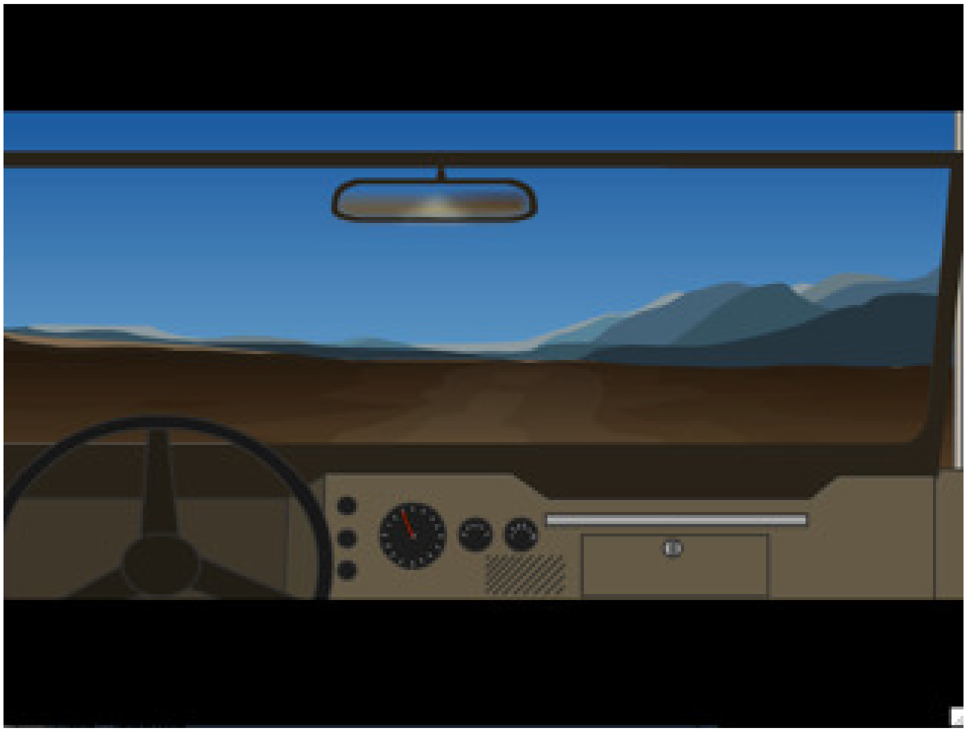

Figure A-7 Jeep

Figure A-8 Arrival to Office

Figure A-9 Office

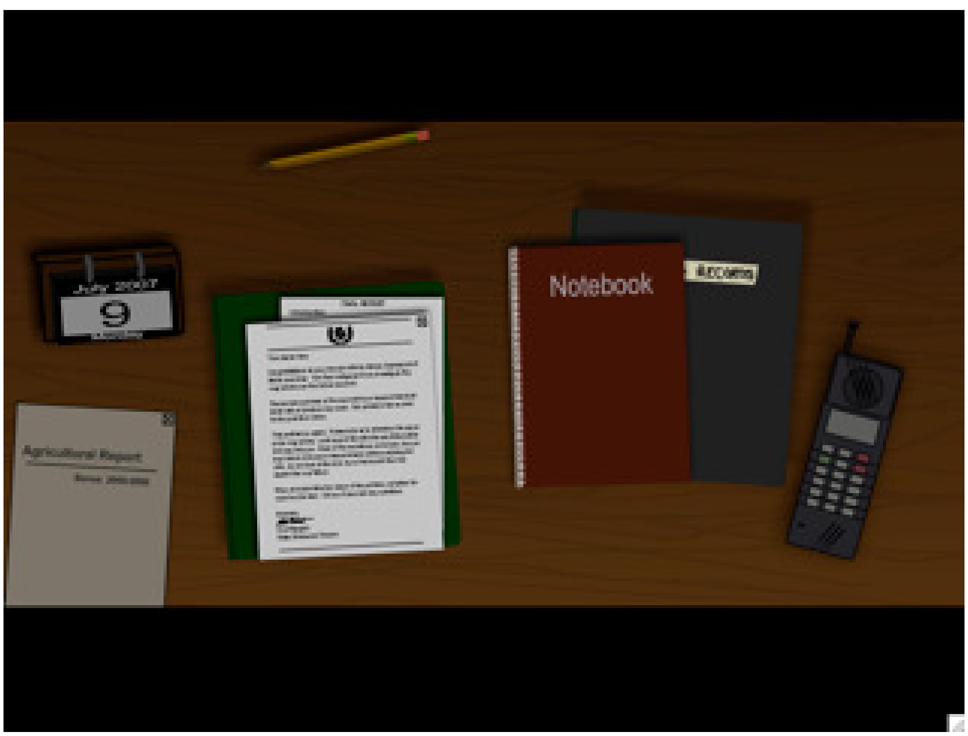

Figure A-10 Desk

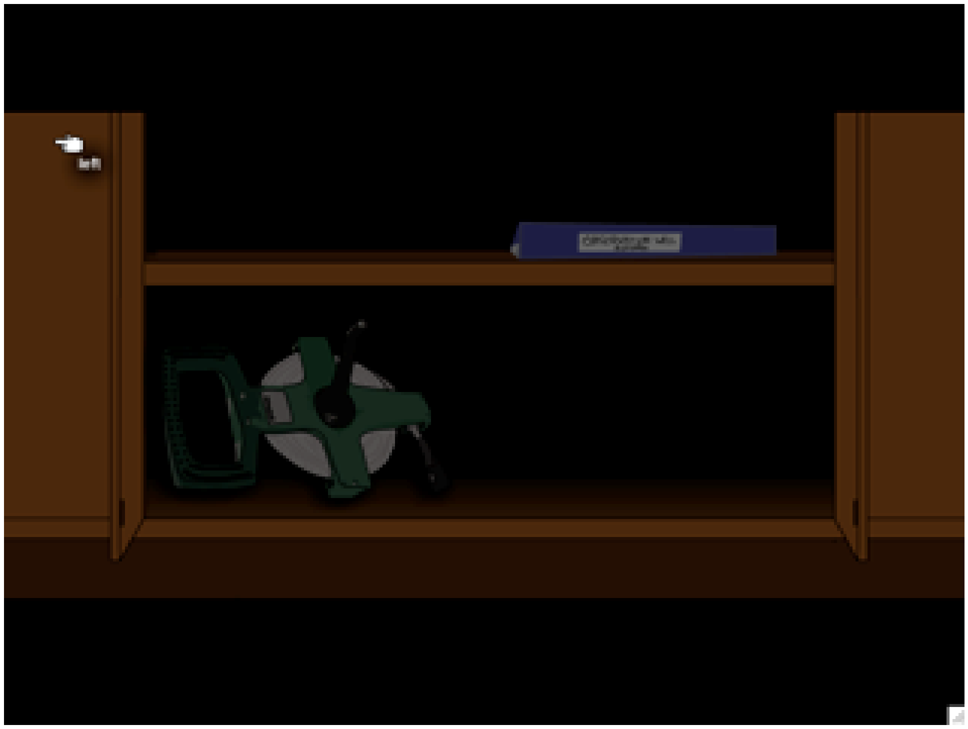

Figure A-11 Cupboard

Figure A-12 Office Door

Figure A-13 Plant

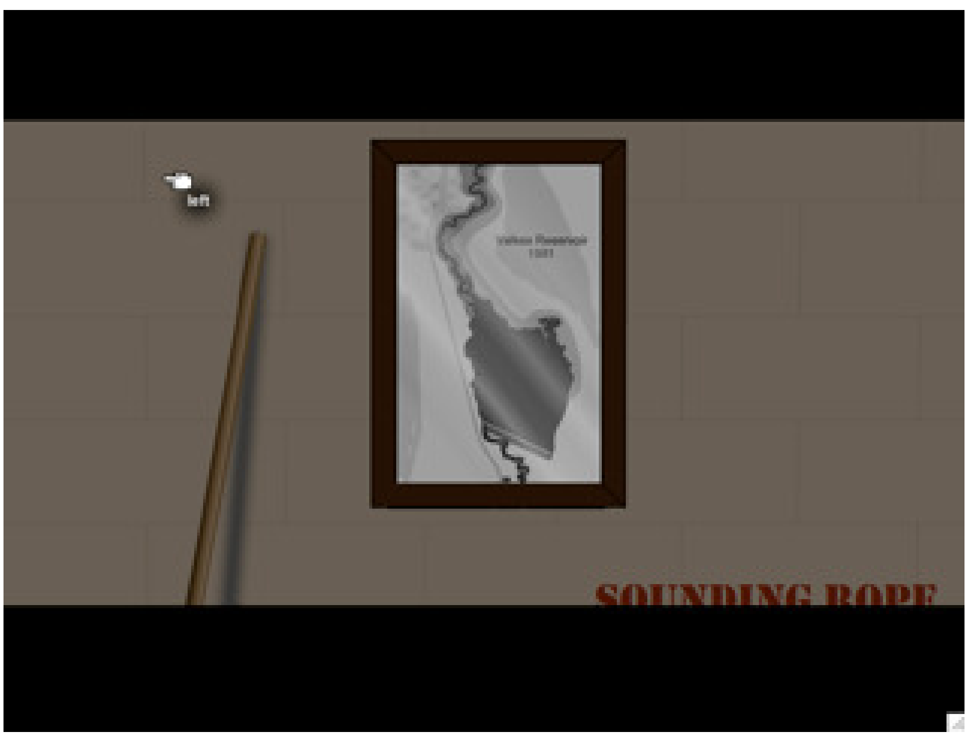

Figure A-14 Old Aerial Map

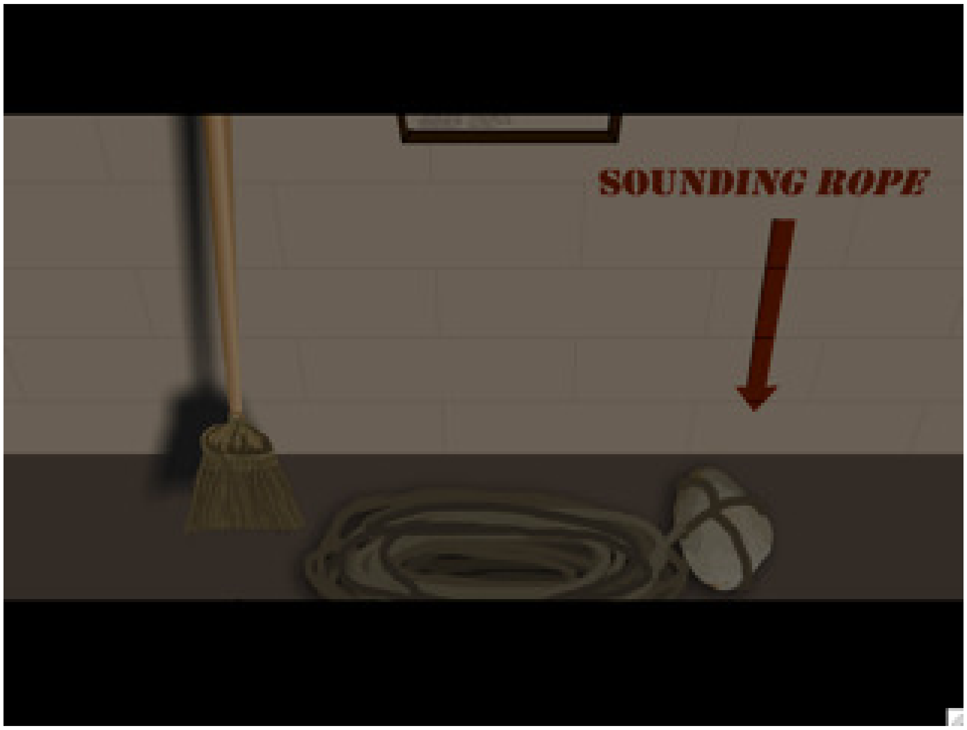

Figure A-15 Sounding Rope

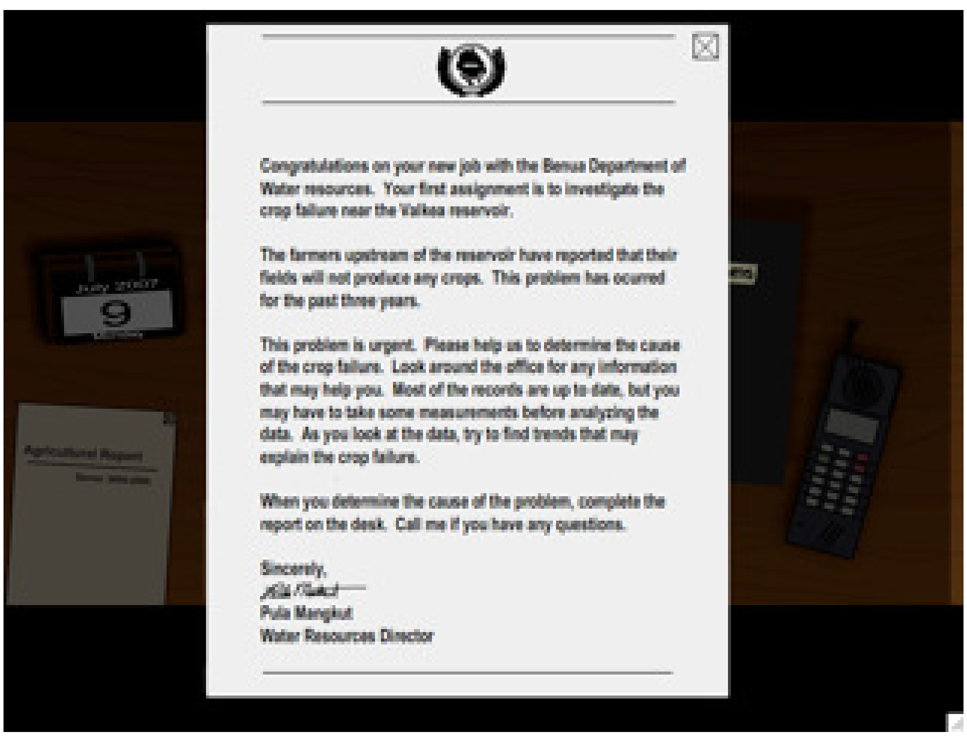

Figure A-16 Supervisor's letter

