An Ecosystem Services Approach to Water Resources

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Summary

In this three-week module, students will investigate the ecosystem services associated with local land use and its relation to water. Students will be introduced to ecosystem services as a way of integrating the components of the hydrologic cycle as a system, synthesizing the interaction between the hydrosphere, geosphere, and biosphere, and linking those processes to the needs and aspirations of particular communities in particular places. Rezoning, annexation, and land-use changes are some of the most common issues that come before local governing bodies; many of these changes involve natural areas and green spaces becoming industrial, commercial, or residential developments. By the end of the module, students will be equipped to actively engage in the public dialogues that are typically part of the process, from understanding and analyzing a problem to presenting reasonable solutions from particular stakeholders' perspectives.

Strengths of the Module

Students who learn with this module will:

- Be able to recognize the range and variety of ecosystem services associated with land use and its relation to the hydrologic cycle. They accomplish this by evaluating how the production of ecosystem services varies over time and among multiple land uses and land covers, explaining the hydrologic cycle using authentic rainfall and runoff data, and assessing human impacts on different components of the hydrologic cycle using a systems-thinking approach.
- Be able to infer and estimate the ecosystem services of natural or pervious land cover based on modeling the impact of development on the hydrologic cycle, specifically stormwater runoff. They accomplish this by modeling the impact of development on stormwater runoff and by assessing methods to mitigate the impact of development on stormwater runoff using low impact development.
- Be able to articulate and evaluate the impact of land use change on water resources utilizing an ecosystem services approach. They accomplish this by recognizing the interests and values of multiple stakeholder groups, creating a presentation, supported by hydrologic data, that aligns with stakeholder group interests, and assessing an ecosystem services approach to land use change.

A great fit for courses in:

- Ecology
- Environmental Studies
- Environmental Science
- Earth Science
- Environmental Ethics
- Land Use Planning and Design
- Physical Geography
- Sustainability

This introductory to intermediate-level module contains three units and is designed to be implemented over three weeks. The overall goal of the module is to use an ecosystem services approach to engage in civic discourse concerning land-use change.

Supported community developed, nationally-recognized Earth Science Literacy Principles :

- Earth Science Literacy 1.1: Earth scientists find solutions to society's needs.
- Earth Science Literacy 1.2: Earth scientists use a large variety of scientific principles to understand how our planet works.
- Earth Science Literacy Big Idea 3: Earth is a complex system of interacting rock, water, air, and life.
- Earth Science Literacy Big Idea 4: Earth is continuously changing.
- Earth Science Literacy Big Idea 5: Earth is the water planet
- Earth Science Literacy Big Idea 7: Humans depend on Earth for resources.
- Earth Science Literacy 8.1: Natural hazards result from natural Earth processes.
- Earth Science Literacy 8.7: Humans cannot eliminate natural hazards, but can engage in activities that reduce their impacts.
- Earth Science Literacy 8.8: An Earth-science-literate public is essential for reducing risks from natural hazards.

Addressed community developed, nationally-recognized Atmospheric Science Literacy Principles :

- Atmospheric Science Literacy Essential Principle 5: Earth's atmosphere continually interacts with the other components of the Earth System.
- Atmospheric Science Literacy Essential Principle 7: Earth's atmosphere and humans are inextricably linked.

Instructor Stories: How this module was adapted
for use at several institutions »

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- Assessment
- Instructor Stories
- Join the Community

View the Instructor Materials »

Related publication:

- Barbanell E., Jarchow M., Ritter J. (2019) Using Ecosystem Services to Engage Students in Public Dialogue About Water Resources. In: Gosselin D., Egger A., Taber J. (eds) Interdisciplinary Teaching About Earth and the Environment for a Sustainable Future. AESS Interdisciplinary Environmental Studies and Sciences Series. Springer, Cham

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Instructor Materials: Overview of the *An Ecosystem Services Approach to Water Resources Module*

Module Goal: To use an ecosystem services approach to engage in civic discourse concerning land-use change. See a [Conceptual model of Hydrologic Ecosystem Services](#) (Acrobat (PDF) 338kB Jan5 18).

Summative Assessment: The summative assessment for the module has two parts. The first part is a group presentation where students will develop a presentation describing a proposed land-use change and mitigation strategy from the perspective of a particular stakeholder group. The second part consists of reflective questions that should be completed individually.

These materials have been reviewed for their alignment with the Next Generation Science Standards. At the top of each page, you can click on the NGSS logo to see the specific connections. Visit [InTeGrate and the NGSS](#) to learn more about the process of alignment and how to use InTeGrate materials to implement the NGSS.

NGSS in this Module

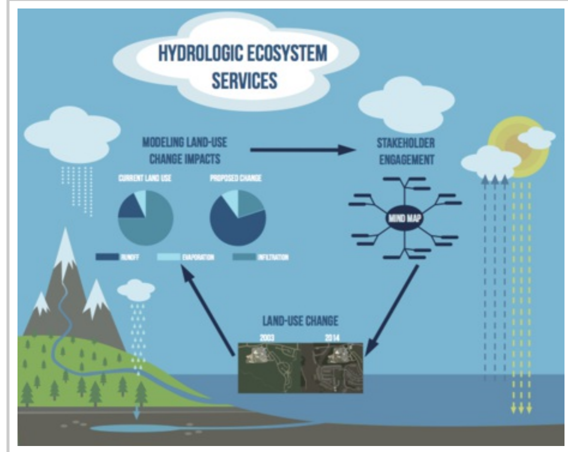
This module provides a series of activities for students to investigate the ecosystem services associated with local land use and its relation to water that could be modified for use by students in K-12 settings. Throughout the module students use Google Earth and EPA's National Stormwater Calculator to model the impact of land cover changes on stormwater runoff. The National Stormwater Calculator could be used at the middle and high school level as can much of the introductory PowerPoints and Google Earth activities.

[Unit 1Recognizing Ecosystem Services and their Relation to the Hydrologic Cycle](#)

At the end of this unit, students will be able to (1) recognize a variety of ecosystem services, (2) identify/describe those services related to the hydrologic cycle, and (3) infer how qualitative changes in land use/cover affect the hydrologic inputs/outputs.

- [Unit 1.1: Mapping Ecosystem Services](#) — Students identify land use and land cover and associated ecosystem services from aerial photographs or maps.
- [Unit 1.2: Exploring the Hydrologic Cycle](#) — Students use rainfall and runoff data to explore the hydrologic cycle and develop a simple hydrologic model (i.e., a regression between rainfall and runoff).
- [Unit 1.3: Understanding Perturbations to Hydrologic Systems](#) — Students use rainfall and runoff data from different land uses to understand perturbations to

hydrologic systems using a systems-based approach.



Unit 2Measuring and Modeling Ecosystem Services

Students will model the impact of changes in land cover on stormwater runoff. At the end of this module, students will be able to execute the model for a proposed land-use change and judge the effectiveness of different types of low-impact development to mitigate change in stormwater runoff.

- Unit 2.1: Hydrologic Impact of Land-Use Change — Students use the National Stormwater Calculator to model the hydrologic impact related to land-use change.
- Unit 2.2: Mitigation Using Low-Impact Development (LID) Controls — Students explore how inputs in the National EPA Stormwater Calculator relative to low impact development allow it to be used for mitigation.
- Unit 2.3: Modeling Land-Use Change and Mitigation Strategies — Students examine the impact of a proposed scenario involving a land-use change and model mitigation strategies.

Unit 3Using an Ecosystem Services Approach for Civic Engagement

Students will create a persuasive argument pertaining to a land-use change that utilizes geoscientific and other data. Students will recognize what stakeholder groups are and how they often have varying interests and values. Students will create a position paper advocating for or against a proposed land-use change.

- Unit 3.1: Land-Use Change and Stakeholders — Students evaluate a proposed land-use change based on perspectives of different stakeholder groups.
- Unit 3.2: Presentation and Reflection — Students compose a position paper for or against a proposed land-use change.

Making the Module Work

To adapt all or part of the Ecosystem Services Approach to Water Resources Module for your classroom you will also want to read through

- Instructor Stories, which detail how the Ecosystem Services Approach to Water Resources Module was adapted for use at three different institutions, as well as our guide to
- Adapting InTeGrate Modules and Courses for Your Classroom, which outlines how to effectively use InTeGrate modules and courses.

Considering using these materials with your students? **Already used some of these materials in a course?**

Get pointers and learn about how it's working for your peers in their classrooms »

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Unit 1: Recognizing Ecosystem Services and their Relation to the Hydrologic Cycle

Developed by Ed Barbanell (University of Utah), Meghann Jarchow (University of South Dakota), and John Ritter (Wittenberg University)
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Profile Meghann Jarchow, University of South Dakota
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Summary

In this module, students investigate the ecosystem services associated with local landscapes, particularly in relation to water resources. This unit, the first of three, provides students with the foundational knowledge, tools, and techniques they will need for exploring the services that natural landscapes provide to humans, with a specific focus on assessing the impact of land-use changes on water runoff. In Unit 1.1, students are introduced to the concept of "ecosystem services," and then, using Google Earth, they identify land use and land-use changes that affect those services. In Unit 1.2, students are introduced to some of the technical vocabulary associated with watersheds, watershed hydrology, and the water balance equation; this is accomplished using actual rainfall-runoff data for a small watershed in Ohio as an example. In Unit 1.3, students evaluate the impact of human-induced changes in land cover and land use on watershed hydrology and water balance in the context of ecosystem services.

Learning Goals

Used this activity? Share your experiences and modifications

Learning goal: Students will be able to recognize the range and variety of ecosystem services associated with land use and its relation to the hydrologic cycle.

Objectives to accomplish this learning goal:

1. Students will be able to evaluate how the production of ecosystem services varies over time and among multiple land uses and land covers.
2. Students will be able to explain the hydrologic cycle using authentic rainfall and runoff data.
3. Students will be able to assess human impacts on different components of the hydrologic cycle using a systems-thinking approach.

Context for Use

The activities in this unit are designed to be used in order and together, but they can also be used individually, with slight modifications. These activities would be appropriate in a range of introductory courses, including courses in sustainability, ecology, environmental science, Earth science and geology, land use planning, anthropology, water resources, and landscape design.

Class Size: This unit can be adapted for a variety of class sizes.
Class Format: These activities are designed for individual lecture sessions, but are suitable for use in a lab setting or as a homework assignment as well. Students can work together, in groups of 2–4, but each student should complete his/her own assignment.
Time Required: The activities are designed to be completed in 50-minute class periods.
Special Equipment: Student groups should have a computer with Google Earth installed. If that is not possible, the instructor can print out the information before class. Not every student needs a computer for this unit, but at least one computer must be available for each group. From the instructors' experiences, having at least one computer per three students is ideal.
Skills or concepts that students should have already mastered before encountering the activity: Units and sub-units in this module are self-contained and presume no familiarity with basic concepts of either ecosystem services or the hydrologic cycle.

Description and Teaching Materials

This unit is made up of three activities:

- Unit 1.1: Mapping Ecosystem Services
- Unit 1.2: Exploring the Hydrologic Cycle
- Unit 1.3: Understanding Perturbations to Hydrologic Systems

The first activity introduces students to the concept of ecosystem services and the use of the Google Earth tool. Students then use the tool to explore landscapes and land-use change, and to evaluate ecosystems services provided by those landscapes. The following two activities focus the study of ecosystem services on the hydrologic cycle. Students use authentic rainfall and runoff data to evaluate impacts on ecosystem services associated with land-use change.