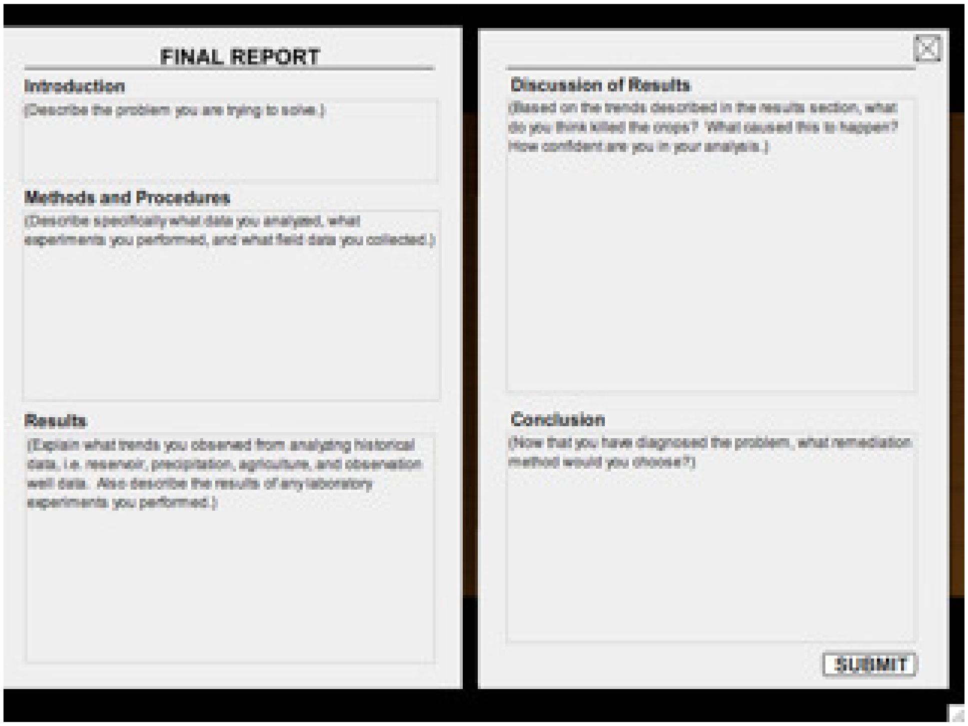

Figure A-17 Final Report

Figure A-18 Agricultural Records

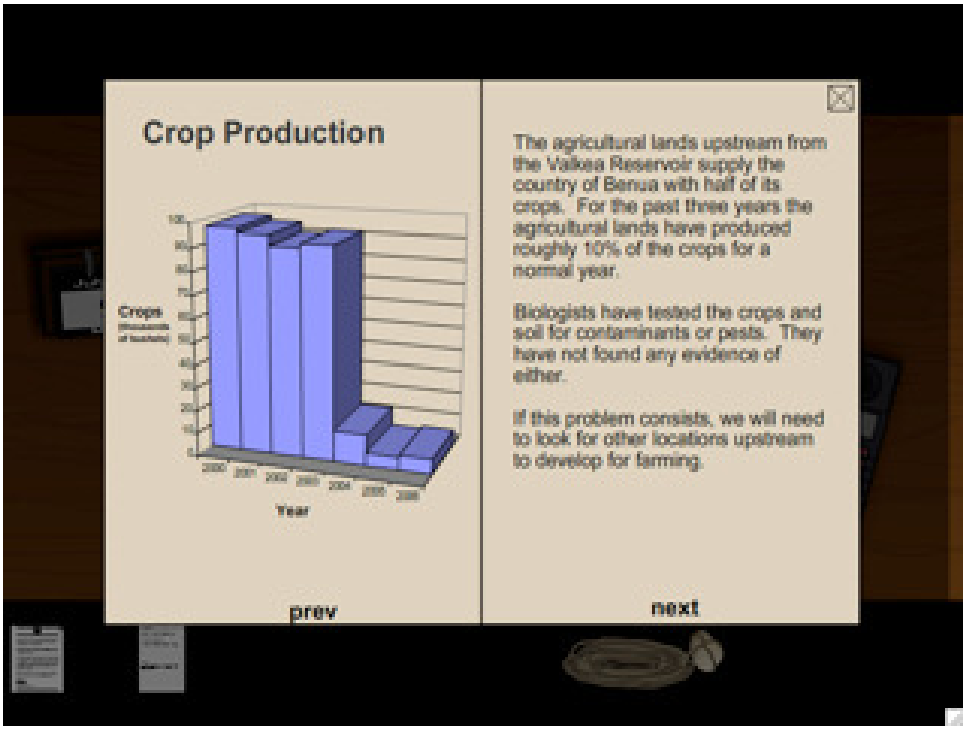

Figure A-19 Crop Production

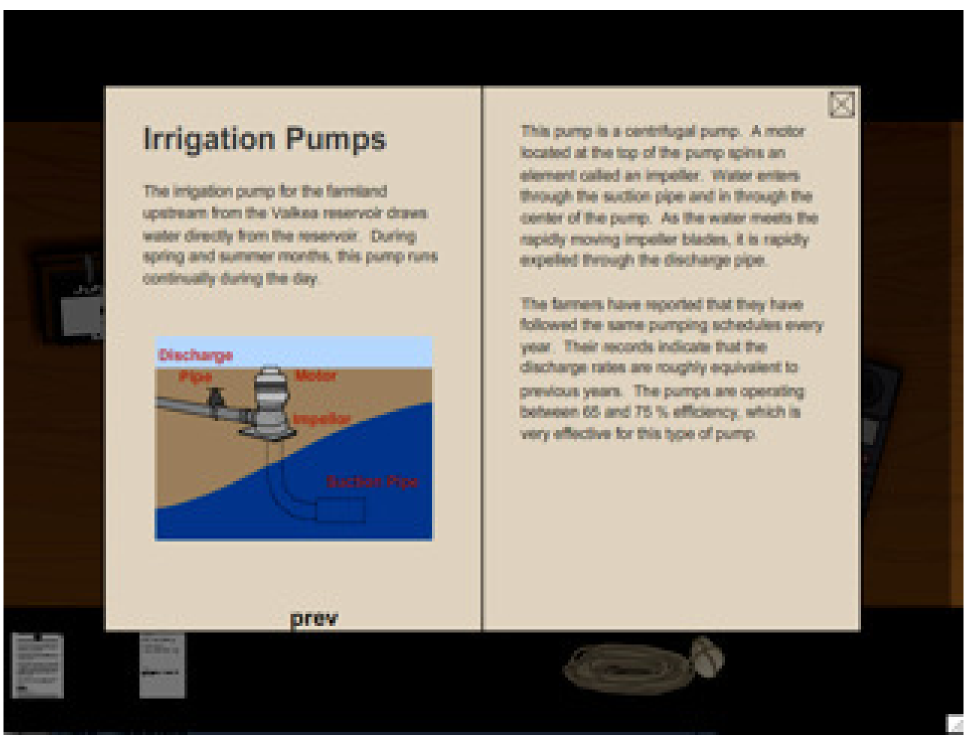

Figure A-20 Irrigation Description

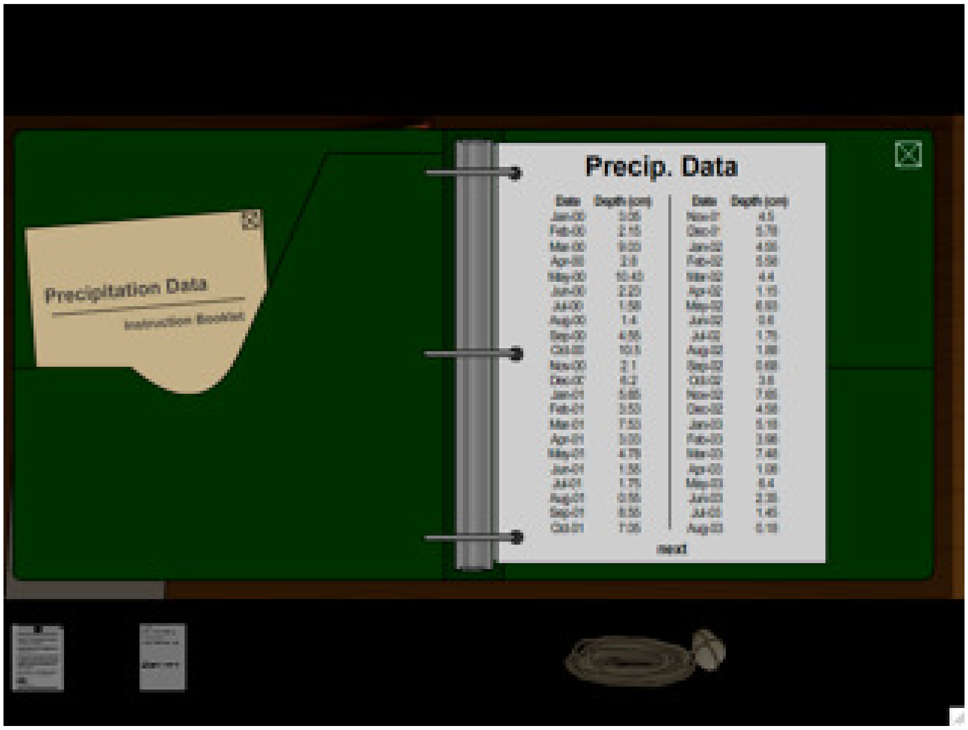

Figure A-21 Precipitation Data

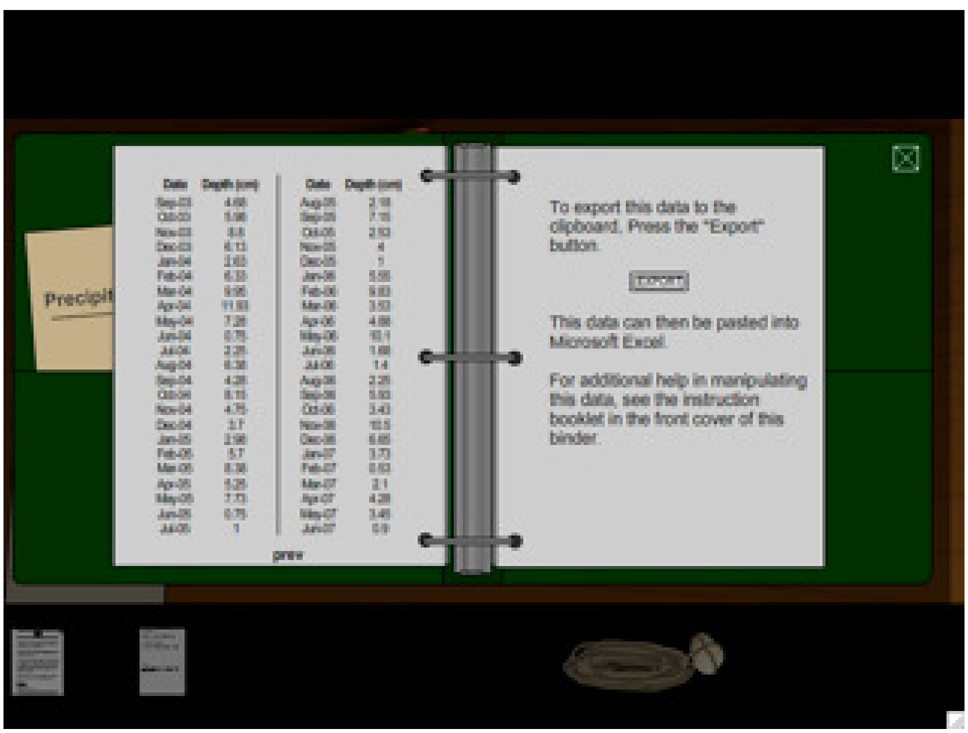

Figure A-22 Precipitation Data (cont.)

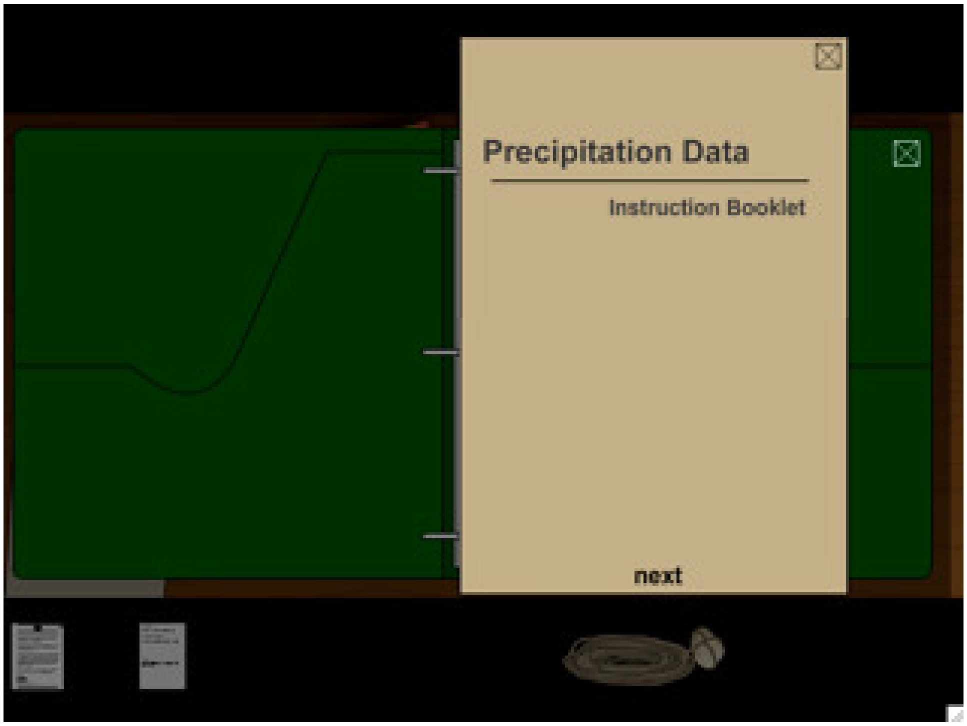

Figure A-23 Precipitation Pamphlet

Figure A-24 Precipitation Pamphlet (cont.)

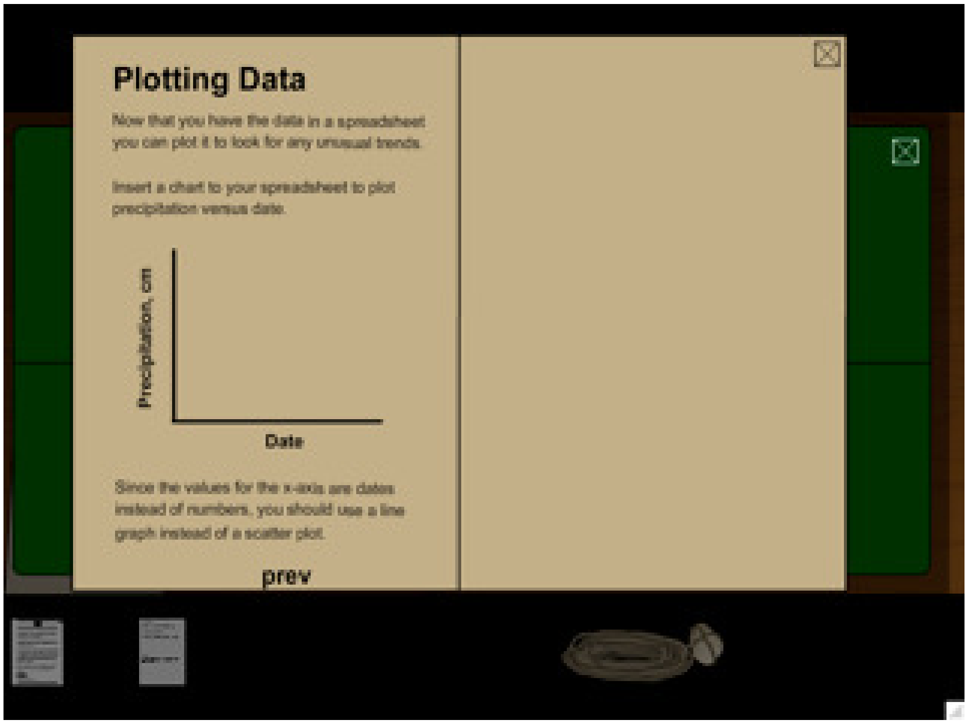

Figure A-25 Plotting Precipitation Data

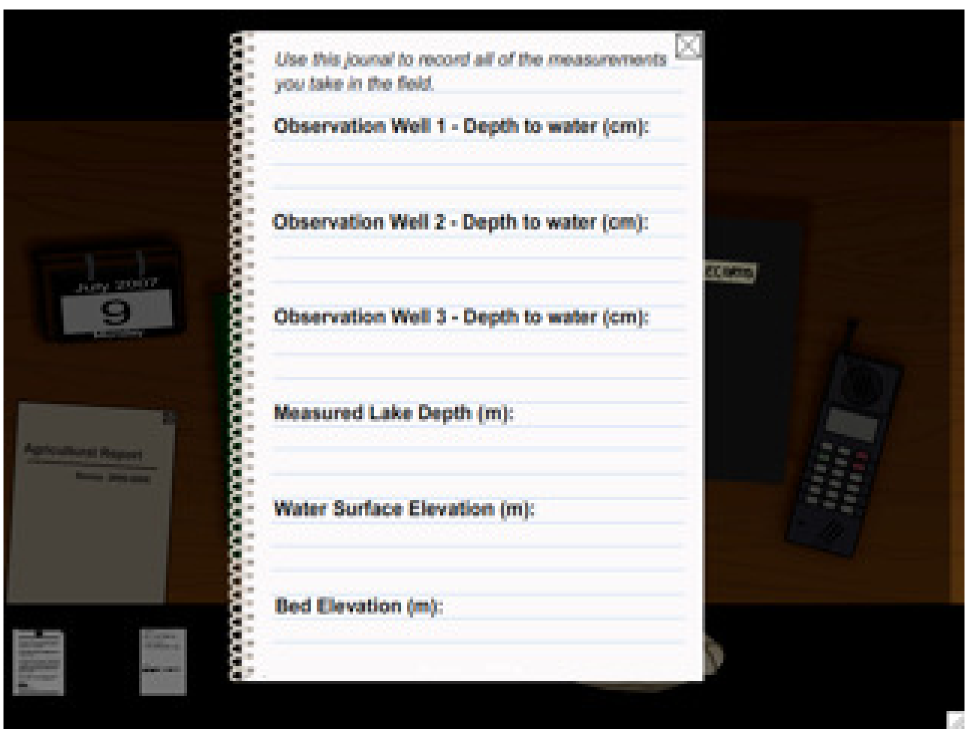

Figure A-26 Notebook

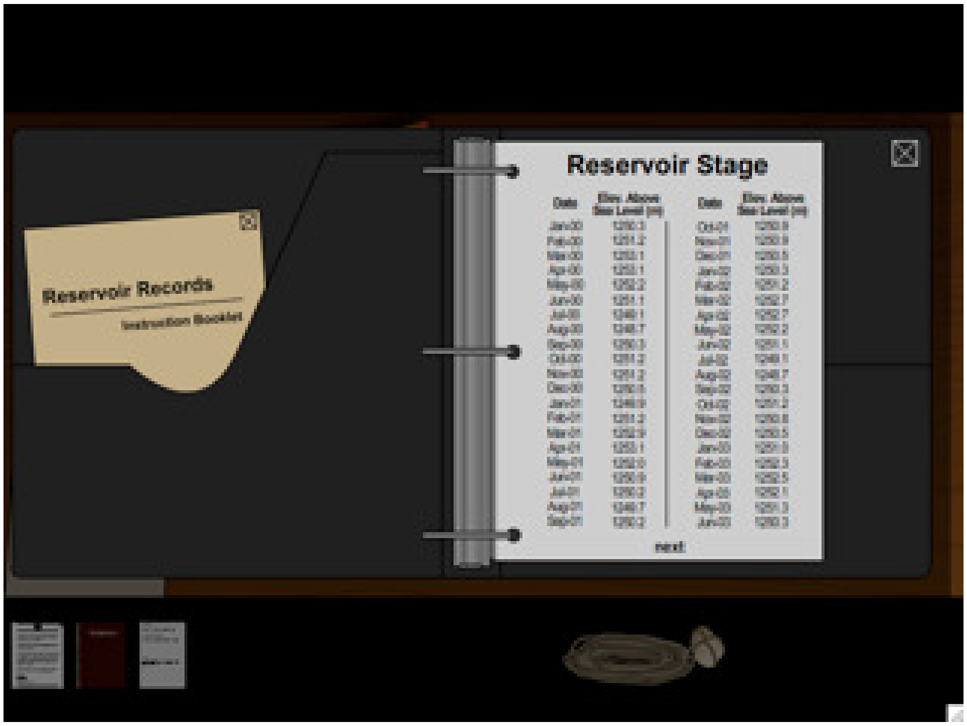

Figure A-27 Reservoir Stage Records

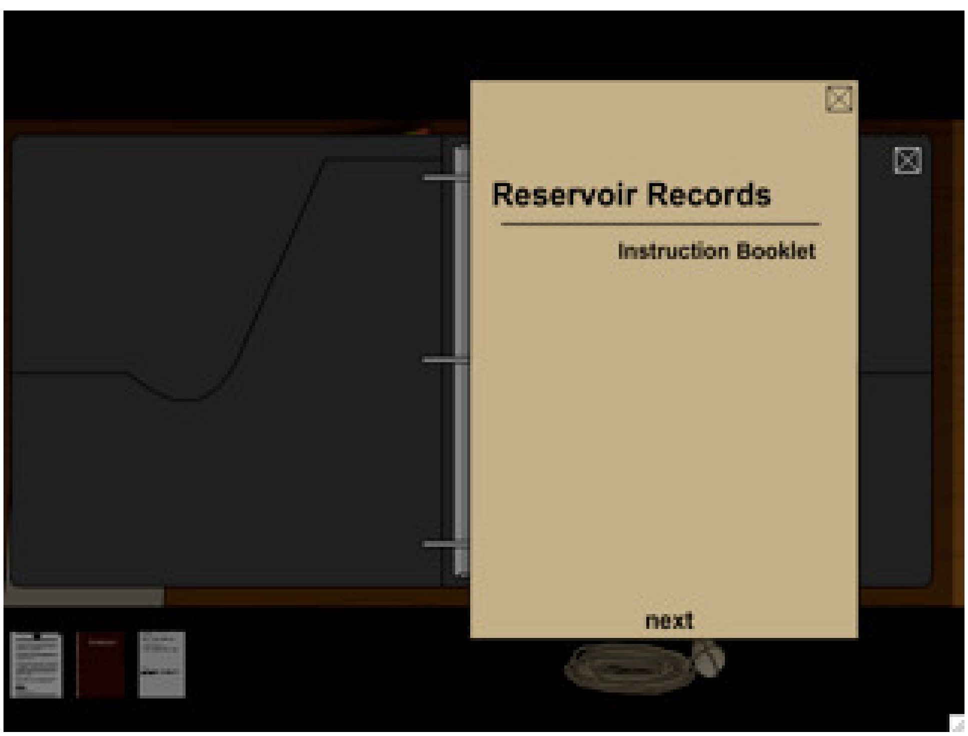

Figure A-28 Reservoir Records Pamphlet

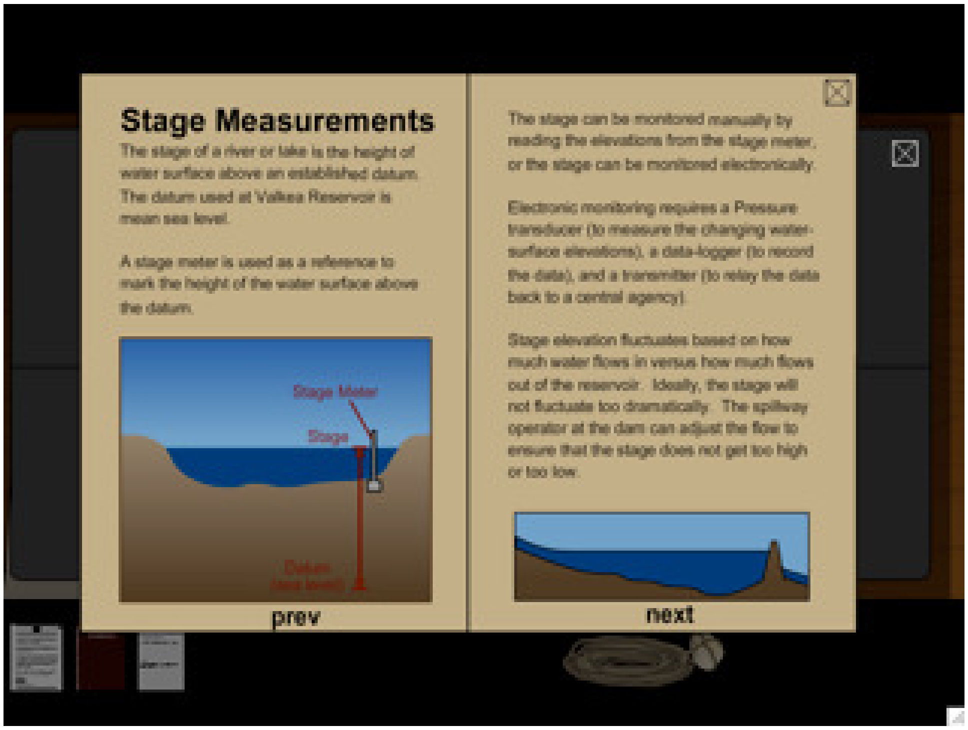

Figure A-29 Stage Measurements

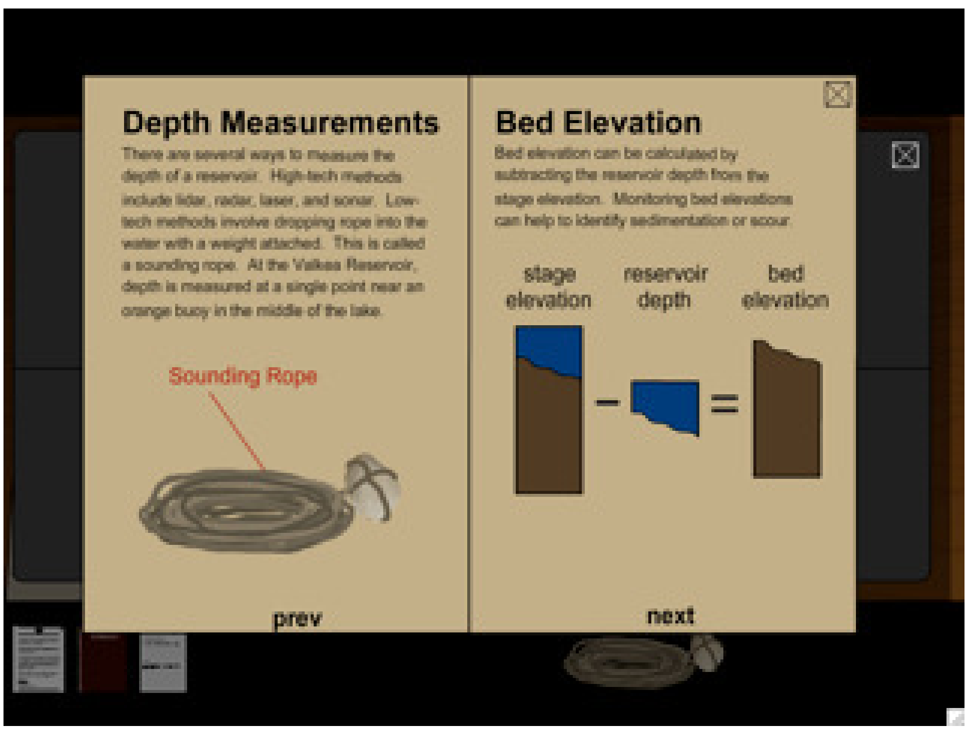

Figure A-30 Depth Measurements/Bed Elevation

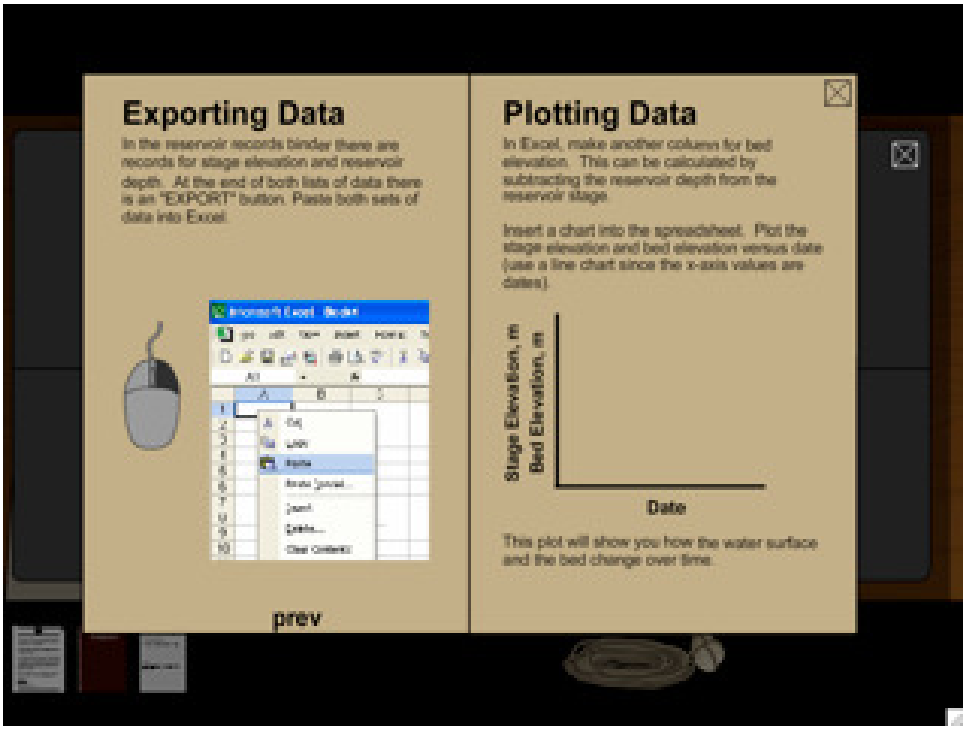

Figure A-31 Exporting/Plotting Data

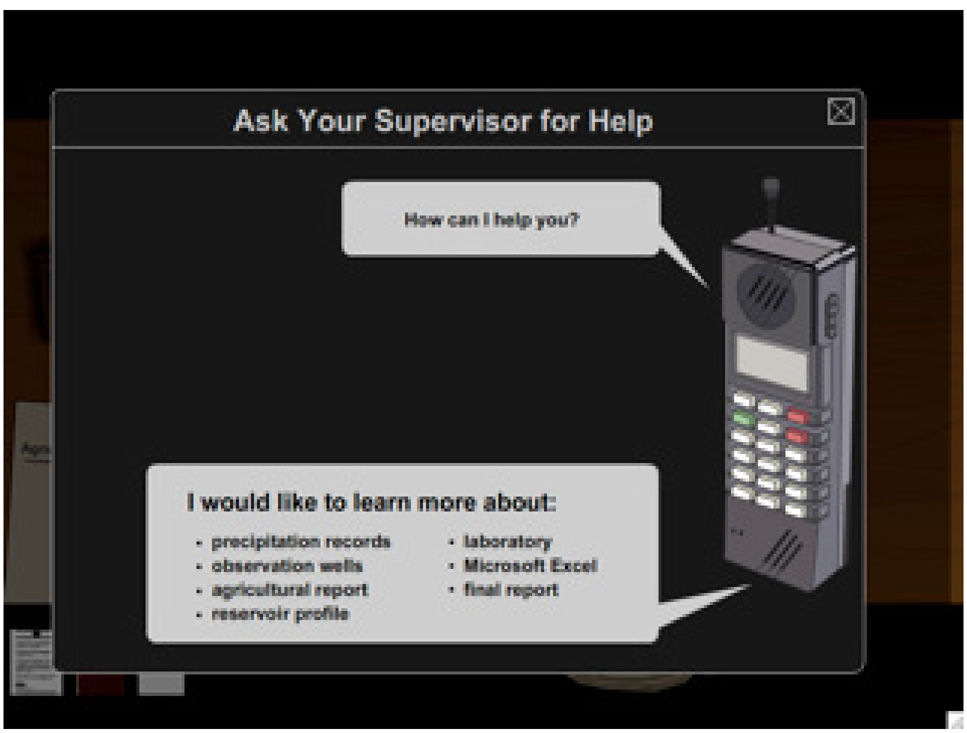

Figure A-32 Cellular Phone

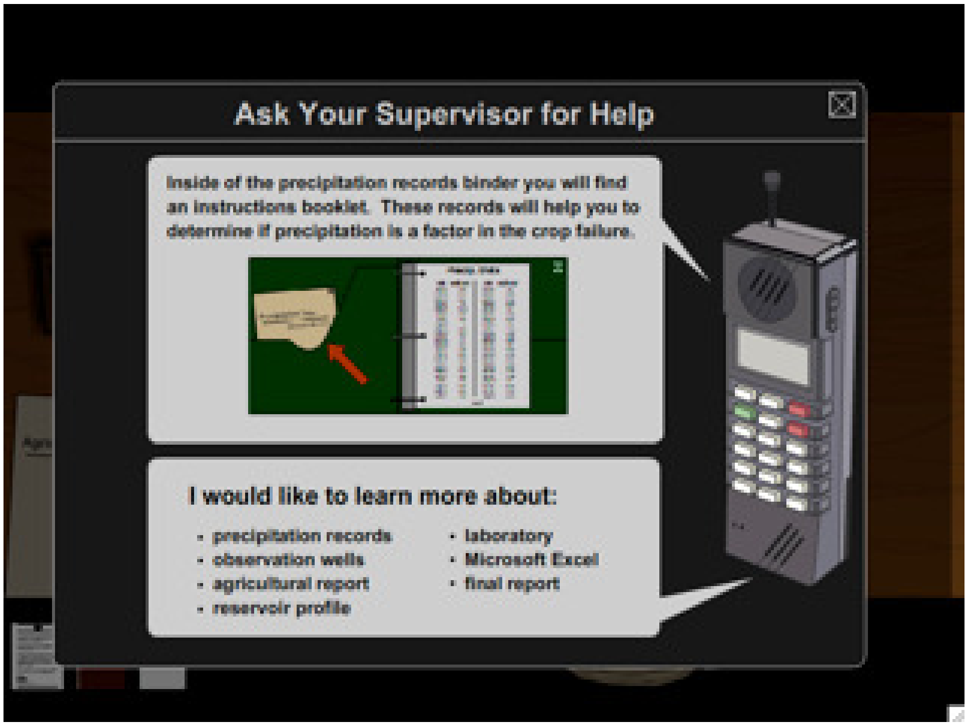