Teaching Notes and Tips

The activities in this unit are designed to be used together, in three 50-minute class sessions, but Unit 1.3 could easily be modified to be completed outside of class. Depending on the class, rainfall-runoff data may be developed locally using data from National Oceanic and Atmospheric Administration (rainfall) and U.S. Geological Survey (streamflow) as a class project. The streamflow data was processed using online hydrograph separation tools available from Purdue University.

Assessment

Assessment activities and associated rubrics are included with each section of the activity. Each of these activities can be included in the class session or assigned as work outside of class.

See the Assessments page for the full list of assessments.

References and Resources

Two readings are included to introduce instructors and students to ecosystem services:

- Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, D.C. and
- Ecosystem Services Fact Sheet (from the Ecological Society of America).

Additional Resources:

- The Graphic of Wetland Ecosystem Services (Acrobat (PDF) 113kB Apr9 15) can be used as the focus for the class session on ecosystem services.
- A good review of the hydrologic or water cycle is available from USGS.
- In preparation for the activities using rainfall-runoff data, students should read the Watershed Hydrology Literacy (Microsoft Word 2007 (.docx) 1.5MB Aug25 16) handout. This handout defines key terms and concepts associated with the hydrologic cycle, watersheds, and water balance.
- An optional watershed literacy quiz (Watershed Hydrology Literacy Assessment (Microsoft Word 2007 (.docx) 14kB Dec1 16)) can be used prior to or following the class.
- Rainfall-runoff data are included for two watersheds in northern Ohio, Rock Creek and Big Creek watersheds, in table form (Rainfall-Runoff Data and Plot (Microsoft Word 2007 (.docx) 46kB Aug28 15)) and a graph with data from the Rock Creek watershed is included for students to use as a template for analyzing the data.

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Unit 1.1: Mapping Ecosystem Services

Developed by Ed Barbanell (University of Utah), Meghann Jarchow (University of South Dakota), and John Ritter (Wittenberg University)
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These materials have been reviewed for their alignment with the Next Generation Science Standards as detailed below. Visit InTeGrate and the NGSS to learn more.

Overview

In this activity, students identify ecosystem services, classify them into one of the four categories as described in the Millennium Ecosystem Assessment (MA), and evaluate how the production of ecosystem services varies over time. Students use Google Earth image data to observe, characterize, and analyze landscapes from different ecosystems.

Science and Engineering Practices

Analyzing and Interpreting Data: Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. MS-P4.2:

Analyzing and Interpreting Data: Analyze and interpret data to provide evidence for phenomena. MS-P4.4:

Cross Cutting Concepts

Stability and Change: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. MS-C7.1:

Patterns: Graphs, charts, and images can be used to identify patterns in data. MS-C1.4:

Disciplinary Core Ideas

Biodiversity and Humans: Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. HS-LS4.D1:

This activity was selected for the On the Cutting Edge Reviewed Teaching Collection

This activity has received positive reviews in a peer review process involving five review categories. The five categories included in the process are

- Scientific Accuracy
- Alignment of Learning Goals, Activities, and Assessments
- Pedagogic Effectiveness
- Robustness (usability and dependability of all components)
- Completeness of the ActivitySheet web page

For more information about the peer review process itself, please see https://serc.carleton.edu/teachearth/activity_review.html.

This page first made public: Dec 2, 2016

Summary

In this activity, students are introduced to the concept of ecosystem services, provided with a tool for exploring these services in particular landscapes, and led through a few examples so that they will be comfortable using the tool. Google Earth is presented as a tool for exploring landscapes and evaluating the ecosystem services provided by those landscapes, including spatial and temporal variability. Students use Google Earth to identify and classify ecosystem services according to the Millennium Ecosystem Assessment (MA) categories, first by looking at an example landscape along the the Missouri River, and then by looking at an example specific to their location.

Learning Goals

Used this activity? Share your experiences and modifications

Overall learning objective for this activity: Students will identify potential ecosystem services provided by multiple land uses and land covers.

Specific learning objectives for this activity:

1. Students will be able to define ecosystems and ecosystem services.
2. Students will be able to identify ecosystem services provided by an ecosystem.
3. Students will be able to classify those services according to one of the four categories as described in the Millennium Ecosystem Assessment (MA).
4. Students will be able to use the basic features of Google Earth.
5. Students will be able to evaluate how the production of ecosystem services varies

over time.

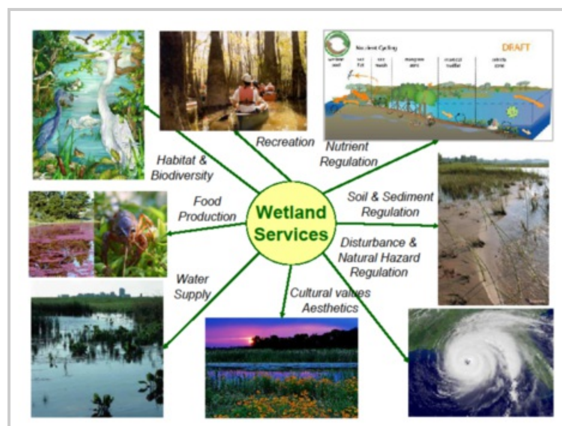
Context for Use

This activity may either be used alone as an introduction to the concept of ecosystem services, or it may be used as an introduction to the Ecosystem Services Approach to Water Resources Module. This activity would be appropriate in a range of introductory courses including sustainability, ecology, Earth science, land-use planning, anthropology, and landscape design.

Class Size: This activity can be adapted for a variety of class sizes.
Class Format: This activity is designed for individual lecture sessions, but it is suitable for use in a lab setting or as a homework assignment as well. Students can work together, in groups of 2–4, but each student should complete his/her own assignment.
Time Required: This activity is designed to be completed in a 50-minute class period.
Special Equipment: Each student group should have a computer with Google Earth installed. If that is not possible, the instructor can print out information before class. Not every student needs a computer for this activity, but at least one computer with Google Earth installed should be available for each group. From the instructors' experiences, having at least one computer per three students is ideal.
Skills or concepts that students should have already mastered before encountering the activity: This activity is self-contained and presumes no familiarity with basic concepts of ecosystem services or the hydrologic cycle.

Description and Teaching Materials

In preparation for this activity, students should read the PowerPoint "An Introduction to Ecosystem Services" (PowerPoint 2007 (.pptx) 5.7MB Nov30 16) and do the accompanying Worksheet on "An Introduction to Ecosystem Services" (Microsoft Word 2007 (.docx) 15kB Nov30 16) as homework prior to coming to class. Both of these documents can also be found on the Student Materials page, under Unit 1.1. The PowerPoint defines the concepts of "ecosystems" and "ecosystem services," provides the background for the Millennium Ecosystem Assessment (MA) and its categorization of ecosystem services, and gives an example of a set of ecosystem services provided by a coastal landscape.



http://www.epa.gov/wetlands/wetlands-education

During class, the students are instructed on how to use several features of Google Earth, including how to navigate to a specified location. They then apply the information from the PowerPoint to evaluate the landscape in that location: they identify several of the ecosystem services provided by the landscape and see how those services have changed over several years. Finally, they apply all this information and knowledge to a local landscape of the instructor's choosing.

Teaching Notes and Tips

Below is a lesson plan for a 50-minute class period. The [Unit 1.1 Presentation](#) (PowerPoint 2007 (.pptx) 5.6MB Nov30 16) is available and follows this lesson plan.

Introduction to the module, unit, and activity (5 min)

The introduction will vary depending on how much of the module is being used in the class. If the whole module is being used, the instructor should introduce the overall module goal to the class: To use an ecosystem services approach to engage in civic discourse concerning land-use change. We will be focusing on this for three weeks. The learning goals for the three weeks are:

- Week 1: Students will be able to recognize the range and variety of ecosystem services associated with land use and its relation to the hydrologic cycle.
- Week 2: Students will be able to infer and estimate the ecosystem services of natural or permeable land cover based on modeling the impact of development on the hydrologic cycle, specifically stormwater runoff.
- Week 3: Students will be able to articulate and evaluate the impact of land-use change on water resources utilizing an ecosystem services approach..

In preparation for class, students should have read the Unit 1.1 Before-class Introductory PowerPoint and completed the accompanying worksheet. These materials introduce students to the concepts of ecosystems and ecosystem services, and show the students how to identify ecosystem services provided by particular landscapes (learning objectives 1 and 2). Learning objectives 3–5 will be addressed in class.

The students will use Google Earth during class. If students have not already installed Google Earth on their computers, they should do that.

Group evaluation of a provided landscape (10 min)

Students will be introduced to the aerial satellite images available from Google Earth. An example from the Missouri River near Vermillion, South Dakota, will be used as the first example (slides 3–7). Slide 3 provides a labelled aerial photograph and slides 4–6 provide ground-level photographs of the same landscape. The instructor can also open Google Earth to navigate around current images of the same landscape (see slide notes).

Labeled Google Earth image of the confluence of the Vermillion and Missouri Rivers. This image is used in the in-class PowerPoint presentation.

After students are familiarized with what they are seeing in aerial satellite images, they should be asked to apply their knowledge from the before-class preparation materials to the Missouri River example (slide 7). Individually or in groups, the students should develop a list of at least two ecosystem services from each Millennium Ecosystem Assessment (MA) category provided by this landscape. The lists should be presented back to class, either orally with the instructor writing the ecosystem services on the board or with the students writing their lists on the board.

Examples of ecosystem services provided by the Missouri River landscape are provided in the notes below slide 7.

Learning to use Google Earth (15 min)

The instructor will provide a tutorial on Google Earth so that the students know its basic features and are able to use it (slides 8–10). The students should have Google Earth open and should work through the tutorial with the instructor. During the tutorial, the instructor should show the students how to use the search panel, layers panel, toolbar buttons, and navigation controls (see slide 8). Within the toolbar, the instructor should describe the "placemark" tool, the "display historical imagery" tool, and the "ruler" tool (slide 9).

After the brief tutorial, students should be asked to use Google Earth by navigating to and evaluating a specified location (see slide 10). The students should learn how to navigate to a location, how to change viewing perspectives, how to measure an area, and how to look at previous years and other seasons. As the students use Google Earth, the instructor should move around the classroom to make sure that the students are able to use Google Earth and to answer any questions that the students have.

The instructor could choose a local landscape rather than the landscape listed in slide 10, if desirable.

Temporal changes in ecosystem services (10 min)

Now that the students are able to use the basic features of Google Earth, the students should be put into groups to use the landscape from slide 10 to (a) list and categorize ecosystem services provided by that landscape and (b) evaluate how the production of those ecosystem services has changed over time (slide 11). This will require the students to use the "display historical imagery" tool to look at previous aerial satellite images of the same landscape. The instructor should point out to the students that the production of ecosystem services can vary over different timescales (e.g. among seasons and/or among years) and discuss how the causes for the changes in the production of ecosystem services can be attributed to either human or non-human activity (e.g. residential development versus high precipitation). For the landscape that students are using here, one conspicuous change in the landscape is a flood that occurred on the creek in September 2003.

Present back to class (7 min)

Each group should select one ecosystem service that they identified as being variable over time. Each group should give a short (~1 min) presentation to the class (a) listing their selected ecosystem service and its MA category and (b) describing how the production of that ecosystem service changed over time including describing the timescale that they are assessing.

Summary and wrap-up (2 min)

The instructor should highlight the diversity of ecosystem services provided by the landscape that were identified by the groups. Alternatively, if all groups selected the same/similar ecosystem services, the instructor should give examples of additional ecosystem services provided by the landscape and how they might change over time. For example, the creek might be used for recreation (e.g. swimming or boating) during the summer, but it is unlikely to be used for that during the winter.