Figure A-33 Precipitation Help

Figure A-34 Observation Well Help

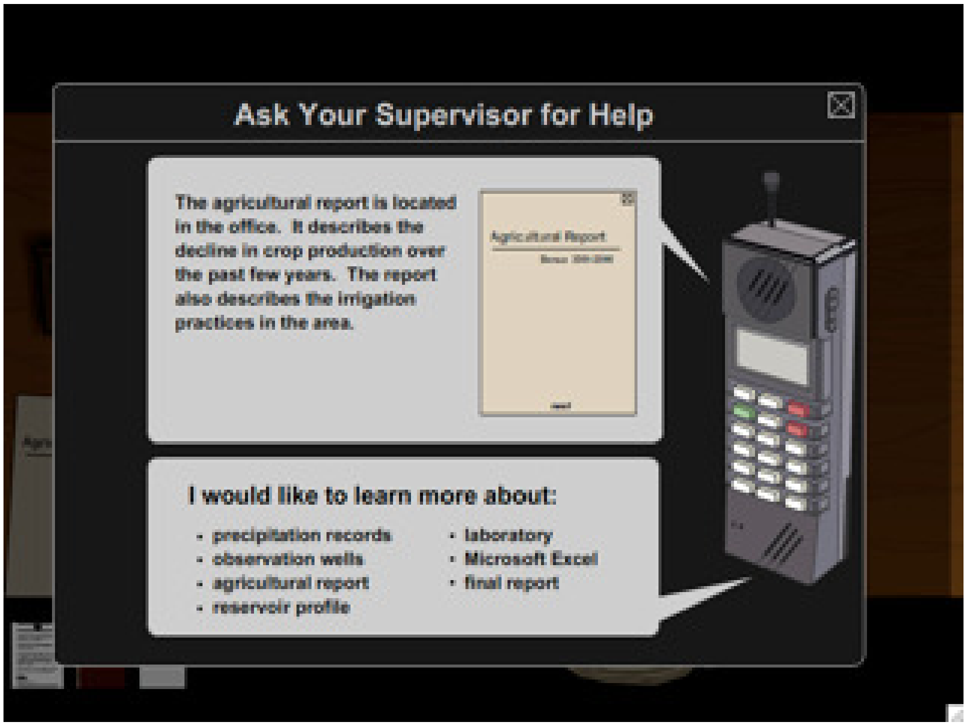

Figure A-35 Agriculture Help

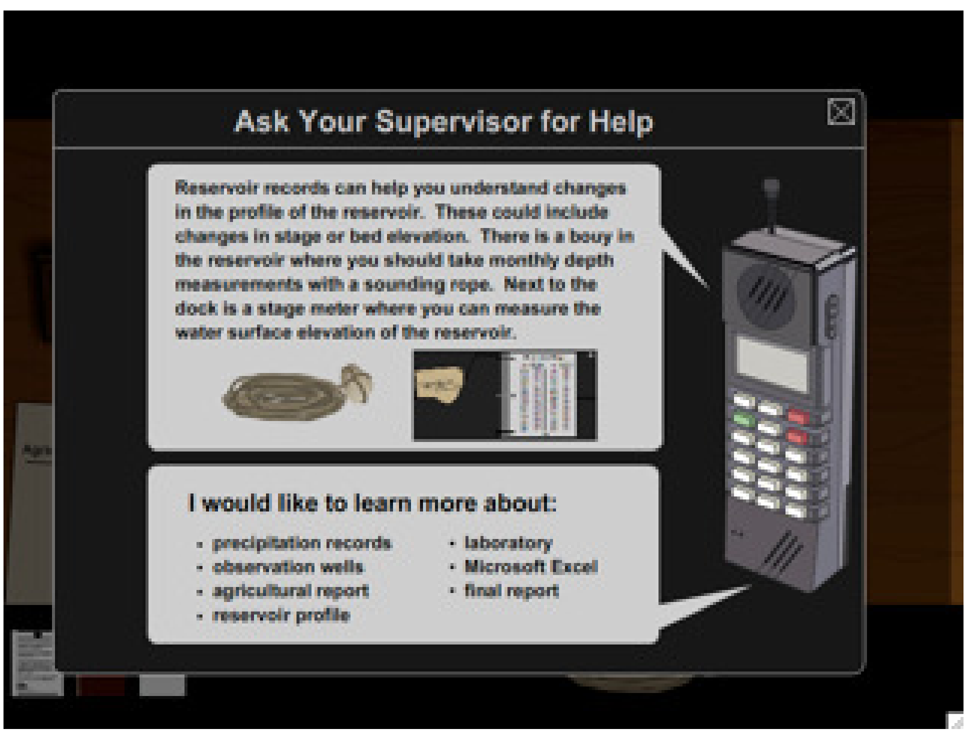

Figure A-36 Reservoir Help

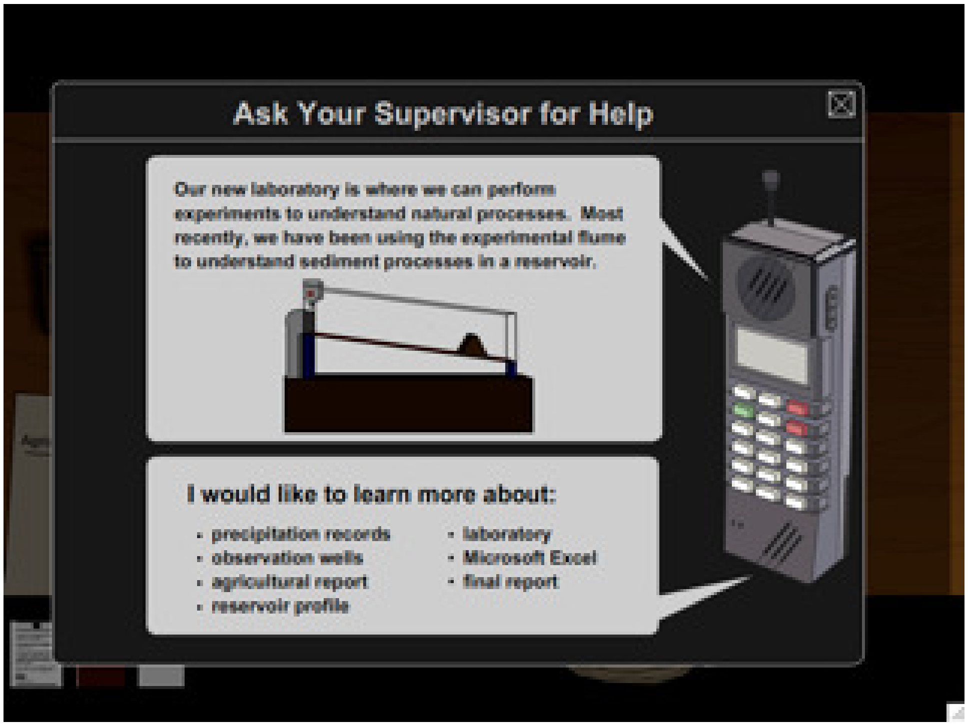

Figure A-37 Laboratory Help

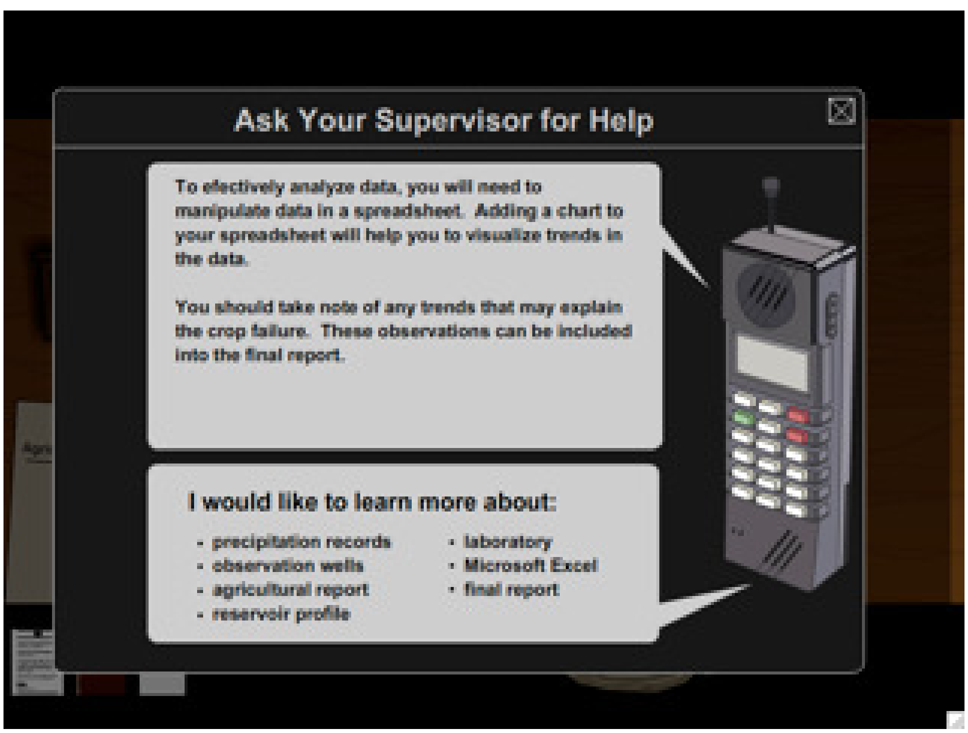

Figure A-38 Microsoft Excel Help

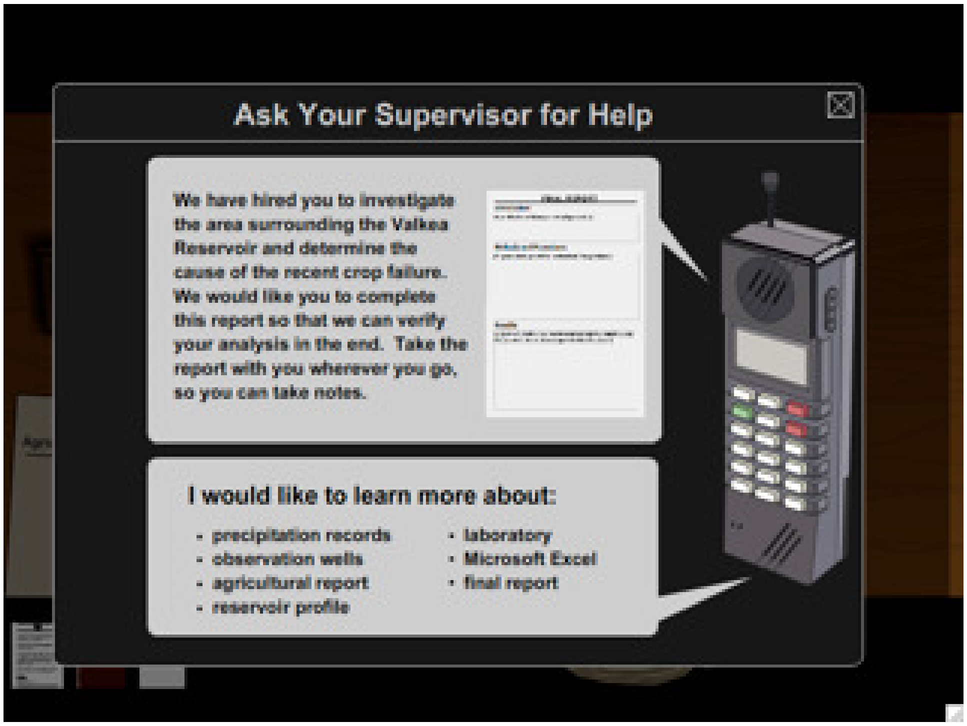

Figure A-39 Final Report Help

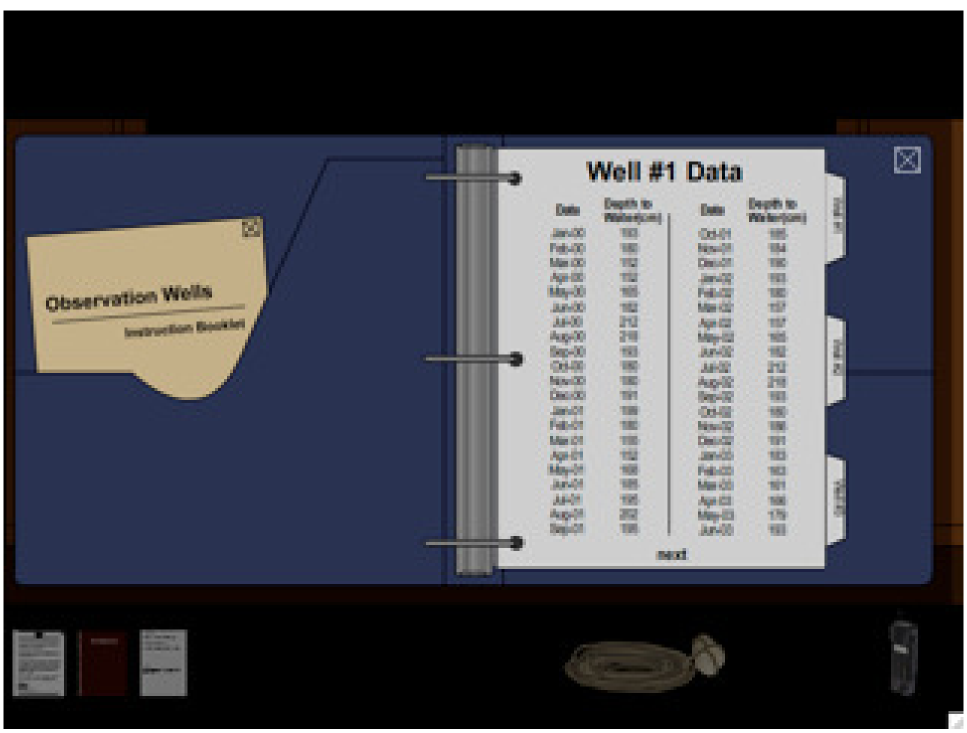

Figure A-40 Observation Well Data

Figure A-41 Observation Wells Pamphlet

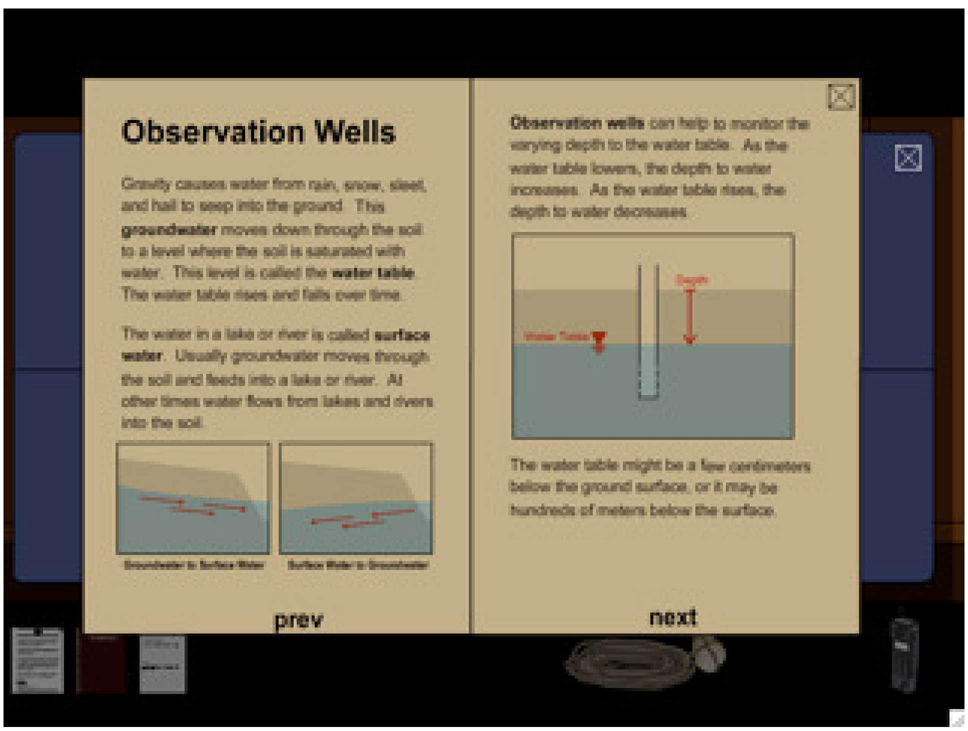

Figure A-42 Observation Wells Pamphlet (cont.)

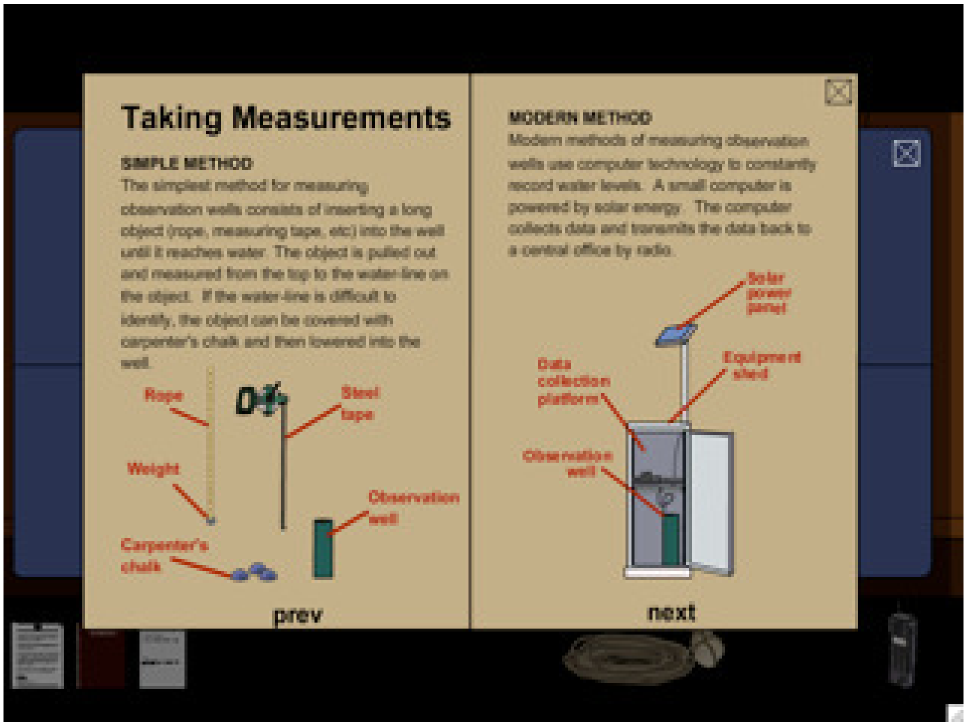

Figure A-43 Taking Observation Well Measurements

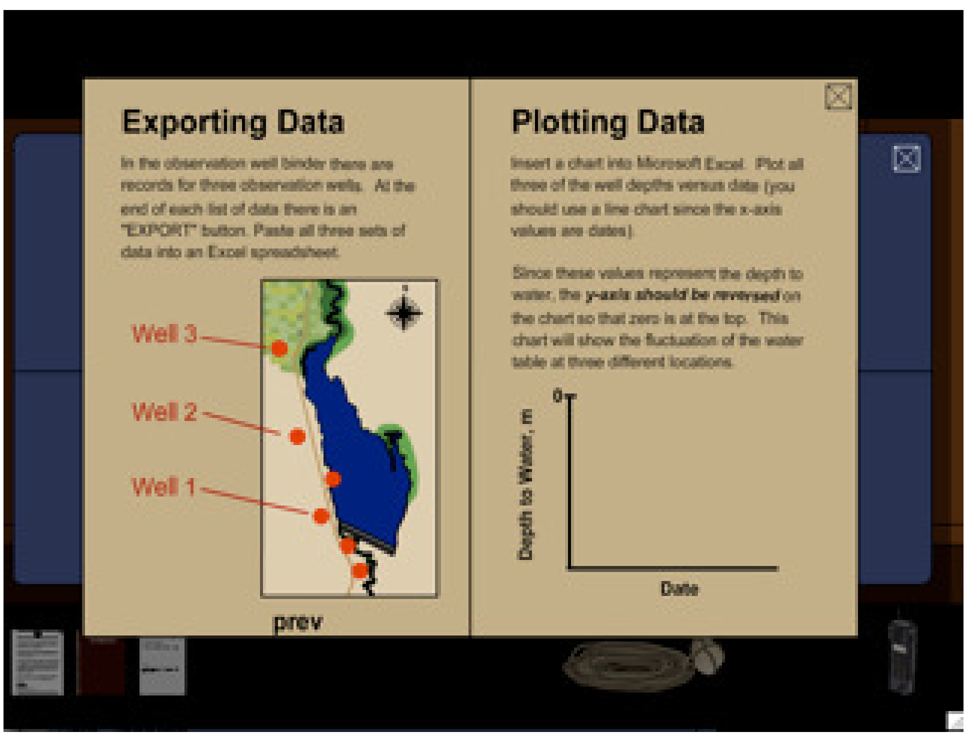

Figure A-44 Exporting and Plotting Well Data

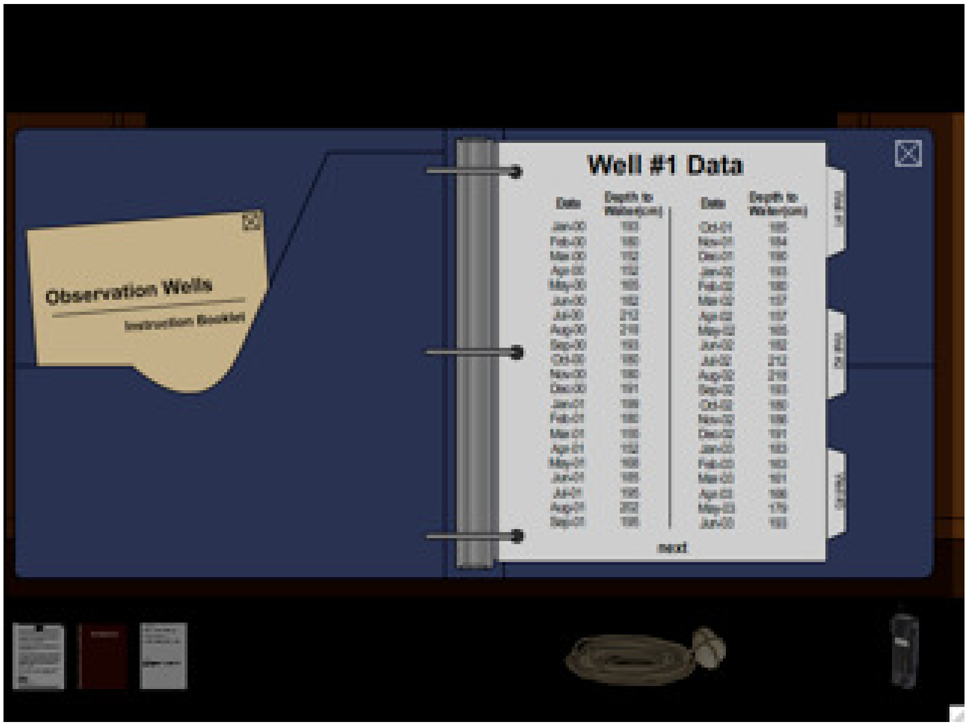

Figure A-45 Observation Well #1 Data

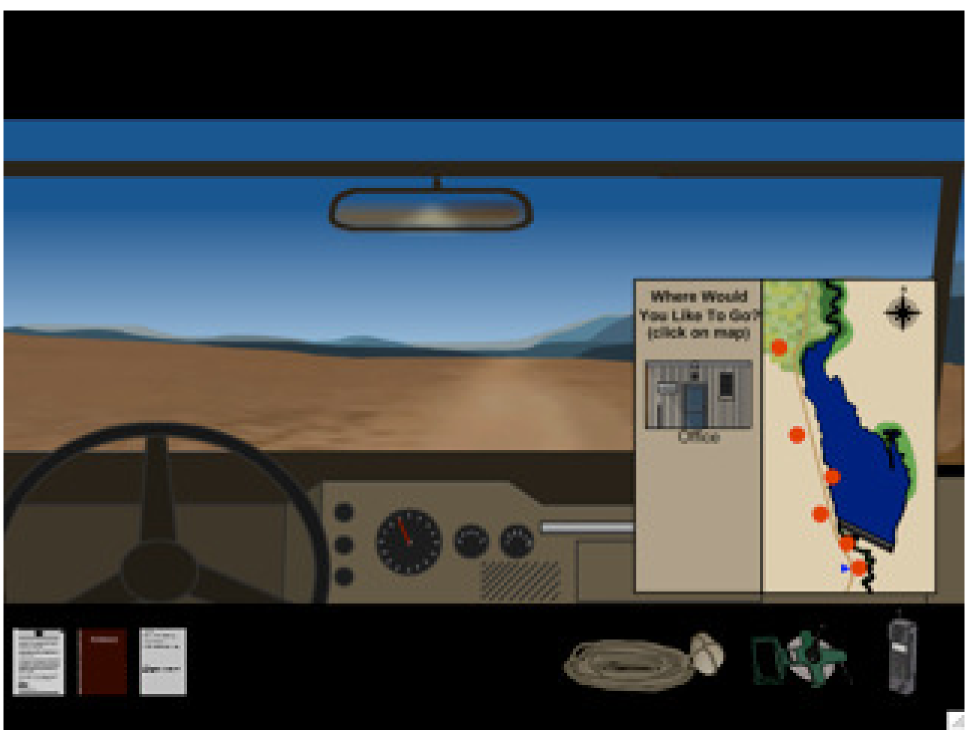

Figure A-46 Navigation Map

Figure A-47 Observation Well #3

Figure A-48 Observation Well #3 Cross-section

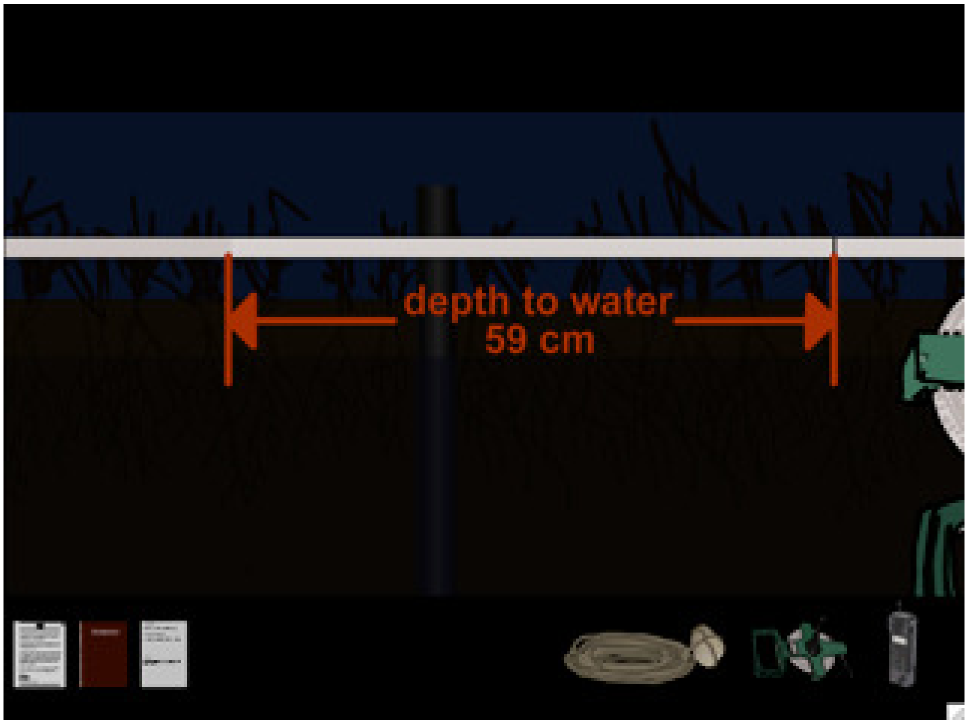

Figure A-49 Observation Well #3 Depth to Water

Figure A-50 View of Jeep from Observation Well #3

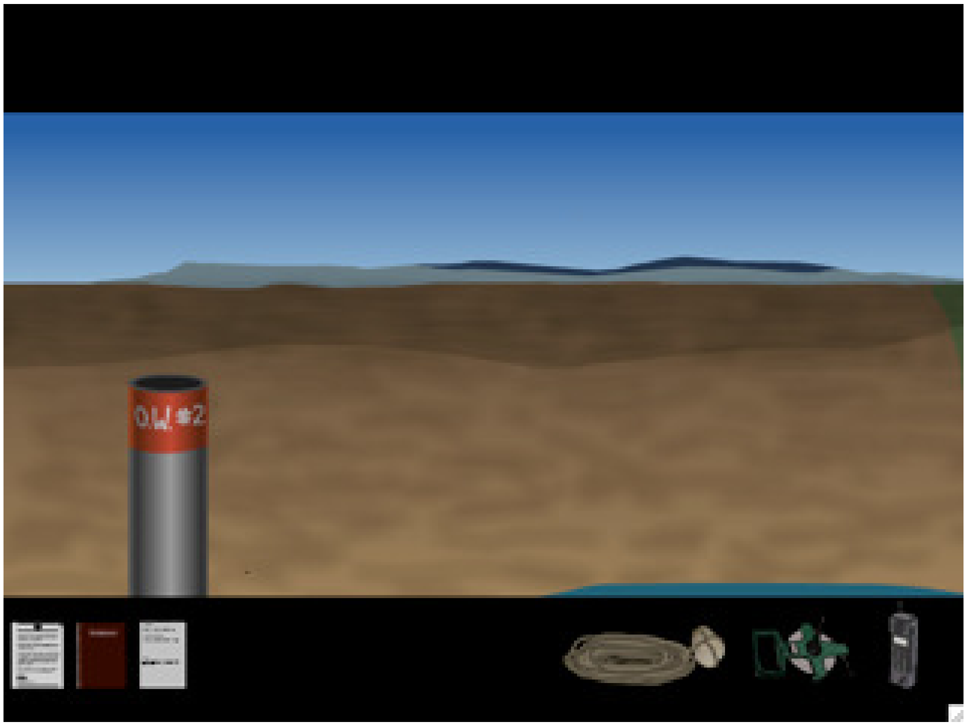

Figure A-51 Observation Well #2