Additional practice

The PowerPoint provides two options for additional practice for students to complete during class (for longer class periods) or as out-of-class work (slides 13 and 14).

Assessment

For the before-class preparation materials, students should complete a Worksheet on "An Introduction to Ecosystem Services" (Microsoft Word 2007 (.docx) 15kB Nov30 16) as homework prior to coming to class. A key is included:

▶ Assessment key for Worksheet on "An Introduction to Ecosystem Services" -- private instructor-only file
Assessment key for Worksheet on "An Introduction to Ecosystem Services"

This file is only accessible to verified educators. If you are a teacher or faculty member and would like access to this file please enter your email address to be verified as belonging to an educator.

Email Adress [ ] Submit

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For an in-class, formative assessment, instructors should provide oral feedback to each group on their presentations.

For an out-of-class formative assessment, instructors should provide Google Earth images of the same landscape during two time periods (e.g. different seasons or different years; see Unit 1.1 Assessment (PowerPoint 2007 (.pptx) 2.7MB Nov30 16) for images). The instructor should ask the students to list and categorize several (3–5) ecosystem services provided by that landscape and describe how the production of one of the listed ecosystem services would vary between the two time periods. A key is included:

▶ Unit 1.1 Assessment key -- private instructor-only file
Unit 1.1 Assessment key

This file is only accessible to verified educators. If you are a teacher or faculty member and would like access to this file please enter your email address to be verified as belonging to an educator.

Email Adress [ ] Submit

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References and Resources

- Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC.
- Ecosystem Services Fact Sheet (from the Ecological Society of America) (Acrobat (PDF) 81kB Apr9 15)

Teaching Themes

- Systems Thinking »
- Real-World Connections »
- Temporal Reasoning »
- Geographic Facility »
- Geoscience Methods »

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Unit 1.2: Exploring the Hydrologic Cycle

Developed by Ed Barbanell (University of Utah), Meghann Jarchow (University of South Dakota), and John Ritter (Wittenberg University)
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These materials have been reviewed for their alignment with the Next Generation Science Standards as detailed below. Visit InTeGrate and the NGSS to learn more.

Overview

Students focus on ecosystem services specifically related to the hydrologic cycle. They use rainfall and runoff data to describe the hydrologic cycle and construct a water balance on a small watershed.

Science and Engineering Practices

Using Mathematics and Computational Thinking: Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems. MS-P5.4:

Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. HS-P4.1:

Cross Cutting Concepts

Systems and System Models: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. MS-C4.2:

Patterns: Graphs, charts, and images can be used to identify patterns in data. MS-C1.4:

Structure and Function: Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. HS-C6.1:

Disciplinary Core Ideas

The Roles of Water in Earth's Surface Processes: Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. MS-ESS2.C1:

Performance Expectations

Earth's Systems: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. MS-ESS2-1:

This activity was selected for the On the Cutting Edge Reviewed Teaching Collection

This activity has received positive reviews in a peer review process involving five review categories. The five categories included in the process are

- Scientific Accuracy
- Alignment of Learning Goals, Activities, and Assessments
- Pedagogic Effectiveness
- Robustness (usability and dependability of all components)
- Completeness of the ActivitySheet web page

For more information about the peer review process itself, please see https://serc.carleton.edu/teachearth/activity_review.html.

This page first made public: Dec 2, 2016

Summary

In this activity, students focus on ecosystem services specifically related to the hydrologic cycle. Using rainfall-runoff data for a small watershed in Ohio, students are introduced to the technical vocabulary associated with watersheds, watershed hydrology, and water balance. Working with hydrologic data will enable the students to test their understanding of watershed hydrology and the water balance equation, which is a measure of how much water is stored within different parts of the watershed.

Learning Goals

Used this activity? Share your experiences and modifications

Overall learning objective for this activity: Students use rainfall and runoff data to describe the hydrologic cycle and construct a water balance on a watershed scale.

Specific learning objectives for this activity:

1. Students characterize the different components and processes of the hydrologic cycle as they relate to a small watershed.
2. Students analyze rainfall and runoff data from a small watershed and use the data to construct a water balance.
3. Students evaluate the role of ecosystems services in watershed hydrology and the water balance.

Context for Use

This activity may be used alone or in combination with Unit 1.1 as introduction to the hydrologic cycle, using rainfall and runoff data from a small watershed in terms of a water balance, in a quantitative manner and at a scale relevant to and understandable by students. It can be used in combination with Unit 1.3 to assess differences in the rainfall-runoff relationship between agricultural watersheds and more urban built-up watersheds, or as an application within the Ecosystem Services Approach to Water Resources Module. This activity would be appropriate in a range of introductory courses, including courses in water resources, sustainability, ecology, environmental science, Earth science and geology, land-use planning, anthropology, and landscape design.

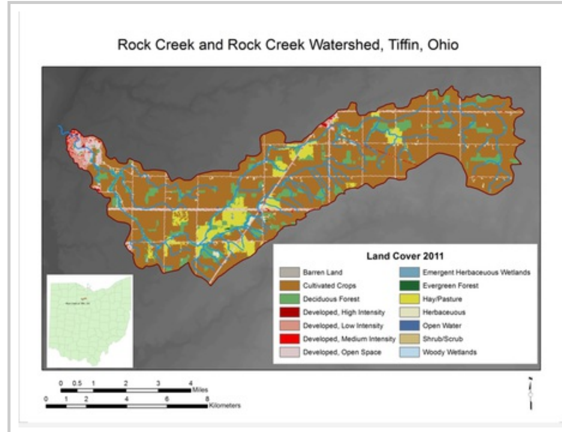
Class Size: This activity can be adapted for a variety of class sizes.
Class Format: This activity is designed for individual lecture sessions, but it is suitable for use in a lab setting or as a homework assignment as well. Students can work together, in groups of 2–4, but each student should complete his/her own assignment.
Time Required: This activity is designed to be completed in a 50-minute class period.
Special Equipment: Student groups should have a computer with Google Earth installed. If that is not possible, the instructor can print out information before class. Not every student needs a computer for this activity, but at least one computer must be available per group. From the instructors' experiences, having at least one computer per three students is ideal.
Skills or concepts that students should have already mastered before encountering the activity: This activity is self-contained and assumes no familiarity with basic concepts of ecosystem services or the hydrologic cycle.

Description and Teaching Materials

In preparation for this activity, students should read the "Watershed Hydrology Literacy" handout (Watershed Hydrology Literacy (Microsoft Word 2007 (.docx) 1.5MB Aug25 16)). This handout defines key terms and concepts associated with the hydrologic cycle, watersheds, and water balance. A watershed literacy quiz can be used prior to the class as homework (Watershed Hydrology Literacy Assessment (Microsoft Word 2007 (.docx) 14kB Dec1 16)).

Rainfall-runoff data for an agricultural watershed in Ohio (Rock Creek) are provided, both as raw data and plotted as an X-Y scatter plot (Rainfall-Runoff Data and Plot (Microsoft Word 2007 (.docx) 46kB Aug28 15)). A Google Earth file of the watershed boundary and drainage network for the watershed is also included (Rock Creek watershed (KMZ File 178kB May28 15)). These materials are used to examine the hydrologic cycle in terms of a water balance in this watershed.

A PowerPoint presentation (Unit 1.2 Presentation (PowerPoint 2007 (.pptx) 3.6MB Dec1 16)) is included with images associated with both the hydrologic cycle and the watershed characteristics, with statistics related to the watershed for which the rainfall and runoff data were determined, and with a plot of the rainfall-runoff data. The presentation includes figures used in the watershed literacy document, the water balance equation, other information about Rock Creek watershed, and applications of the water balance equation to Rock Creek watershed. The presentation supplements the different sections in the teaching notes and tips, and it can be used in a coincident way with the resources there (e.g., the hydrologic cycle and basic terms can be used in the introduction as a reminder), in place of one or more of the resources (e.g., the maps of Rock Creek watershed in the presentation can be used in lieu of the Google Earth session), or to support discussion or application (e.g., the water balance equation solved for average data for Rock Creek watershed).



Rock Creek, OH Watershed w/ground cover

Teaching Notes and Tips

Introduction to the hydrologic cycle (5 min)

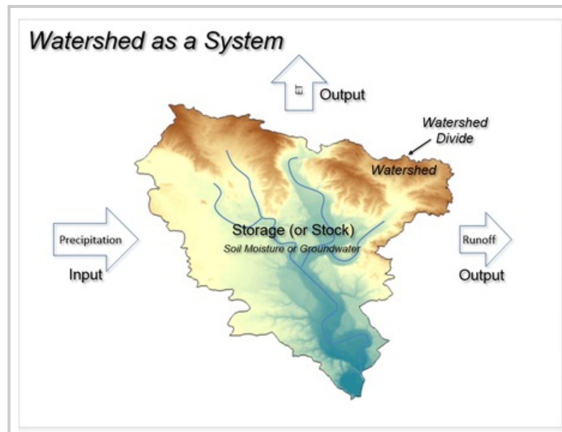
Use one of the following resources to introduce the hydrologic cycle to your class. The students already have an image in mind of the typical water cycle, illustrating rain falling over a landscape with a stream flowing into an ocean. Your intent here should be to provide a concrete sense of the hydrologic cycle, placing it within the context of watersheds, ideally your local watershed. Several tools are available to start this discussion relative to your campus location:

- *Surf Your Watershed*â€”through the EPA, for a general location within a watershed. Good for accessing other sites relative to environmental issues such as impaired watersheds or stream reaches.
- *EDNA Derived Watersheds for Major Named Rivers*â€”if you wish to use a drainage network as a discussion starter, the USGS site provides the most detailed network. Selecting a watershed from the list spawns a Google Earth session. Expand Watershed Layers, turn off the Land Cover layer, turn on the Streams, and zoom in to your area of interest.

  One of the EarthLabs activities, titled *What's a Watershed?*, may provide a useful, extra activity associated with this unit.

- *Streamerâ€”*from the USGS, this is an especially good way to illustrate upstream contributing networks if you reside along a larger stream, or the downstream destination of flow using the Trace Upstream and Trace Downstream tools. The Trace Upstream tool is nice because it shows the drainage network upstream and the basic outline of the watershed. The Trace Downstream tool can be used to illustrate where runoff (and hence sediment, pollutants, flood discharge) ultimately ends up. The drainage networks area not detailed (i.e., first-, second- and third-order streams, and maybe higher, are not shown), but the tracer tools and Trace Report functions are neat.

Use one of these, or Google Earth, to review important terminology associated with the hydrologic cycle, specifically: precipitation, runoff, infiltration, evaporation, and transpiration. You might include a review of the hydrologic data associated with your specific campus location. For example, you could guide a discussion on the pathway a rainfall drop would follow depending on where it fell on campus: it may infiltrate and transpire through plants, it may simply evaporate, or it may run off from sidewalks and roadwaysâ€”and if it does, what path does it take? Where does it ultimately flow?



A Watershed as a System

If systems theory and systems thinking have already been introduced in class, you can introduce the hydrologic cycle from a systems perspective. The watershed is the system, its divide is the system boundary. Water is input in the system as rainfall, and it is output through evaporation or transpiration or flows overland or in stream networks, leaving the system at the watershed outlet. Some rainfall is stored temporarily within the system. Storage occurs within different system reservoirs such as in lakes and ponds, in the soil as soil moisture, or deeper in the ground as groundwater. The particular pathway and amount of water moving through the system is dependent on system variables like vegetation, soils, and land use. Feedback occurs within the hydrologic cycle. For example, with increased runoff, soils erode. Exposure of impermeable clays deeper in the soil profile cause further increases in runoff, a positive feedback.

Refocus the discussion relative to value of the hydrologic cycle (5 min)

Ask the following questions of your class: What is the value of the hydrologic cycle? What is its purpose? What are its strengths and weaknesses? Wait for their responses and write them on the overhead or the board.

- Strengths: simplified, easy to understand, a teaching tool, global view of the main processes and pathways for water movement
- Weaknesses: not very detailed, may or may not be applicable locally, not very functional except as a learning tool

This will provide a good transition to a watershed-based hydrologic cycle and, specifically, the water balance equation. The water balance equation describes the flow of water in and out of a system. It is represented by the equation:

P = Q + ET + Î”S,

where P is precipitation, Q is runoff, ET is evaporation, and Î”S is the change in storage (all these figures are expressed in inches). In this module, the system is a watershed and the boundary of the system is the watershed divide.

Strengths of examining the hydrologic cycle in terms of a watershed water balance (10 min)

Begin by having students brainstorm on the strengths of a watershed water balance, asking them to go beyond general statements. They might start with the strengths discussed for the hydrologic cycle, but encourage discussion that builds on the weaknesses previously identified. It is detailed, it is local but useful, and it is functional. If they have completed the watershed hydrology literacy quiz, they can incorporate that information in their analysis.

Strengthsâ€”simplified, easy to understand, inputs are measured locally (e.g., the daily weather report, especially reference to depths of rainfall in the viewer region following a rainfall event), outputs are more evident (e.g., flooding) or significant (e.g., water supply), quantitative using simple math (addition and subtraction), specific to a watershed, functional (i.e., if streamflow from a watershed is the basis for a public water supply or for irrigation, the amount available as output cannot exceed input and is in fact much less), illustrates variability (e.g., seasonal, year-to-year).

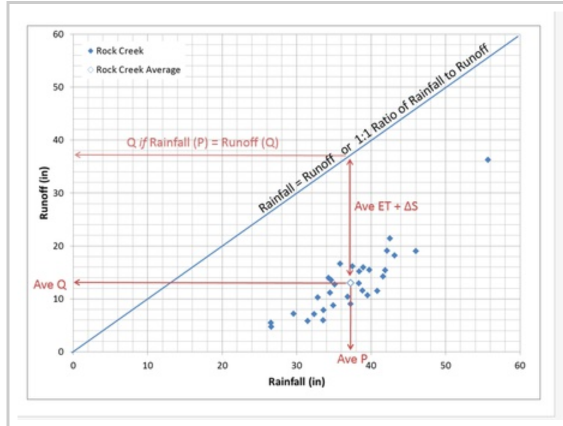
Introduce the Rock Creek watershed (10 min)

Open Rock Creek watershed (KMZ File 178kB May28 15) to spawn a session of Google Earth. This will provide an opportunity for clearing up any misconceptions about watersheds and inputs/outputs of the watershed system; it also address the ET and Î”S terms in the water balance equation. The following questions might help guide further discussion:

- Where might precipitation fall in the map area during a given rainfall event? Where does it flow to in general? In what direction? To where? What area defines the water balance?
- How is precipitation, or the input to this watershed system, measured? Where? Rainfall is generally measured at a rain gage and reported as a depth, but it is really a volume when considered over the area (depth x area) of the watershed.
- What are the potential areas, or reservoirs, where water is stored? Ask them to visualize a rainfall event. What happens to rainfall, most of it in fact, after rainfall ends? Using prompts like "Why (or when) do we water our lawns?" can get these conversations going depending on the level of the course.
- When and where does evaporation occur? Transpiration?
- Where is output, or runoff, measured in the watershed? Where does it come from? The stream network? But where does streamflow come from? Watershed output is the measured streamflow at the outlet, generally as a volume or volume per time (i.e., streamflow discharge or total discharge). It is converted to a depth, referred to as runoff when distributed over the entire watershed area (volume/area).

Assess comprehension and application using rainfall-runoff data from Rock

Creek watershed (15 min)



Rainfall-Runoff Plot for Rock Creek

Pass out copies of either the rainfall-runoff data or a plot of the data (depending on whether you intend to have students plot the data following class). If you want students to plot data in a spreadsheet, a spreadsheet version of [Table 1] (Excel 2007 (.xlsx) 15kB Dec1 16) is available. You will need to modify it to restrict the data you make available to one or the other watershed. Regardless of whether the data or a plot of the data is used, the class discussion is the same.

- How is scientific data plotted? By convention, the independent variable is plotted on the X-axis and the dependent variable is plotted on the Y-axis. Which is the independent variable? Which is the dependent variable?
- If runoff equaled rainfall, what would the relations look like on an X-Y scatterplot? Does runoff equal rainfall? Does output equal input? Go back and forth between input/rainfall and output/runoff. Use them interchangeably in your presentation and discussion.
- If runoff is not equal to rainfall, is there a consistent ratio between them? Students can calculate this for several data pairs or visualize this on the plot.
- The discussion should end with a sense of why this is not the case. Where is the missing water? And in what proportion or range of proportions?

Summarize the average rainfall-runoff data from Rock Creek watershed by illustrating it in the water balance equation (5 min)

Write the water balance equation on the board (P = Q + ET + Î”S). Ask students what terms can be quantified from the Rock Creek watershed data. This can be done for any given year. It can be done for an average over the years of record as well. For the Rock Creek watershed, the average for the period of record would be

P = Q + ET + Î”S

37.37 in = 13.02 in + ET + Î”S

The remainder, to balance the equation, is 24.25 in. This is the amount of water that is stored within the watershed, either temporarily (as soil moisture that eventually leaves the watershed through evaporation and transpiration), or more permanently (by percolating more deeply and becoming groundwater).

Assign homework for the following activity:

Work to be assigned for the following class should include plotting the rainfall-runoff data for Big Creek watershed. It is to be plotted on the previously supplied plot of Rock Creek data using a different symbol so that a direct comparison of rainfall-runoff data can be made for the two watersheds. To facilitate work in the next activity, students should also calculate values for average annual rainfall and average annual runoff for both watersheds. A Google Earth file of the boundary and drainage network for each watershed is included for either instructor or student use (Rock Creek & Big Creek watersheds (KMZ File 232kB May29 15)). These materials are used to examine changes in land use and their impact on the water balance equation.

Assessment

In a one-minute paper, ask students to answer either of the following questions or design one of your own:

- Describe one ecosystem service the Rock Creek watershed provides relative to the water balance of this watershed.
- How does the watershed ecosystem regulate the water balance of the Rock Creek watershed?

Assessment

Homework assigned for the following class should include plotting the rainfall-runoff data for Big Creek watershed. Students should plot the rainfall-runoff data for Big Creek watershed on the previously supplied plot of Rock Creek data using a different symbol. This can be graded for completeness and attention to detail (i.e., correct plotting positions). A key is included:

▸ Rainfall-Runoff Data and Plot Key -- private instructor-only file
Rainfall-Runoff Data and Plot Key

This file is only accessible to verified educators. If you are a teacher or faculty member and would like access to this file please enter your email address to be verified as belonging to an educator.

Email Adress [ ] Submit

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Use a one-minute paper to assess application to Unit 1.2. Use either of the following questions or design one of your own. Describe one ecosystem service the Rock Creek watershed provides relative to the water balance of this watershed. How does the watershed ecosystem regulate the water balance of the Rock Creek watershed? An assessment, based on a one-minute paper, and rubric are included: (Unit 1.2 Assessment (Microsoft Word 2007 (.docx) 18kB Sep3 16)). A key is included:

▸ Unit 1.2 Assessment Key -- private instructor-only file
Unit 1.2 Assessment Key

This file is only accessible to verified educators. If you are a teacher or faculty member and would like access to this file please enter your email address to be verified as belonging to an educator.

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References and Resources

- A good review of the hydrologic or water cycle is available at http://water.usgs.gov/edu/watercyclesummary.html.
- In preparation for this activity, students should read the "Watershed Hydrology Literacy" handout (Watershed Hydrology Literacy (Microsoft Word 2007 (.docx) 1.5MB Aug25 16)). This handout defines key terms and concepts associated with the hydrologic cycle, watersheds, and water balance. A watershed literacy assessment can be assigned as homework prior to or following the class (Watershed Hydrology Literacy Assessment (Microsoft Word 2007 (.docx) 14kB Dec1 16)).
- A PowerPoint presentation (Unit 1.2 Presentation (PowerPoint 2007 (.pptx) 3.6MB Dec1 16)) is included with images associated with the hydrologic cycle and watershed characteristics, statistics related to the watershed for which the rainfall and runoff data were determined, and a plot of the rainfall-runoff data.
- Rock Creek and Big Creek data are included in table form, with the Rock Creek data plotted (Rainfall-Runoff Data and Plot (Microsoft Word 2007 (.docx) 46kB Aug28 15)).

Teaching Themes

- Geographic Facility »
- Geoscience Methods »
- Authentic Data »

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Unit 1.3: Understanding Perturbations to Hydrologic Systems

Developed by Ed Barbanell (University of Utah), Meghann Jarchow (University of South Dakota), and John Ritter (Wittenberg University)
Author Profiles
Profile Ed Barbanell, University of Utah

Profile Meghann Jarchow, University of South Dakota

Profile John Ritter, Wittenberg University

These materials have been reviewed for their alignment with the Next Generation Science Standards as detailed below. Visit InTeGrate and the NGSS to learn more.

Overview

Students examine the impact of land use on runoff using rainfall-runoff data for two small watersheds in Ohio, one dominated by agricultural land uses and the other dominated by urban land uses. The Unit 1.3 Assessment key is not there. What is posted is the student version.

Science and Engineering Practices

Constructing Explanations and Designing Solutions: Construct an explanation using models or representations. MS-P6.2:

Analyzing and Interpreting Data: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. MS-P4.1:

Using Mathematics and Computational Thinking: Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. HS-P5.2:

Obtaining, Evaluating, and Communicating Information: Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). HS-P8.5:

Cross Cutting Concepts

Systems and System Models: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. MS-C4.2:

Patterns: Graphs, charts, and images can be used to identify patterns in data. MS-C1.4:

Systems and System Models: Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. HS-C4.3:

Structure and Function: Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. HS-C6.1:

Disciplinary Core Ideas

The Roles of Water in Earth's Surface Processes: Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. MS-ESS2.C1:

Biodiversity and Humans: Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on —for example, water purification and recycling. MS-LS4.D1:

Performance Expectations

Earth and Human Activity: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. HS-ESS3-6:

This activity was selected for the On the Cutting Edge Reviewed Teaching Collection

This activity has received positive reviews in a peer review process involving five review categories. The five categories included in the process are

- Scientific Accuracy
- Alignment of Learning Goals, Activities, and Assessments
- Pedagogic Effectiveness
- Robustness (usability and dependability of all components)
- Completeness of the ActivitySheet web page

For more information about the peer review process itself, please see https://serc.carleton.edu/teachearth/activity_review.html.

This page first made public: Dec 2, 2016

Summary

In this activity, students examine the impact of land use on runoff. Using rainfall-runoff data for two small watersheds in Ohio, one dominated by agricultural land uses and the other dominated by urban land uses, students evaluate natural and human factors that impact watershed hydrology and water balance, and generate potential provisioning and regulating services provided by natural ecosystems within watersheds.