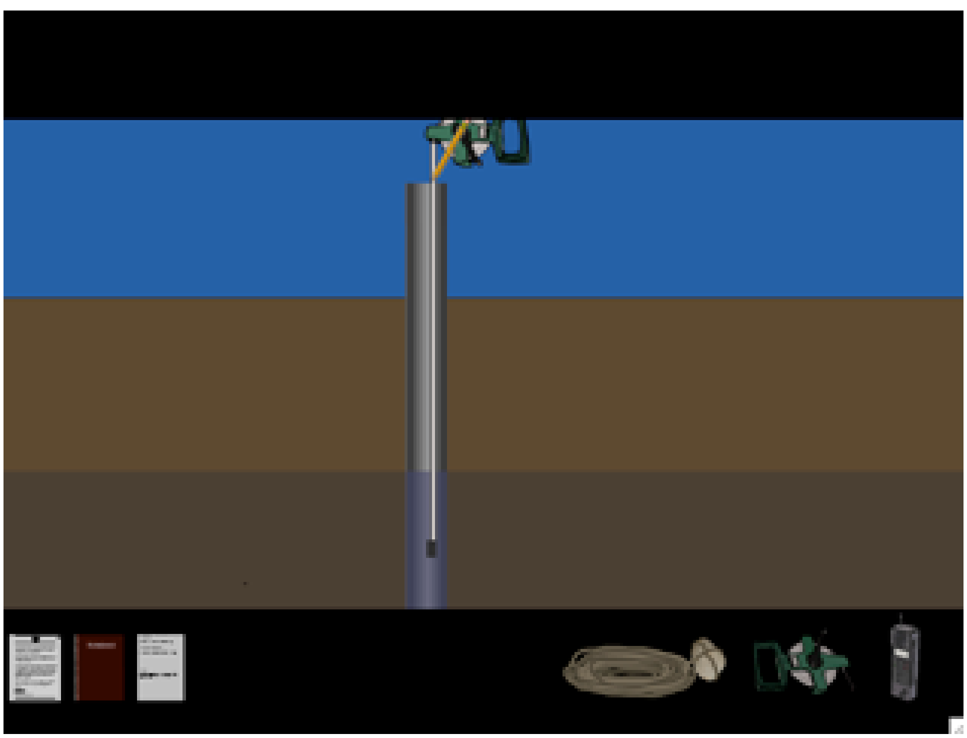

Figure A-52 Observation Well #2 Cross-section

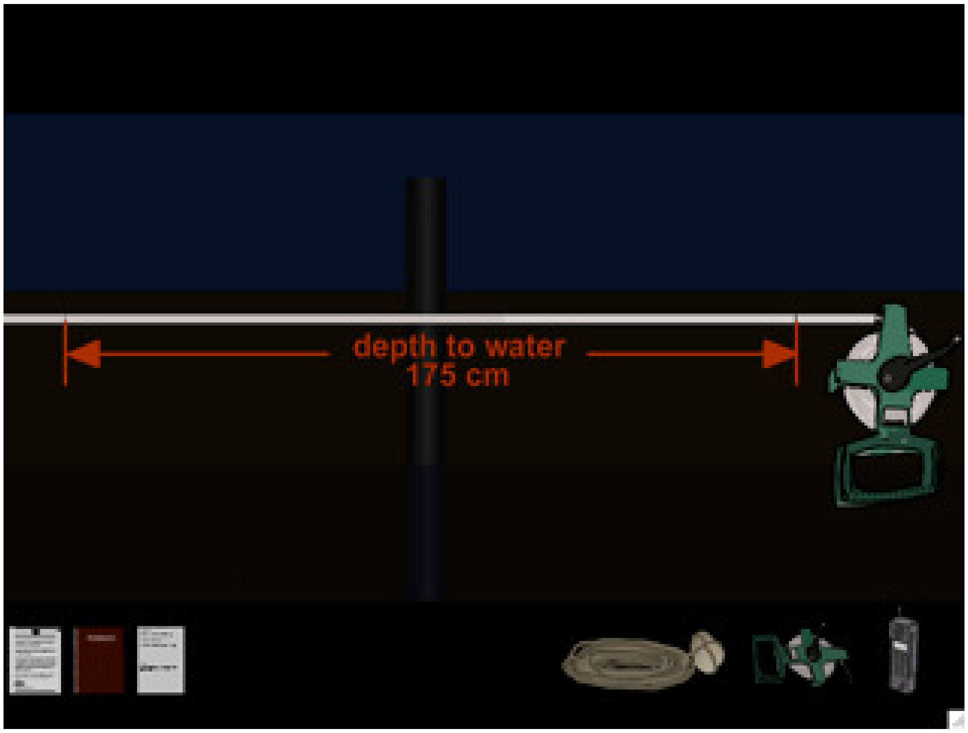

Figure A-53 Observation Well #2 Depth to Water

Figure A-54 View of Jeep from Observation Well #2

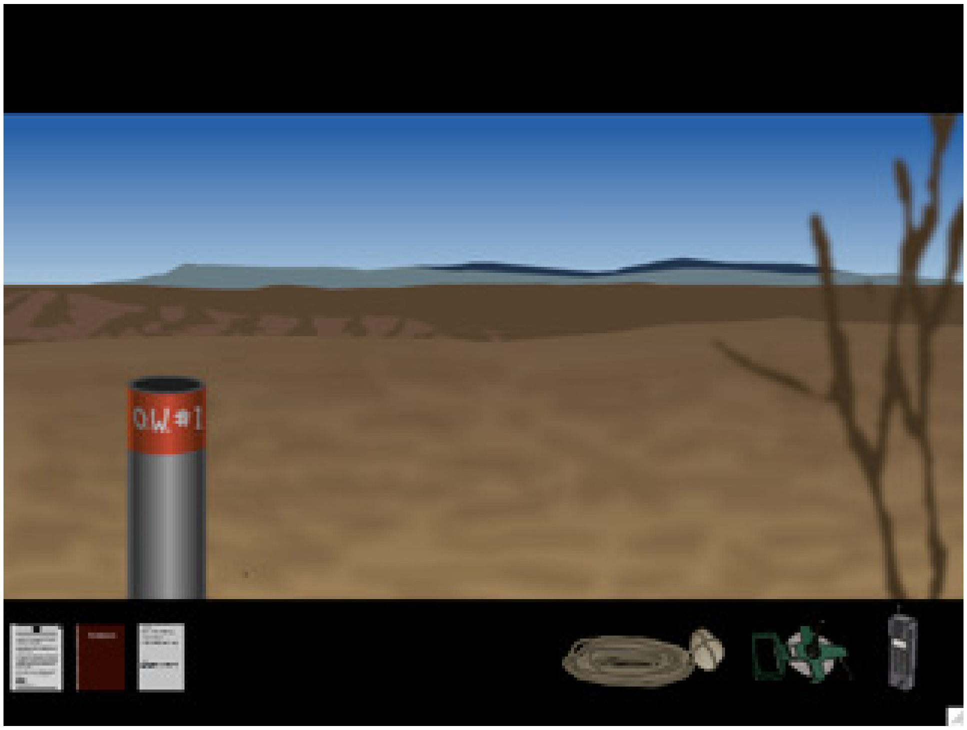

Figure A-55 Observation Well #1

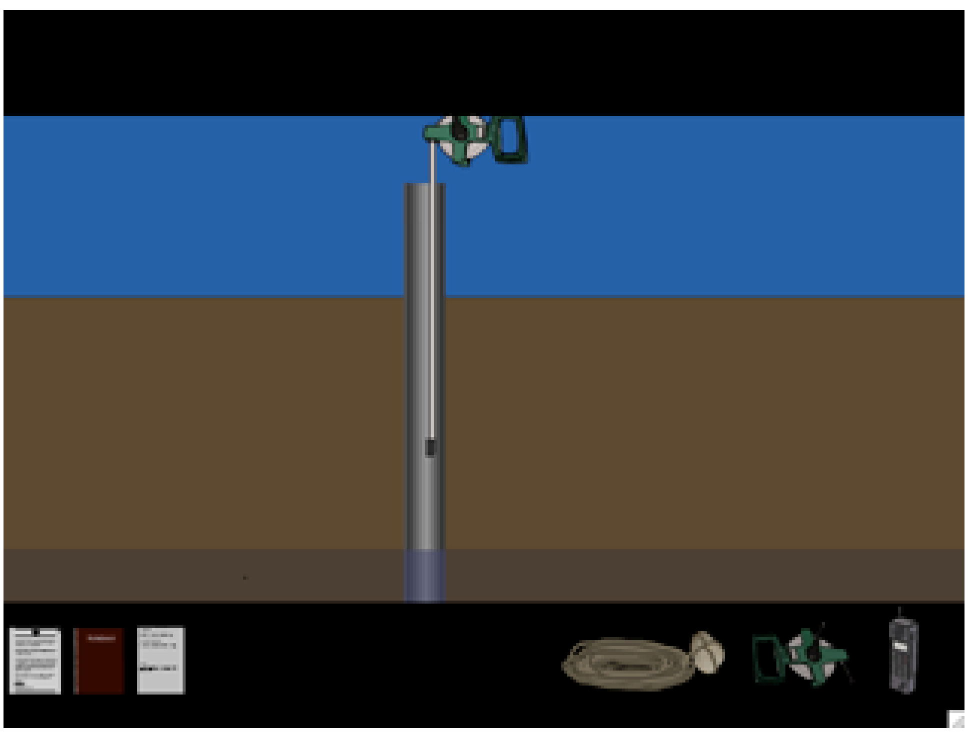

Figure A-56 Observation Well #1 Cross-section

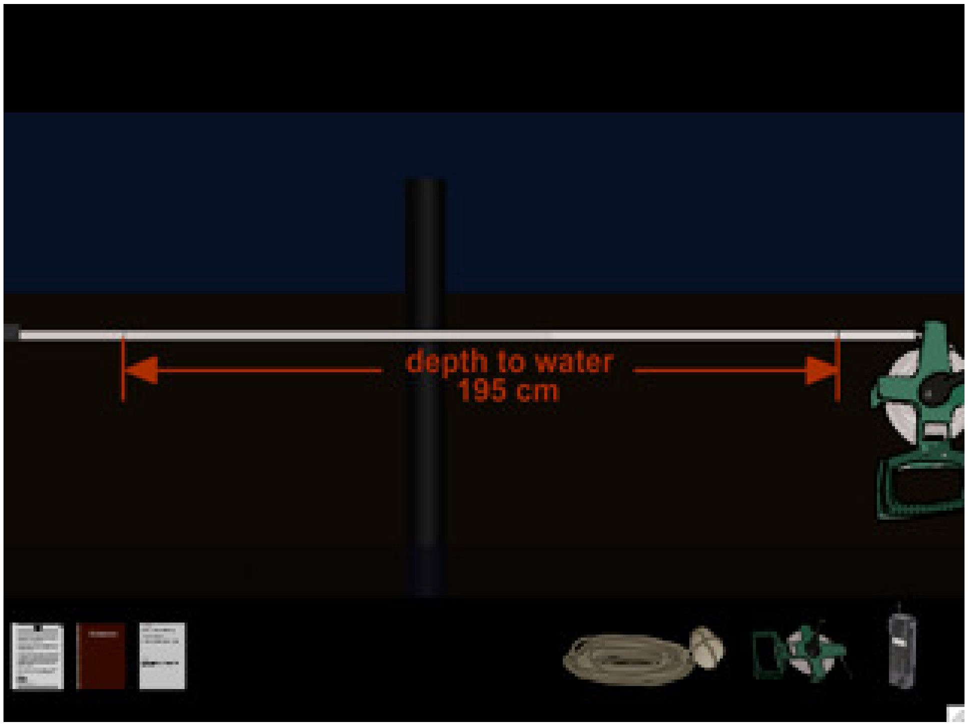

Figure A-57 Observation Well #1 Depth to Water

Figure A-58 View of Jeep from Observation Well #1

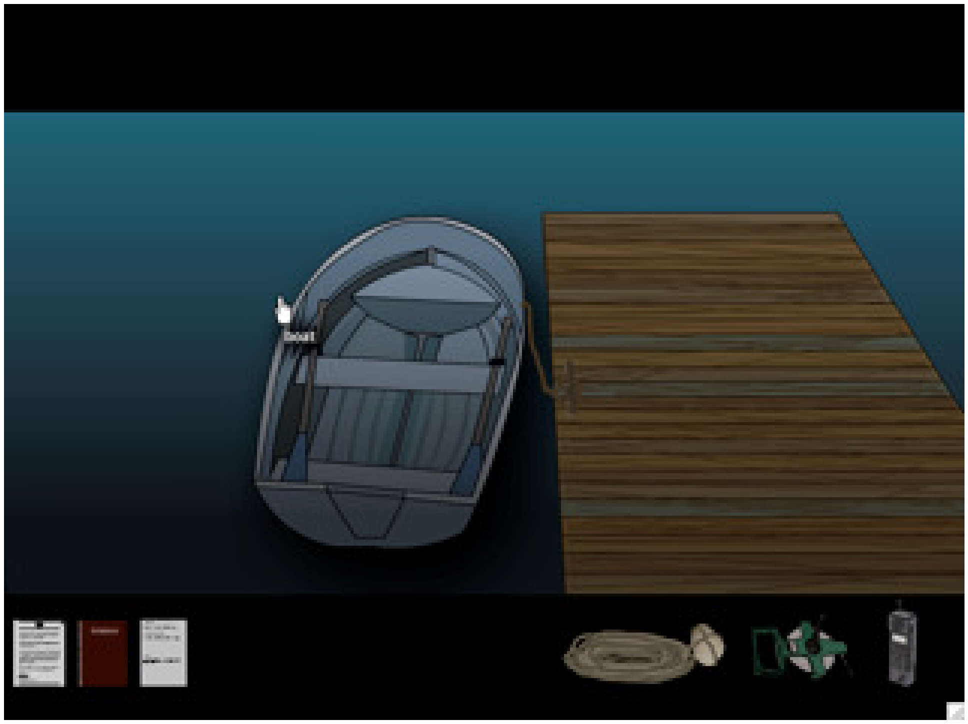

Figure A-59 Dock with Boat

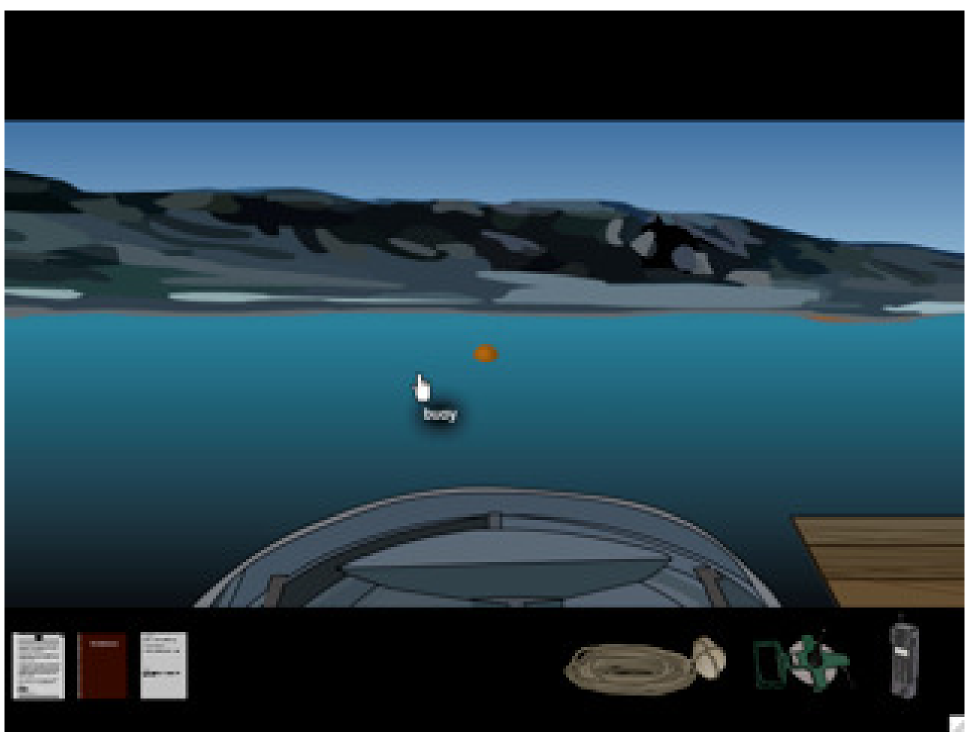

Figure A-60 View of Buoy from Dock

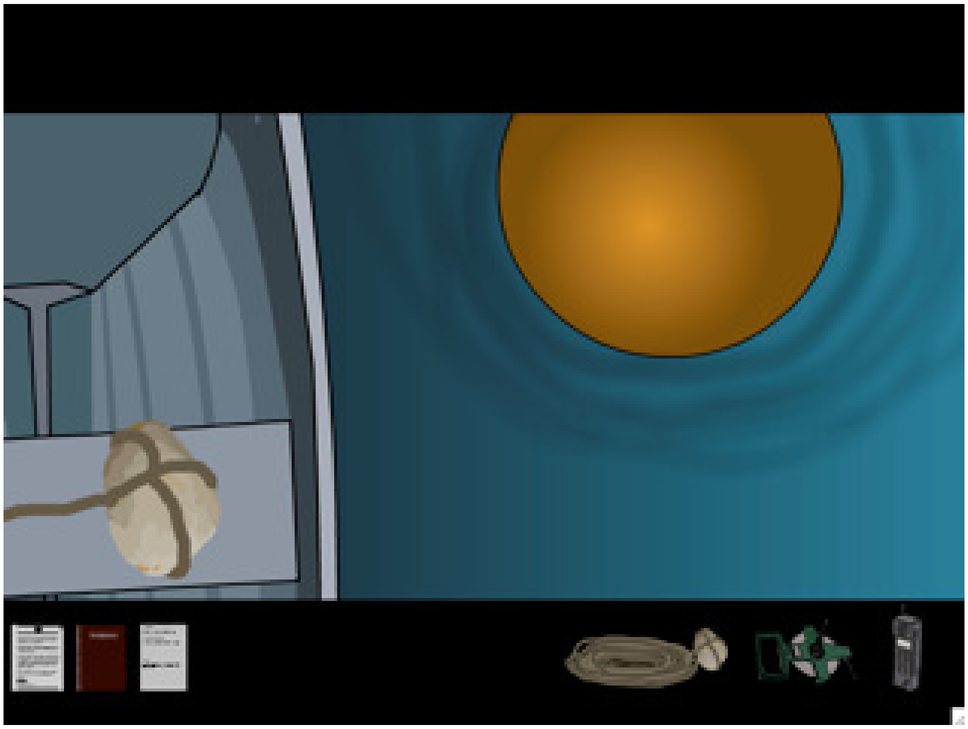

Figure A-61 Buoy

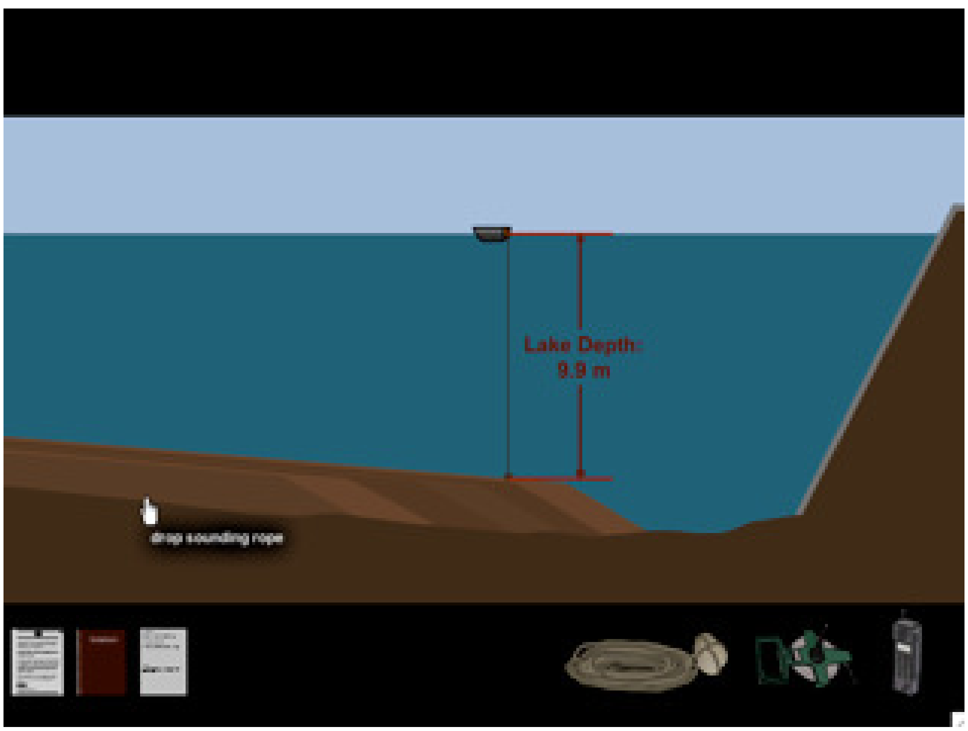

Figure A-62 Reservoir Depth Measurement

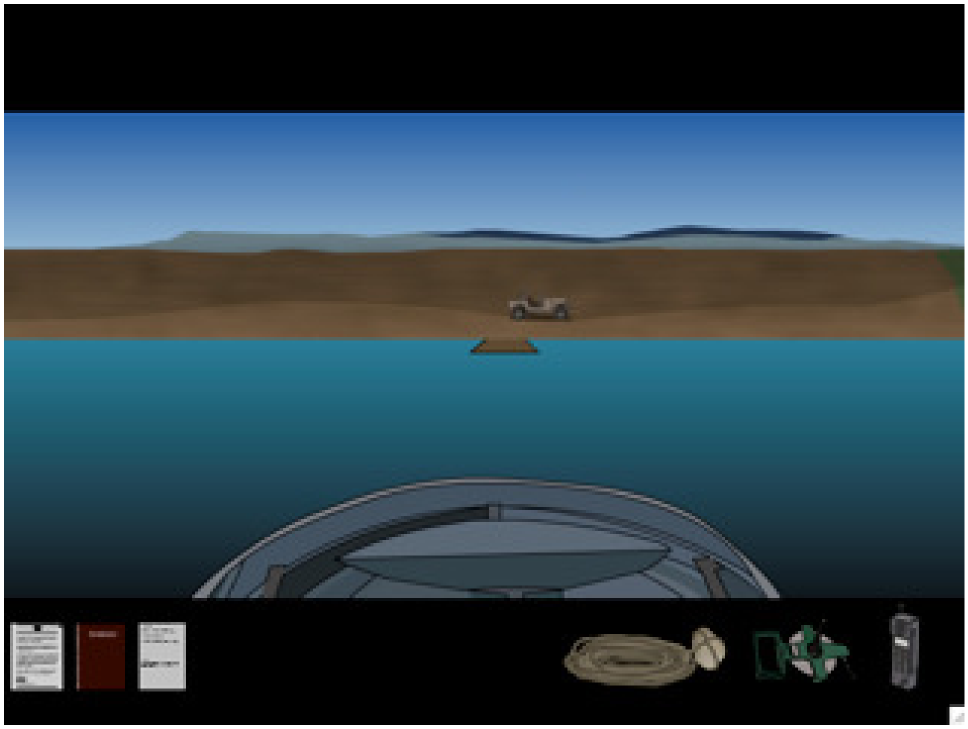

Figure A-63 View of Shore from Buoy

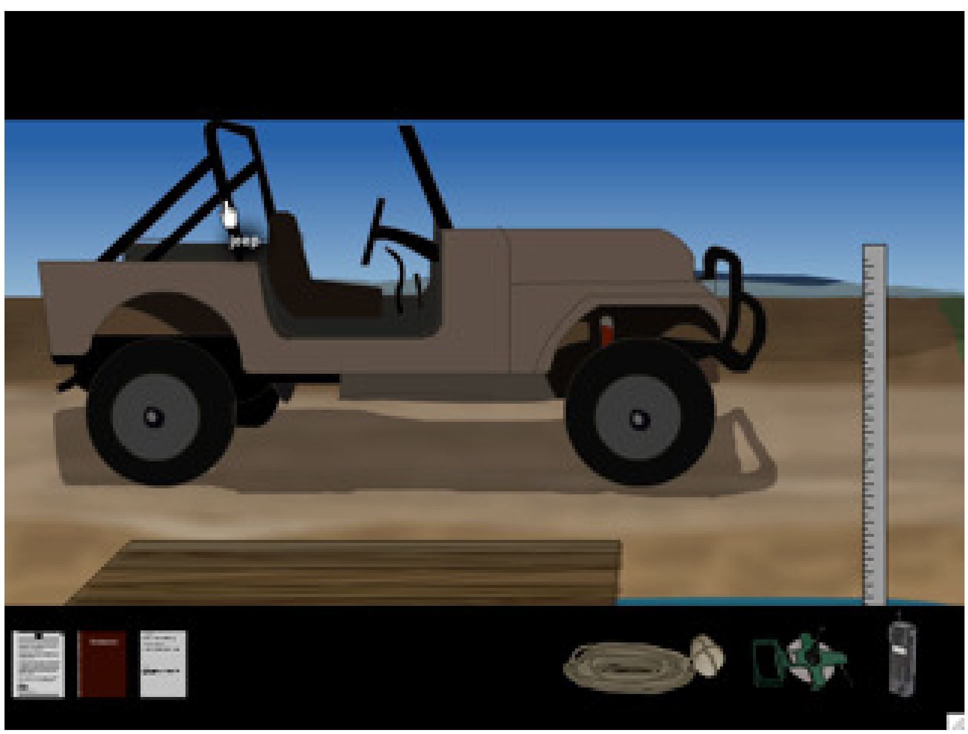

Figure A-64 View of Jeep from Dock

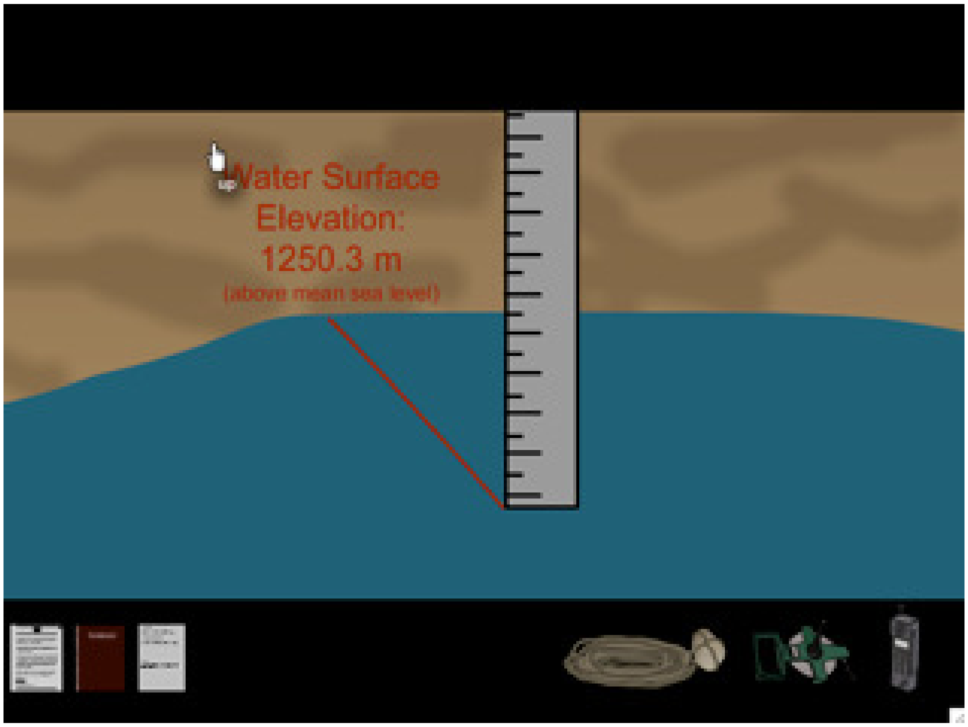

Figure A-65 Reservoir Stage Meter

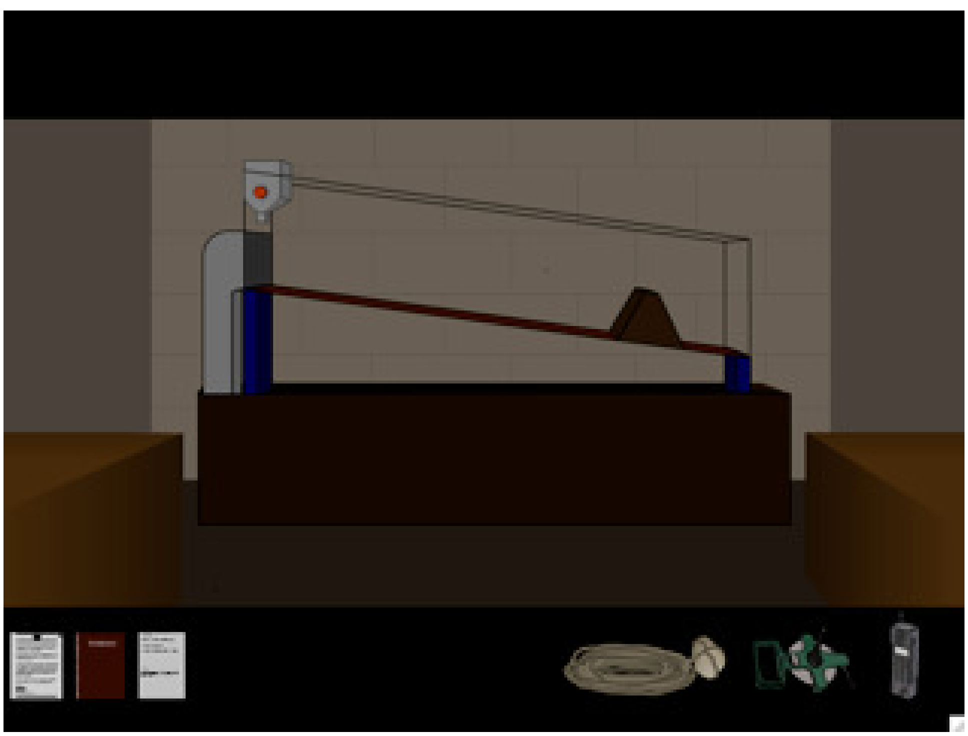

Figure A-66 Experimental Flume

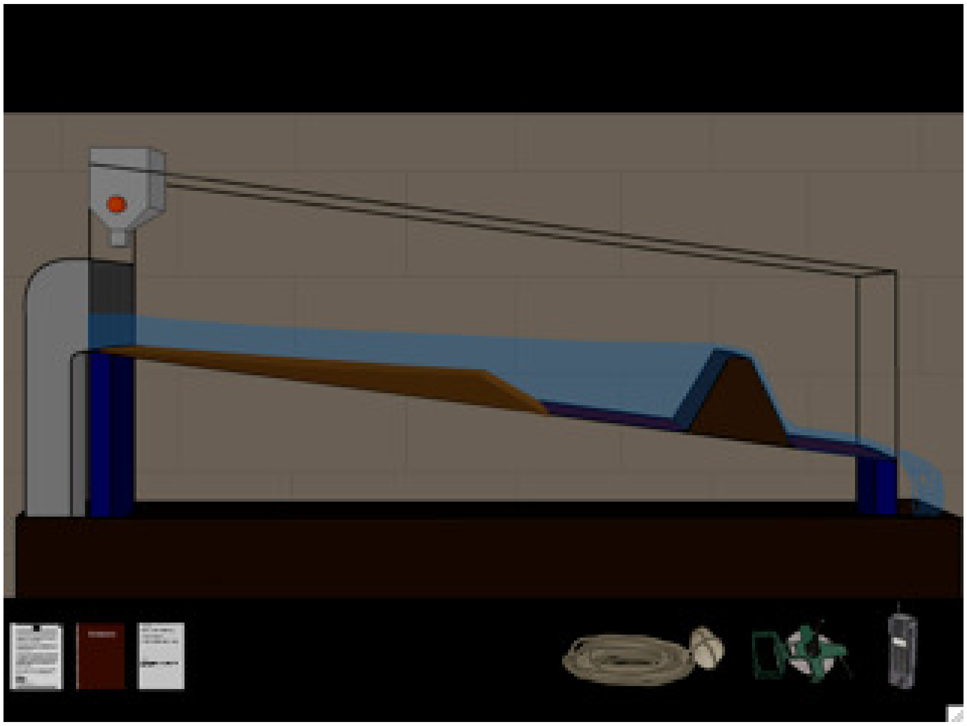

Figure A-67 Depositional Delta in Flume

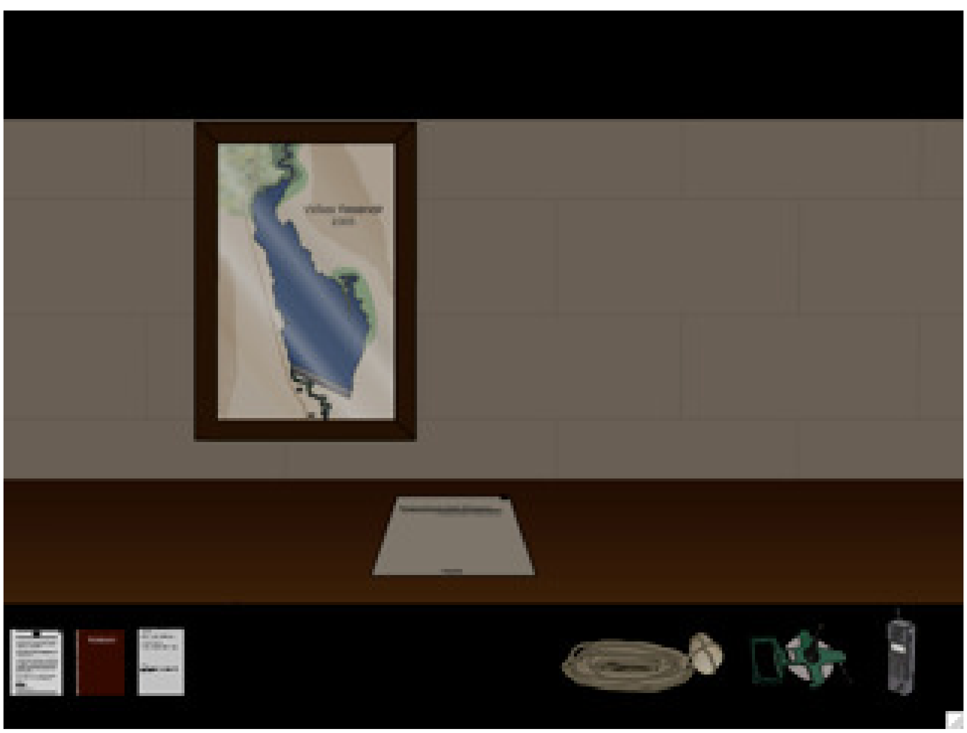

Figure A-68 Laboratory Desk