Learning Goals

Used this activity? Share your experiences and modifications

Overall learning objective for this activity: Students will use rainfall and runoff data to describe the hydrologic cycle and construct a water balance on a watershed scale.

Specific learning objectives for this activity:

1. Students will analyze rainfall and runoff data from two small watersheds, one agricultural and one urban, and use them to construct a water balance equation.
2. Students will compare and contrast, quantifying the difference in the water balance between the two different land uses.
3. Students will evaluate the role of ecosystems services in watershed hydrology and the water balance.

Context for Use

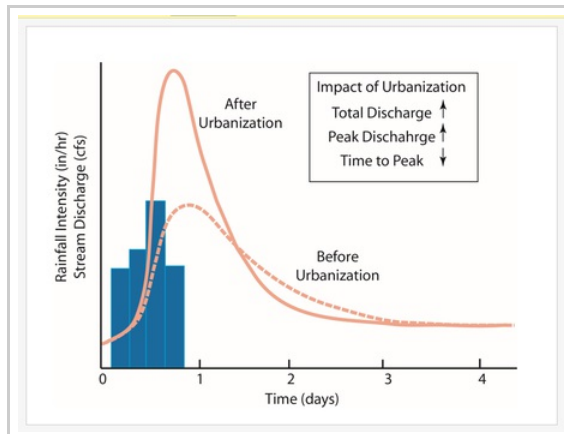
This activity may be used alone as an introduction to watershed rainfall and runoff data, from which the impact of land use on runoff can be analyzed quantitatively. It can be used in combination with Units 1.1 and 1.2 to explore the role of ecosystem services within a watershed that help regulate the hydrologic cycle and provide for freshwater resources. This activity would be appropriate in a range of introductory courses, including courses in water resources, sustainability, ecology, Earth science and geology, land-use planning, anthropology, and landscape design.

Class Size: This activity can be adapted for a variety of class sizes.
Class Format: This activity is designed for individual lecture sessions, but it is suitable for use in a lab setting or as a homework assignment as well. Students can work together, in groups of 2–4, but each student should complete his/her own assignment.
Time Required: This activity is designed to be completed in a 50-minute class period.
Special Equipment: Student groups should have a computer with Google Earth installed. If that is not possible, the instructor can print out information before class. Not every student needs a computer for this activity, but at least one computer must be available per group. From the instructors' experiences, having at least one computer per three students is ideal.
Skills or concepts that students should have already mastered before encountering the activity: This activity is self-contained and assumes no familiarity with basic concepts of ecosystem services or the hydrologic cycle.

Description and Teaching Materials

Rainfall-runoff data for both an agricultural watershed (Rock Creek) and an urban watershed (Big Creek) in Ohio are provided in table form (Rainfall-Runoff Data for Big Creek and Rock Creek Watersheds (Microsoft Word 2007 (.docx) 47kB Aug15 16)). An X-Y scatter plot for the agricultural watershed (Rock Creek) is also provided on which the urban watershed data (Big Creek) can be plotted by the students. Google Earth files of the boundary and drainage network (Rock Creek & Big Creek watersheds (KMZ File 232kB May29 15)) and land cover for each watershed (Big Creek and Rock Creek Land Cover (KMZ File 101kB Dec2 16)) are also included for use presentation or discussion. These materials are used to examine changes in land use and their impact on the water balance equation.

A PowerPoint presentation (Unit 1.3 Presentation (PowerPoint 2007 (.pptx) 8.9MB Dec2 16)) is included with images associated with the hydrologic cycle and watershed characteristics, statistics related to the watershed for which the rainfall and runoff data were determined, and a plot of the combined rainfall-runoff data from both watersheds. It is supplementary to the different sections in the teaching notes and tips. It can be used in a coincident way with the outline to support discussion of the homework (e.g., the combined data for Rock Creek and Big Creek watersheds), examination and discussion of land use in the two watersheds (e.g., the maps of Rock Creek and Big Creek watershed and tables of information in the presentation can be used in lieu of the Google Earth session), or discussion of the impact of land use change on ecosystem services (i.e., impact of urbanization on the stormflow hydrograph).



Impacts of Urbanizaion on Streamflow

Teaching Notes and Tips

Below is a lesson plan for a 50-minute class period.

Examine the rainfall-runoff data (10 min)

Data for Big Creek watershed should have been plotted for homework. Ask students to summarize the average rainfall-runoff data from Big Creek for comparison with Rock Creek using the water balance equation.

For the Rock Creek watershed, recall that the average values for P and Q for the period of record were

$P = Q + ET + \Delta S$

$37.37 \text{ in} = 13.02 \text{ in} + ET + \Delta S$

The remainder, to balance the equation, is 24.25 in, the amount of water that is stored within the watershed as soil moisture and eventually leaves the watershed through evaporation and transpiration or percolates more deeply and becomes groundwater.

Similar to Unit 1.2, write the water balance equation on the board (P = Q + ET + ΔS). Ask students again what terms can be quantified from the Big Creek watershed data. This can be done for any given year, or it can be done for an average over the years of record as well, as was done for Rock Creek watershed. For the Big Creek watershed, the average for the period of record would be

$$P = Q + ET + \Delta S$$

$$38.15 \text{ in} = 20.29 \text{ in} + ET + \Delta S$$

The remainder, to balance the equation, is 17.86 in, the amount of water that is stored within the water as soil moisture and eventually leaves the watershed through evaporation and transpiration or percolates more deeply and becomes groundwater.

Watershed	P (in)	Q (in)	ET +ΔS (in)
Rock Creek	37.37	13.02	24.25
Big Creek	38.15	20.29	17.86

Brainstorming reasons for the differences in the two data sets (10 min)

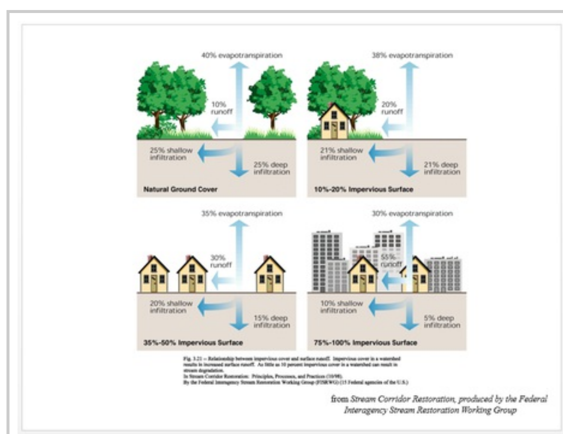
The data sets are similar in that the range of annual rainfall for the Big Creek watershed is within the range of rainfall for the Rock Creek watershed. The difference is in runoff. Have students pair up to brainstorm the reasons for the difference. Follow this with a general session focused on the watershed as a system and around the water balance equation. Reasons should be attributable to either a change in evapotranspiration or in storage within the watershed and the system variables that affect it. It is certainly a way to organize the ideas from the brainstorming session.

Examining land use (15 min)

Review the Rock Creek and Big Creek watersheds. Make available to students the Google Earth file that shows the boundaries and drainage network for the two watersheds ([Rock Creek & Big Creek watersheds] (KMZ File 232kB May29 15)). Alternatively, slides in the PowerPoint presentation contain the same information.

Allow them time to examine land use in the two watersheds and reconcile the reasons for the differences in the two data sets with the information from Google Earth. This is the beginning of bringing together content from Unit 1.1 and Unit 1.2.

Individually or in pairs, have students tie land use differences to their respective impacts on the hydrologic cycle. They should be as specific as possible and use the language introduced in Units 1.1 and 1.2. Open the discussion up in the last 5 minutes so that ideas are shared and a uniform sense of the impact is available to the class as a



Effects of Urbanization on Water Infiltration whole.

Following deforestation for agricultural purposes at the time of Euro-American settlement, the change from agricultural land uses to urban land uses is the most pervasive. Many of your students will have come from homes that were built in the past 30–50 years in suburbia. It is valuable to point this out. If you are using Google Earth, the "Show historical imagery" function could be used for an area with which you are familiar that shows urban or suburban development. This was also covered in Unit 1.1 with some examples, so you could simply use those if you prefer. The main point here is that impervious surfaces cause the perturbation or disturbance of the system, creating a positive feedback between other system variables that is deleterious.

Ecosystem services (15 min)

The remainder of the class should be spent discussing the impacts to ecosystem services caused by urbanization and the ways to mitigate/remedy those impacts. Critical questions include the following:

- What ecosystem services are impacted during conversion of land use from agricultural uses to urban uses?
- In what ways is the impact mitigated in urban watersheds?
- Are there ways in which natural ecosystem services can be restored or mimicked in the urban watershed to restore some of the services more natural areas provide?
- How does the systems perspective allow for identification of the services a watershed provides?

Assessment

The critical questions suggested at the very end of the Teaching Notes and Tips can be used for a written assignment for assessment. In that case, a summary of the water balance for watersheds dominated by different land uses should be included to preface the questions. A Unit 1.3 Assessment (Microsoft Word 2007 (.docx) 20kB Sep3 16) is included. A key is also included:

▶ Unit 1.3 Assessment Key -- private instructor-only file
Unit 1.3 Assessment Key

This file is only accessible to verified educators. If you are a teacher or faculty member and would like access to this file please enter your email address to be verified as belonging to an educator.

Email Adress [ ] Submit

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References and Resources

- A good review of the hydrologic or water cycle is available at http://water.usgs.gov/edu/watercyclesummary.html.
- If Unit 1.3 is being used alone, students should read the "Watershed Hydrology Literacy" handout (Watershed Hydrology Literacy (Microsoft Word 2007 (.docx) 1.5MB Aug25 16)) as before-class preparation material. This handout defines key terms and concepts associated with the hydrologic cycle, watersheds, and water balance. A watershed literacy quiz is included (Watershed Hydrology Literacy Assessment (Microsoft Word 2007 (.docx) 14kB Dec1 16)) to focus students on local aspects of the hydrologic cycle and watersheds.
- A Power Point presentation (Unit 1.3 Presentation (PowerPoint 2007 (.pptx) 8.9MB Dec2 16)) is included with images associated with the hydrologic cycle and watershed characteristics, statistics related to the watershed for which the rainfall and runoff data were determined, and a plot of the rainfall-runoff data.
- Rock Creek and Big Creek data are included in table form, with the Rock Creek data plotted (Rainfall-Runoff Data and Plot (Microsoft Word 2007 (.docx) 46kB Aug28 15)).

Teaching Themes

- Real-World Connections »
- Geographic Facility »
- Authentic Data »

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Unit 2: Measuring and Modeling Ecosystem Services

Developed by Ed Barbanell (University of Utah), Meghann Jarchow (University of South Dakota), and John Ritter (Wittenberg University)
Author Profiles
Profile Ed Barbanell, University of Utah
Profile John Ritter, Wittenberg University
Profile Meghann Jarchow, University of South Dakota

Summary

In this unit, students will model stormwater runoff for a landscape that has different land covers, to reflect the changes in the hydrologic cycle as land use changes. In doing this, they will (a) recognize the ecosystem services provided by natural or permeable land covers relative to stormwater runoff, (b) see how those services are impacted by land-use changes, and (c) consider what potential solutions are available to mitigate the impact of such changes.

Learning Goals

Used this activity? Share your experiences and modifications

Students will be able to infer and estimate the ecosystem services of natural or permeable land cover based on modeling the impact of development on the hydrologic cycle, specifically stormwater runoff.

Objectives to accomplish learning goal 2:

1. Students will model the impact of development on stormwater runoff.
2. Students will assess methods to mitigate the impact of development on stormwater runoff using using low impact development (LID).