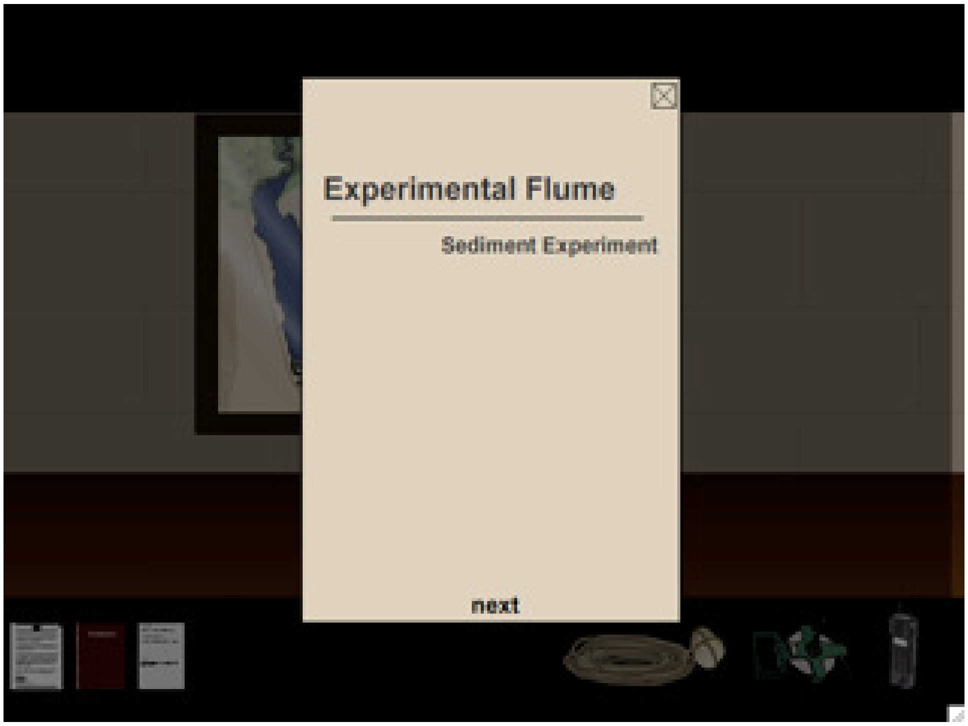

Figure A-69 Experimental Flume Pamphlet

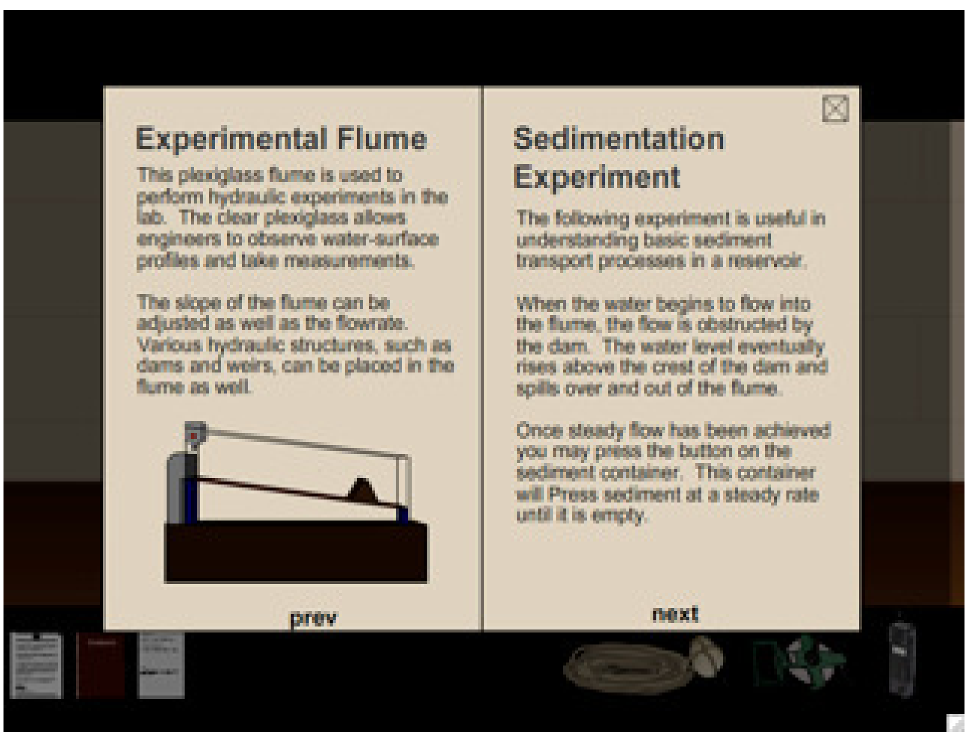

Figure A-70 Sediment Experiment Instructions

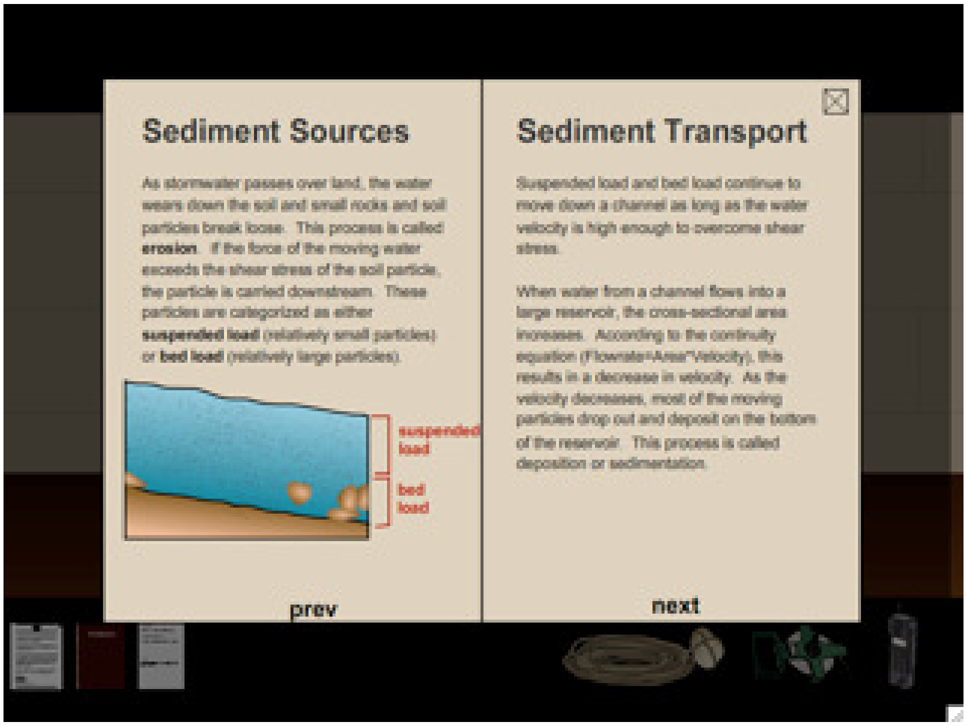

Figure A-71 Sediment Transport Information

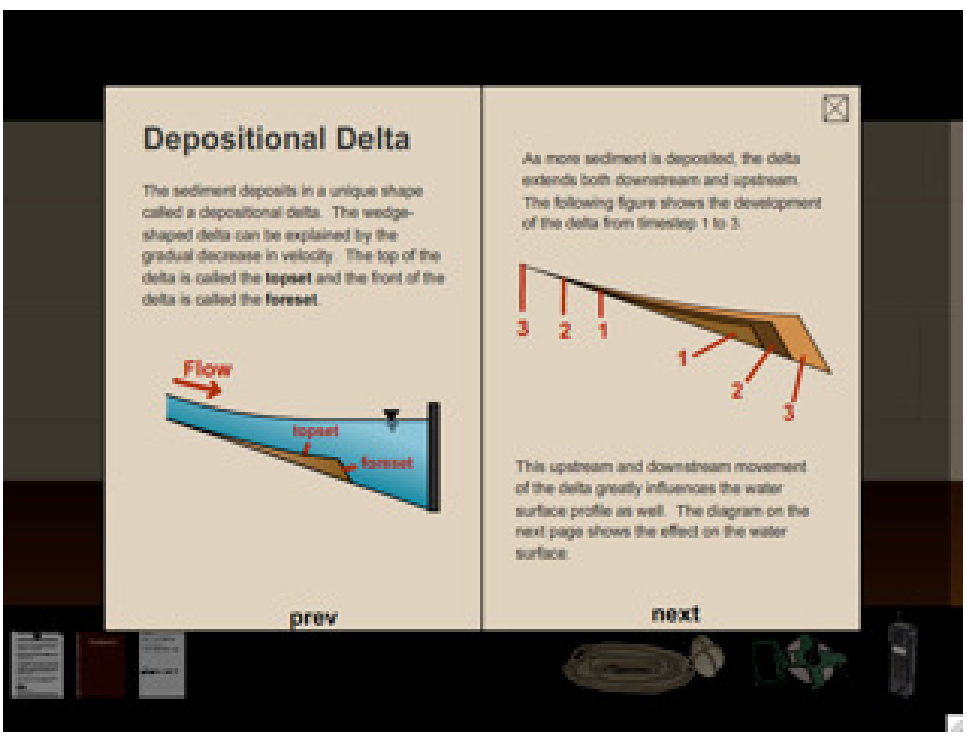

Figure A-72 Depositional Delta Description

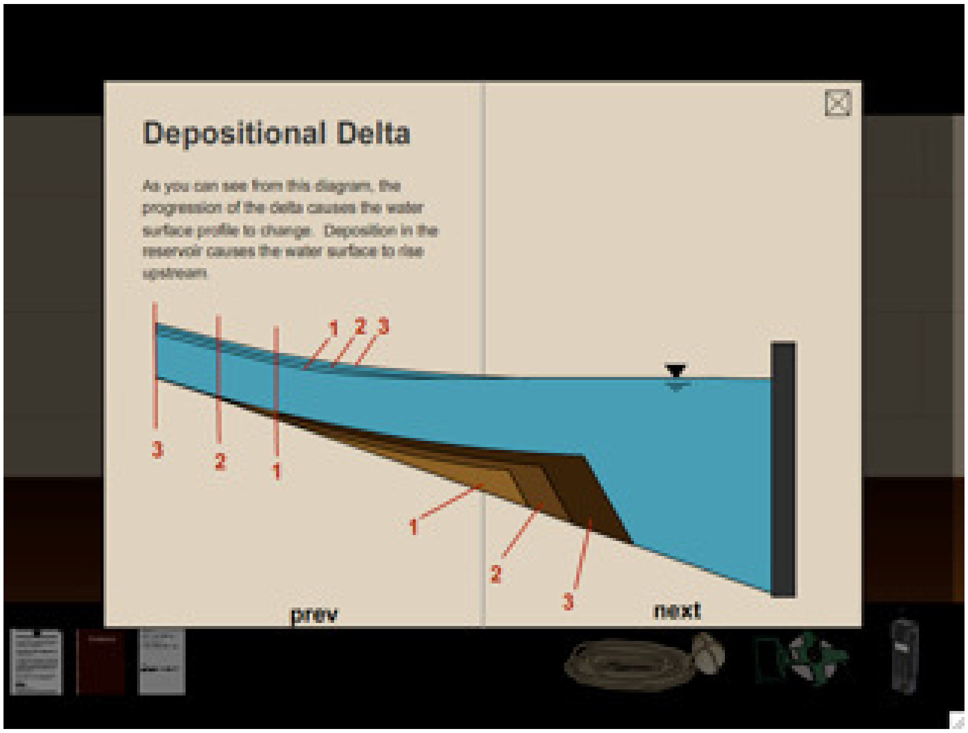

Figure A-73 Depositional Delta Detail

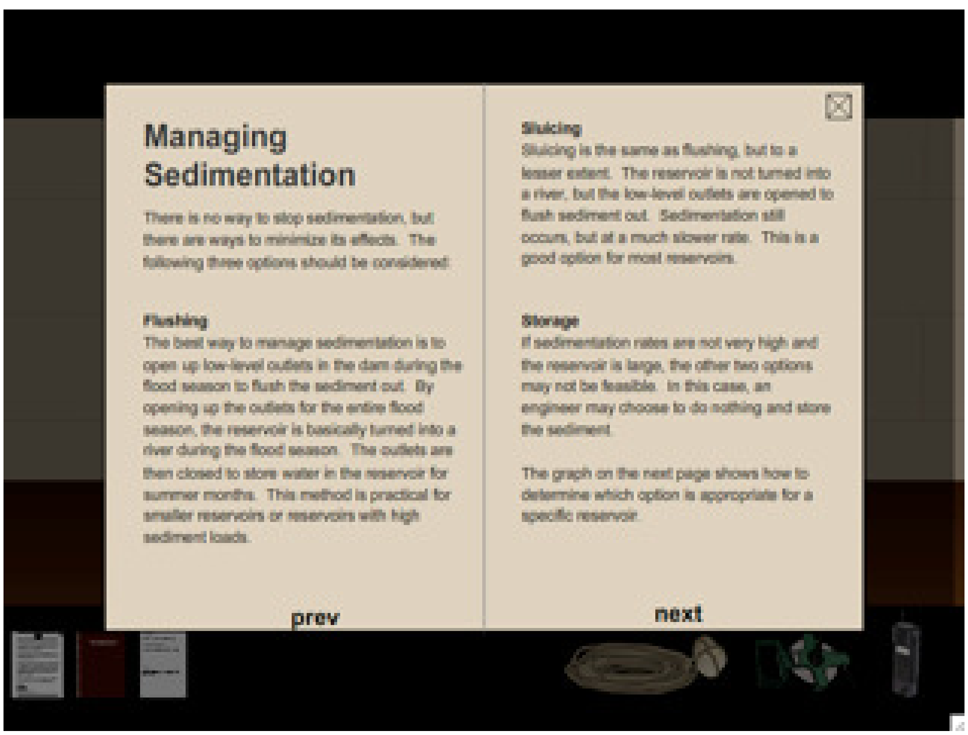

Figure A-74 Managing Sedimentation Information

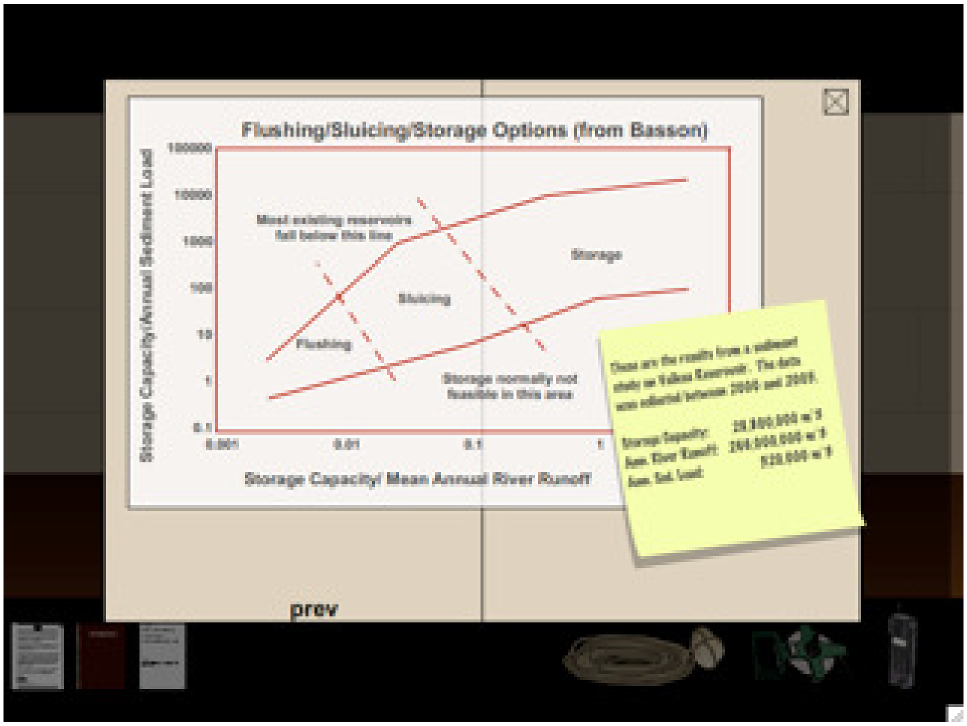

Figure A-75 Sediment Management Graph

Figure A-76 Laboratory Exit