Context for Use

This activity may be used either alone or in combination with Unit 1 as an introduction to modeling the impact of land-use change on stormwater runoff. It would be appropriate for use in a range of introductory courses, including courses in sustainability, ecology, environmental science, Earth science and geology, land-use planning, anthropology, water resources, and landscape design.

Class Size: This unit can be adapted for a variety of class sizes.
Class Format: This unit is designed for individual lecture sessions, but it is suitable for

use in a lab setting or as a homework assignment as well. Students can work together, in groups of 2–4, but each student should complete his/her own assignment.
Time Required: The activities are designed to be completed in 50-minute class periods.
Special Equipment: Student groups should have a computer running Windows that has access to the Internet. The U.S. Environmental Protection Agency's National Stormwater Calculator, which runs only on Windows, must be installed from the Internet. The link is provided in the References and Resources section below. Because the calculator downloads soils data from a national database, Internet access is required during the activities in this unit. Not every student needs a computer for this activity, but at least one computer must be available per group. From the instructors' experiences, having at least one computer per three students is ideal.
Skills or concepts that students should have already mastered before encountering the activity: Activities in this unit assume familiarity with basic concepts of ecosystem services and the hydrologic cycle.

Description and Teaching Materials

The unit is made up of three activities:

1. Modeling the hydrologic impact of land-use change using the EPA's National Stormwater Calculator (Calculator);
2. Mitigation of increases in stormwater runoff using low impact development (LID) controls; and
3. Modeling land-use change and mitigation strategies for a local land-use change.

The unit is designed for students to work in groups using the EPA's National Stormwater Calculator (Calculator). Either student laptops or university/college computers can be used, but the Calculator must be installed. The link is provided in the References and Resources section below. Because the Calculator downloads soils data from a national database, Internet access is also required. Not every student needs a computer for this unit, but at least one computer must be available per group.

Teaching Notes and Tips

The activities can be used in different ways. Units 2.1 and 2.2 can be used alone to introduce the Calculator and the use of LID controls to reduce stormwater runoff. Unit 2.3 can be used as a template, modified to represent a local problem on or near the instructor's campus. If the instructor is continuing with Unit 3: Using an Ecosystem Services Approach for Civic Engagement, the study site used in Unit 2.3 can serve as the focus for analysis of stakeholders' perspective as the students work to develop presentations about the proposed land-use change.

Assessment

Ecosystem services and rainfall-runoff data in the context of the hydrologic cycle and water balance equation from Unit 1 is the foundation upon which students understand the need to consider impacts of development on stormwater generation and its management. Stormwater is currently managed in the campus environment; some students will be cognizant of that, and others will not. In this unit, students not only model changes in stormwater runoff that occur with development, but they also have to consider ways of mitigating or reducing it—in effect, managing it. Incorporating pre- and post-Unit 2 wrappers with the following three questions will allow the instructor to assess both prior knowledge and student learning:

- Is stormwater runoff generated by your campus? Yes or no, explain how you know this.
- What does the campus do to manage stormwater? Be as specific as possible.
- What could the campus do to manage their stormwater to take advantage of ecosystem services? Be as specific as possible.

One of these questions is part of a think-pair-share exercise in Unit 2.2. Answers to that question could also be recorded in writing for the assessment of student learning.

The pre- and post-assessment wrappers are included as Pre-Unit 2 Assessment Wrapper (Microsoft Word 2007 (.docx) 14kB Sep4 16) and Post-Unit 2 Assessment Wrapper (Microsoft Word 2007 (.docx) 14kB Sep4 16), respectively.

References and Resources

National Stormwater Calculator User's Guide Version 1.1

Description and download page for National Stormwater Calculator

Considering using these materials with your students?
Get pointers and learn about how it's working for your peers in their classrooms »

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Unit 2.1: Hydrologic Impact of Land-Use Change

Developed by Ed Barbanell (University of Utah), Meghann Jarchow (University of South Dakota), and John Ritter (Wittenberg University)
Author Profiles
Profile John Ritter, Wittenberg University
Profile Meghann Jarchow, University of South Dakota
Profile Ed Barbanell, University of Utah

These materials have been reviewed for their alignment with the Next Generation Science Standards as detailed below. Visit InTeGrate and the NGSS to learn more.

Overview

Students model the impact of land-cover changes on stormwater runoff using the EPA's National Stormwater Calculator. Students are provided with a particular site—a residential neighborhood—and model two land-use scenarios associated with it.

Science and Engineering Practices

Constructing Explanations and Designing Solutions: Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena. MS-P6.1:

Developing and Using Models: Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. HS-P2.6:

Cross Cutting Concepts

Systems and System Models: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. MS-C4.2:

Systems and System Models: Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. HS-C4.3:

Patterns: Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. HS-C1.3:

Disciplinary Core Ideas

Human Impacts on Earth Systems: Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. MS-ESS3.C2:

Biodiversity and Humans: Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on —for example, water purification and recycling. MS-LS4.D1:

Human Impacts on Earth Systems: The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. HS-ESS3.C1:

Performance Expectations

Earth and Human Activity: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. HS-ESS3-6:

This activity was selected for the On the Cutting Edge Exemplary Teaching Collection

Resources in this top level collection a) must have scored Exemplary or Very Good in all five review categories, and must also rate as "Exemplary" in at least three of the five categories. The five categories included in the peer review process are

- Scientific Accuracy
- Alignment of Learning Goals, Activities, and Assessments
- Pedagogic Effectiveness
- Robustness (usability and dependability of all components)
- Completeness of the ActivitySheet web page

For more information about the peer review process itself, please see https://serc.carleton.edu/teachearth/activity_review.html.

This page first made public: Dec 2, 2016

Summary

In this activity, students model the impact of land-cover changes on stormwater runoff using the EPA's National Stormwater Calculator (Calculator). The students are introduced to the Calculator through a tutorial. Students are provided with a particular site—a residential neighborhood—and model two land-use scenarios associated with it:

(1) a pre-expansion scenario that includes current forest and developed land cover, and (2) a post-expansion scenario, under which the forest cover will be developed as low-intensity residential.

Learning Goals

Used this activity? Share your experiences and modifications

Overall learning objective for this activity: Students will be able to model the impact of land-use change on the hydrologic cycle.

Specific learning objectives for this activity:

1. Students will be able to use the EPA's National Stormwater Calculator to model the impact of development on stormwater runoff.
2. Students will be able to compare the relation between rainfall and runoff data from different land use scenarios, one representing pre-expansion and the other post-expansion relative to a residential neighborhood.
3. Students will be able to assess the role ecosystem services associated with permeable land covers, like forest cover, play in regulating the hydrologic cycle.

Context for Use

This activity is designed to be used in conjunction with the Unit 1 activities to evaluate the change in stormwater runoff in the context of lost ecosystem services. It may also be used alone as an introduction to the EPA's National Stormwater Calculator (Calculator) from which the impact of land-use change on runoff can be analyzed quantitatively. This activity would be appropriate in a range of introductory courses in water resources, sustainability, ecology, environmental science, Earth science and geology, land-use planning, anthropology, and landscape design.

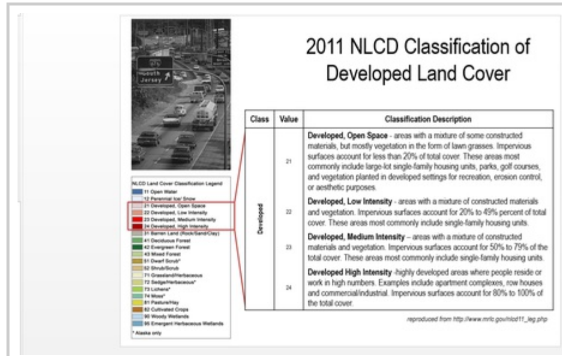
The activity is designed for students to work in groups using the Calculator. Either student laptops or university/college computers can be used for the activity, but the Calculator must be installed. The link is provided in the References and Resources section below. Because the Calculator downloads soils data from a national database, Internet access is required. Not every student needs a computer for this activity, but at least one computer must be available per group.

Class Size: This activity can be adapted for a variety of class sizes.
Class Format: This activity is designed for individual lecture sessions, but it is suitable for use in a lab setting or as a homework assignment as well. Students can work together, in groups of 2–4, but each student should complete his/her own assignment.
Time Required: This activity is designed to be completed in a 50-minute class period.
Special Equipment: Student groups should have a computer running Windows that has access to the Internet. The Calculator, which runs only on Windows, must be installed from the Internet. The link is provided in the References and Resources section below. Because the Calculator downloads soils data from a national database, Internet access is required during this activity. Not every student needs a computer for this activity, but at least one computer must be available per group. From the instructors' experiences, having at least one computer per three students is ideal.

Skills or concepts that students should have already mastered before encountering the activity: This activity assumes familiarity with basic concepts of ecosystem services and the hydrologic cycle.

Description and Teaching Materials

Prior to class, students should read the fact sheet produced by the U.S. Geological Survey called *Effects of Urban Development on Floods* *(Acrobat (PDF) 111kB Jun14 15)*, available also at USGS. They should also read the one-page technical fact sheet (Acrobat (PDF) 396kB Jun14 15) on the EPA's National Stormwater Calculator. It is also available at EPA.



Permeability of Different Land-Cove Types

The Unit 2.1 Presentation (PowerPoint 2007 (.pptx) 11.3MB Sep4 16) review of the impact of land-use change on the rainfall-runoff relationship is included. It introduces students to the permeability associated with different land-cover types.

It is assumed that the Calculator has been downloaded and installed on the instructor's computer and on a computer available to each student group. The URLs for the program and users guide are included in the References and Resources section below. Instructors should be familiar with the calculator prior to class, downloading it on their computer for presentation, perhaps having skimmed the user's guide for a functional knowledge of the program or having at least worked through the tutorial. Following a short introduction to the program by the instructor, students will follow the Unit 2.1 Tutorial (Microsoft Word 2007 (.docx) 5.6MB Dec1 16) to model the impact of a proposed development on stormwater runoff.

A particular Calculator location file is used in this activity so that the instructor and students are all working from the same baseline site information. To download the location file, click on Thomaston Trail Expansion.swc (ShockWave Component (SWC) 1kB Jun19 15), and select Save File, and then "OK." The file will be downloaded into your computer's Downloads folder as "thomaston_trail_expansion.v3.swc." It can then be **opened from within the Calculator** as described in Part 1 of the Unit 2.1 Tutorial (Microsoft Word 2007 (.docx) 5.6MB Dec1 16). Students will complete the exercise by answering the questions about their work and the data they collected in the Unit 2.1 Assessment (Microsoft Word 2007 (.docx) 16kB Sep4 16).

Teaching Notes and Tips

Introduction to Urban and Suburban Development (10 min)

Impermeable surfaces associated with urban and suburban development (i.e., roofs, sidewalks, driveways, roads, parking lots) produce greater stormwater runoff than permeable surfaces associated with other land uses. Unit 2.1 Presentation (PowerPoint 2007

(.pptx) 11.3MB Sep4 16) provides a series of slides that can be used to illustrate the problem:

1. increased runoff (conceptually using percentages, with data using the water-balance data from Unit 1);
2. impact on streamflow (changes in the streamflow hydrograph); and
3. impact on water quality.

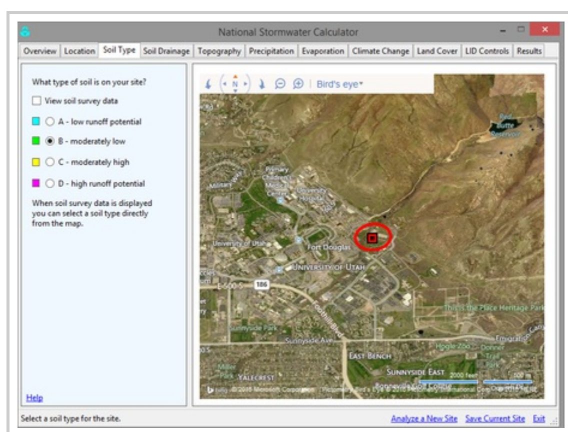
Additional slides introduce students to different land covers and their varying levels of permeability, going from the aerial image which they have had some experience with via Google Earth, land cover from the 2011 National Land Cover Database (NLCD), and estimated percent impermeability from the 2011 NLCD (the latter two determined by remote sensing from satellite data).

Introduction to the EPA's National Stormwater Calculator (20–40 min, depending how the Calculator is introduced)

Transition from the PowerPoint presentation that addresses the problem to the EPA's National Stormwater Calculator (Calculator) that provides part of the solution. The Calculator provides a means for its intended users (site developers, landscape architects, urban planners, and homeowners) to evaluate the impact of land-use change on stormwater runoff. Its intended uses are for analyzing changes in hydrology at the screening or planning level, assessing long-term performance of stormwater management practices, and identifying practices that can help meet stated performance goals (e.g., minimal hydrologic impact). It is not intended for construction-level design. In the tutorial and assessment materials accompanying this unit, students are being considered urban planners, analyzing the changes in hydrology that will result from expansion of a residential area into an area that is currently forested.

A short [YouTube video about the Calculator] from the EPA is a simple transition.

Instructors should be familiar with the Calculator prior to class, downloading it on the instructor's computer for presentation, perhaps having skimmed the user's guide for a functional knowledge or having at least worked through the tutorial. If the first and last of these have been done, there are a couple of ways to introduce the Calculator and its use:



The EPA's National Stormwater Calculator

1. With students focused on instructor, present the use of the Calculator using any location of the instructor's choosing. The instructor would likely create a hypothetical scenario that enables him or her to run a baseline model for comparison with the model for a land-use change. More intentionally, a scenario involving real change previously examined through Google Earth, could be

2. Assign the tutorial for in-class work, and help students work through it in real time. ***If this alternative is chosen, the remainder of the class session should be devoted to this.*** If

students finish early, they should answer the questions at the end of the tutorial.

Use of the Calculator (0–20 min, depending how the Calculator is introduced)

Assign the Unit 2.1 Tutorial (Microsoft Word 2007 (.docx) 5.6MB Dec1 16). Spend a minute on the problem outlined at the beginning of the tutorial. What is critical here is that development of the forested area is assumed to be consistent with the development that has already occurred. That is, the ratio of permeable to impermeable surface is similar, lot size and homes are similar, and they are uniformly spaced. That will be important to highlight again in discussion related to Unit 2.2 and implementation of Unit 2.3.

Give students time to work through at least the pre-development scenario from the tutorial for use as baseline data. They will record their results in the Stormwater Calculator Tutorial Results Table (Microsoft Word 2007 (.docx) 19kB Jun20 16), referred to as Table 1 in the tutorials. If students finish their modeling effort early, they will complete the exercise by answering the questions about their work and the data they collected in the Unit 2.1 Assessment (Microsoft Word 2007 (.docx) 16kB Sep4 16).

If students do not complete the modeling, assign the remainder of the work and answering the questions in the Unit 2.1 Assessment (Microsoft Word 2007 (.docx) 16kB Sep4 16) for homework. Alternatively, a part of the next class session can be used to complete the work.

Assessment

Students have used the Calculator to model changes in stormwater runoff. Their ability to analyze the results and their understanding of the implications relative to ecosystem services are assessed based on their answers to the questions assigned in the Unit 2.1 Assessment (Microsoft Word 2007 (.docx) 16kB Sep4 16). Answers can be turned in for grading or simply checked by the instructor for completeness. Students' answers can be a basis for class discussion in the next activity to evaluate student learning. A key is included:

▸ Unit 2.1 Assessment Key -- private instructor-only file
Unit 2.1 Assessment Key

This file is only accessible to verified educators. If you are a teacher or faculty member and would like access to this file please enter your email address to be verified as belonging to an educator.

Email Adress [ ] Submit

.

References and Resources

National Stormwater Calculator User's Guide Version 1.1

Description and download page for National Stormwater Calculator

Green Technology Webinar Series—Stormwater Management: Low Impact Development and Greening Corporate Grounds

Teaching Themes

- Systems Thinking »
- Real-World Connections »
- Geographic Facility »
- Geoscience Methods »
- Authentic Data »

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Unit 2.2: Mitigation Using Low Impact Development (LID) Controls

Developed by Ed Barbanell (University of Utah), Meghann Jarchow (University of South Dakota), and John Ritter (Wittenberg University)
Author Profiles
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Profile Ed Barbanell, University of Utah

Profile Meghann Jarchow, University of South Dakota

These materials have been reviewed for their alignment with the Next Generation Science Standards as detailed below. Visit InTeGrate and the NGSS to learn more.

Overview

Students use the EPA's National Stormwater Calculator to mitigate increased stormwater runoff resulting from development with low impact development (LID) controls. Students assess the LID controls in terms of the ecosystem services that they are intended to replace and discuss alternative development designs to reduce the need for them.

Science and Engineering Practices

Constructing Explanations and Designing Solutions: Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena. MS-P6.1:

Developing and Using Models: Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. HS-P2.6:

Cross Cutting Concepts

Systems and System Models: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. MS-C4.2:

Systems and System Models: Systems can be designed to do specific tasks. HS-C4.1:

Systems and System Models: Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. HS-C4.3:

Patterns: Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. HS-C1.3:

Disciplinary Core Ideas

Biodiversity and Humans: Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. MS-LS4.D1:

Human Impacts on Earth Systems: The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. HS-ESS3.C1:

Human Impacts on Earth Systems: Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. HS-ESS3.C2:

Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. HS-ETS1.B1:

Defining and Delimiting Engineering Problems: Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities HS-ETS1.A2:

Performance Expectations

Engineering Design: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. HS-ETS1-4:

Earth and Human Activity: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. HS-ESS3-6:

This activity was selected for the On the Cutting Edge Reviewed Teaching Collection

This activity has received positive reviews in a peer review process involving five review categories. The five categories included in the process are

- Scientific Accuracy
- Alignment of Learning Goals, Activities, and Assessments
- Pedagogic Effectiveness
- Robustness (usability and dependability of all components)

- Completeness of the ActivitySheet web page

For more information about the peer review process itself, please see https://serc.carleton.edu/teachearth/activity_review.html.

This page first made public: Dec 2, 2016

Summary

In this activity, students model the impact of changes in land cover on stormwater runoff using the EPA's National Stormwater Calculator. Students mitigate increased stormwater runoff resulting from development with low impact development (LID) controls. Students assess the LID controls in terms of the ecosystem services that they are intended to replace and discuss alternative development designs to reduce the need for them.

Learning Goals

Used this activity? Share your experiences and modifications

Overall learning objective for this activity: Students will be able to assess the effectiveness of low impact development (LID) controls on the hydrologic impacts associated with land-use change.

Specific learning objectives for this activity:

1. Students will be able to use the EPA's National Stormwater Calculator to model ways to mitigate the impact of development on stormwater runoff.
2. Students will be able to incorporate LID controls into simulations of hydrology relative to expansion of a residential neighborhood.
3. Students will be able to characterize the ecosystem services replaced by LID controls.

Context for Use

This activity is designed to be used in conjunction with the Unit 2.1 activity introducing the National Stormwater Calculator. This activity would be appropriate in a range of introductory courses in water resources, sustainability, ecology, environmental science, Earth science and geology, land use planning, anthropology, and landscape design.

Class Size: This activity can be adapted for a variety of class sizes.
Class Format: This activity is designed for individual lecture sessions, but it is suitable for use in a lab setting or as a homework assignment as well. Students can work together, in groups of 2–4, but each student should complete his/her own assignment.
Time Required: This activity is designed to be completed in a 50-minute class period.
Special Equipment: Student groups should have a computer running Windows that has access to the Internet. The Calculator, which runs only on Windows, must be installed from the Internet. The link is provided in the References and Resources section below. Because the Calculator downloads soils data from a national database,

internet access is required during this activity. Not every student needs a computer for this activity, but at least one computer must be available per group. From the instructors' experiences, having at least one computer per three students is ideal.
Skills or concepts that students should have already mastered before encountering the activity: This activity assumes familiarity with basic concepts of ecosystem services and the hydrologic cycle.

Description and Teaching Materials

It is assumed that the Calculator has been downloaded and installed on the instructor's computer and on a computer available to each student group. Students will need to have completed the Unit 2.1 Tutorial (Microsoft Word 2007 (.docx) 5.6MB Dec1 16) for the pre-expansion (or baseline) data. Students will follow the Unit 2.2 Tutorial (Microsoft Word 2007 (.docx) 492kB Dec2 16) to model the impact of a proposed expansion of a residential neighborhood on stormwater runoff using LID controls to mitigate increases from pre-expansion levels.

If students have completed the Unit 2.1 Tutorial and Assessment, they will have previously saved a location file called **Thomaston Trails Expansion Baseline.swc**. Instructions in the Unit 2.2 Tutorial and Assessment will guide them using this file as the starting point. Following completion of the tutorial, students will answer a series of questions in the Unit 2.2 Assessment (Microsoft Word 2007 (.docx) 21kB Sep4 16) pertaining to their model results.

Teaching Notes and Tips

Review Answers for Question 7 from the Assigned Questions from Previous Session (5-10 min)

The connection between ecosystem services from Unit 1 and runoff modeled using the Calculator should be made explicit before moving on. You can do this by generating class discussion around question 7 from the assigned homework Unit 2.1 Assessment (Microsoft Word 2007 (.docx) 16kB Sep4 16).

Question 7: How are these impacts on the hydrologic cycle affecting the ecosystem services (Unit 1.1) provided by the forest cover?

Potential Answer: *Forests and forest soils (any permeable surface, for that matter) absorb rainfall. By decreasing runoff, they reduce downstream erosion and flooding while recharging groundwater, which results in sustained baseflow of streams. Any of the following ecosystem services from the Ecosystem Services Fact Sheet (from the Ecological Society of America) is arguably impacted:*

- moderate weather extremes and their impacts (indirectly)
- mitigate drought and floods (directly)
- cycle and move nutrients (directly and indirectly)
- protect stream and river channels and coastal shores from erosion (directly)
- detoxify and decompose wastes (directly and indirectly)
- generate and preserve soils and renew their fertility (directly)

- contribute to climate stability (indirectly)
- purify the air and water (directly and indirectly)
- pollinate crops and natural vegetation (indirectly)

directlyâ€”as a direct result of infiltration of rainfall by the forest/permeable soil (e.g., infiltrated water does not contribute to flooding, but does recharge groundwater that increases resilience against drought)

indirectly â€”indirectly resulting from infiltration of rainfall by the forest/permeable soil (e.g., increased soil moisture maintains dense plant growth that consumes, maintains, or stabilizes CO_2)

Think-Pair-Share (5-10 min)

Begin with a think-pair-share exercise relative to the local campus and the general awareness of the students regarding issues like stormwater runoff, which are normally in the background (learn more about think-pair-share). Built environment, with impermeable surfaces, characterizes most campuses. Ask students to consider their local campus environment. Pose a rhetorical question: Has our campus impacted the hydrologic cycle? Based on the results from the previous class, the answer should be a resounding yes. If it is not, explore this through discussion. Impermeable surfaces negate the possibility of infiltration by the site's original soil.

Think-Pair-Share: What has the campus done to manage stormwater?

Answers may vary from no real recognition of how stormwater is removed from campus to either traditional or green methods for dealing with stormwater.

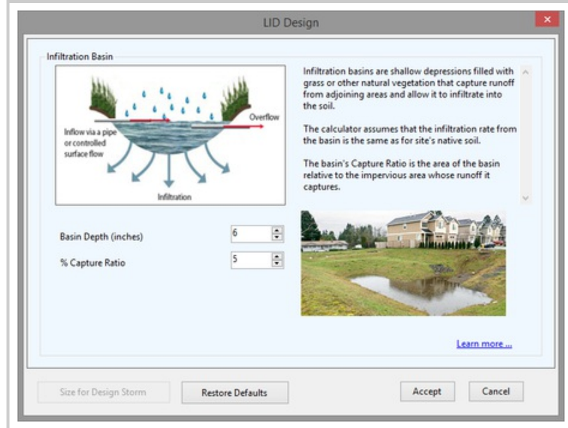
> Traditional methods: catch basins, combined sewers, curbs and gutters, culverts, detention basins, lined storm channels, retention basins, roof downspouts, storm drains and pipe network, tiles
>
> Green infrastructure, LID controls, environmental site design: bioretention cells, curb and gutter elimination, grassed swales, green parking design, infiltration trenches, inlet protection devices, permeable pavement, permeable pavers, rain barrels and cisterns, rain gardens, riparian buffers, sand and organic filters, soil amendments, stormwater planters, tree box filters, vegetated filter strips, vegetated roofs

You may also choose to use this as a unit wrapper around Unit 2 as described in the assessment section of the unit page. If so, you should ask students to write down their response in the "think" part of this exercise and collect their responses. Then finish the think-pair-share in discussion format. This should transition to LID controls on stormwater.

Introduce LID Controls in the National Stormwater Calculator (10 min)

Use Table 2 in the Calculator User's Guide Version 1.1 and associated text and images to introduce LID controls as a means of mitigating stormwater generated from new (or old) development. You can do this straight from the pdf file of the manual.

Alternatively, as a pre-class assignment, you can have the students watch the first 20â€“25 minutes of the YouTube video "Green Technology Webinar Series â€“ Stormwater Management: Low Impact Development and Greening Corporate Grounds."



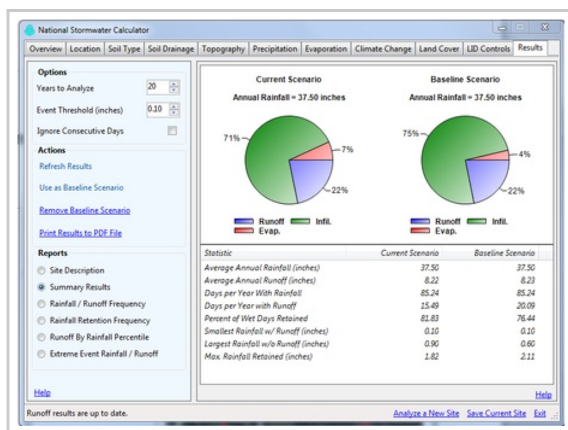
Using LIDs controls in the Calculator

Most new development should have minimal hydrologic impact going forward, so your introduction should refer to the utility of the Calculator for analyzing changes in hydrology at the screening or planning level. The effectiveness of LID controls can be evaluated by iterating through simulations and examining results. At this point, a simple understanding of the LID controls available in the Calculator will suffice; later, students will be asked to be more critical in their selection of LID controls.

Use of the National Stormwater Calculator (20 min)

Assign the Unit 2.2 Tutorial (Microsoft Word 2007 (.docx) 492kB Dec2 16). Remind students of the problem they worked on during the previous meeting or for homework. The goal here is to reduce the hydrologic impact of the proposed land use change to zero using LID controls. In other words, with the change in land cover to support the expansion, stormwater runoff will not increase over the amount prior to expansion, the baseline result from Unit 2.1 Tutorial and Assessment. This may take several iterations, but encourage students to understand the controls and not to use them carte blanche. There are costs associated with installation and maintenance that will be borne by the homeowners, so there is an economic incentive to optimize the use of LID controls.

Students will record their results in the Stormwater Calculator Tutorial Results Table (Microsoft Word 2007 (.docx) 19kB Jun20 16), referred to as Table 1 in the tutorials. Assign students the questions in the Unit 2.2 Assessment (Microsoft Word 2007 (.docx) 21kB Sep4 16). If students are finished early, they can start these.



Modeling Land-Use Changes in the Calculator

Leave students with a parting question: In planning the development of the expansion area, can you do so in such a way as to optimize natural ecosystem services to reduce the need for and cost of LID controls?

Assessment

Students have used the calculator to model the impact of LID controls for mitigating stormwater runoff. Their ability to analyze the results, and their understanding of the implications relative to LID controls and the ecosystem services that they are replacing are assessed based on their answers to the questions assigned in Unit 2.2 Assessment (Microsoft Word 2007 (.docx) 21kB Sep4 16). Answers can be turned in for grading or simply checked for completeness. Student answers can be the basis for class discussion in the next unit to evaluate student learning. A key is included: ▶ Unit 2.2 Assessment Key -- private instructor-only file

Unit 2.2 Assessment Key

This file is only accessible to verified educators. If you are a teacher or faculty member and would like access to this file please enter your email address to be verified as belonging to an educator.

Email Adress [ ] Submit

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References and Resources

National Stormwater Calculator User's Guide Version 1.1

Description and download page for National Stormwater Calculator

Green Technology Webinar Series — Stormwater Management: Low Impact Development and Greening Corporate Grounds

Teaching Themes

- Systems Thinking »
- Real-World Connections »
- Geographic Facility »
- Geoscience Methods »
- Authentic Data »

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Unit 2.3: Modeling Land-Use Change and Mitigation Strategies

Developed by Ed Barbanell (University of Utah), Meghann Jarchow (University of South Dakota), and John Ritter (Wittenberg University)
Author Profiles
Profile John Ritter, Wittenberg University
Profile Meghann Jarchow, University of South Dakota
Profile Ed Barbanell, University of Utah

These materials have been reviewed for their alignment with the Next Generation Science Standards as detailed below. Visit InTeGrate and the NGSS to learn more.

Overview

Given a description of proposed land-use change, students devise and execute a series of simulations in the EPA's National Stormwater Calculator to model the potential impact on stormwater retention. Then they utilize low impact development (LID) controls to mitigate stormwater runoff.

Science and Engineering Practices

Constructing Explanations and Designing Solutions: Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena. MS-P6.1:

Obtaining, Evaluating, and Communicating Information: Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). HS-P8.5:

Developing and Using Models: Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system HS-P2.3:

Developing and Using Models: Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. HS-P2.6:

Cross Cutting Concepts

Systems and System Models: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. MS-C4.2:

Systems and System Models: Systems can be designed to do specific tasks. HS-C4.1:

Systems and System Models: Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. HS-C4.3:

Patterns: Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. HS-C1.3:

Cause and effect: Systems can be designed to cause a desired effect. HS-C2.3:

Disciplinary Core Ideas

Biodiversity and Humans: Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on —for example, water purification and recycling. MS-LS4.D1:

Human Impacts on Earth Systems: The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. HS-ESS3.C1:

Human Impacts on Earth Systems: Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. HS-ESS3.C2:

Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. HS-ETS1.B1:

Defining and Delimiting Engineering Problems: Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities HS-ETS1.A2:

Performance Expectations

Earth's Systems: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity. MS-ESS2-4:

Engineering Design: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. HS-ETS1-4:

Earth and Human Activity: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. HS-ESS3-6:

Earth and Human Activity: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. HS-ESS3-4:

This activity was selected for the On the Cutting Edge Reviewed Teaching Collection

This activity has received positive reviews in a peer review process involving five review categories. The five categories included in the process are

- Scientific Accuracy
- Alignment of Learning Goals, Activities, and Assessments
- Pedagogic Effectiveness
- Robustness (usability and dependability of all components)
- Completeness of the ActivitySheet web page

For more information about the peer review process itself, please see https://serc.carleton.edu/teachearth/activity_review.html.

This page first made public: Dec 2, 2016

Summary

In this activity, students model the impact of a proposed land-use change for a local site using the EPA's National Stormwater Calculator (Calculator). Given a description of the proposed land-use change, students devise and execute a series of simulations in the Calculator that model its potential impact on stormwater retention. Using additional simulations, students explore changes to the site that utilize low impact development (LID) controls to mitigate stormwater runoff.

Learning Goals

Used this activity? Share your experiences and modifications

Overall learning objective for this activity: Students will be able to create a model to simulate the impact of a local land-use change and to propose and evaluate alternatives using low impact development (LID) controls.

Specific learning objectives for this activity:

1. Students will be able to appraise existing ecosystem services at a site of planned development.
2. Students will be able to use the National Stormwater Calculator to create a model to simulate the impact of land-use change on stormwater runoff.
3. Students will be able to use the model to identify and evaluate alternatives to the planned development to reduce the impact of development on stormwater runoff.

Context for Use

This activity is designed to be used in conjunction with Units 2.1 and 2.2 using the National Stormwater Calculator (Calculator). Units 2.1 and 2.2 introduced the Calculator using an example location provided with the activities. In this activity, students apply the Calculator to another situation, ideally addressing a hypothetical land-use scenario located on or near their campus. This activity would be appropriate in a range of introductory courses in water resources, sustainability, ecology, environmental science, Earth science and geology, land use planning, anthropology, and landscape design.

Class Size: This activity can be adapted for a variety of class sizes.
Class Format: This activity is designed for individual lecture sessions, but it is suitable for use in a lab setting or as a homework assignment as well. Students can work together, in groups of 2–4, but each student should complete his/her own assignment.
Time Required: This activity is designed to be completed in a 50-minute class period.
Special Equipment: Student groups should have a computer running Windows that has access to the Internet. The Calculator, which runs only on Windows, must be installed from the Internet. The link is provided in the References and Resources section below. Because the Calculator downloads soils data from a national database, Internet access is required during this activity. Not every student needs a computer for this activity, but at least one computer must be available per group. From the instructors' experiences, having at least one computer per three students is ideal.
Skills or concepts that students should have already mastered before encountering the activity: This activity assumes familiarity with basic concepts of ecosystem services and the hydrologic cycle.

Description and Teaching Materials

In this activity, students model a hypothetical land-use change either on their campus or in the local community/surrounding region. Three different examples are provided, and they should be used by the instructor for generating his or her own local example. The provided examples are similar in overall design, to illustrate the transferable nature of the activity to the instructor's locale. As such, any one of them can be used as a template for creating an example for a local land-use change.

Each example includes (a) a land use change-description and (b) a National Stormwater Calculator location file (.swc). (Note: To download a location file, click on the link, and select Save File, and then "OK." The file will be downloaded into your computer's Downloads folder. It can then be **opened from within the Calculator** as described in Part 1 of the Unit 2.1 Tutorial (Microsoft Word 2007 (.docx) 5.6MB Dec1 16).)

Athletic and Recreational Facility - image modified from Google Earth

- Athletic and Recreational Facility, Springfield, OH:

  Athletic and Recreational Facility Example (Microsoft Word 2007 (.docx) 558kB Sep4 16)

Athletic and Recreational Facility Location -- Stormwater Calculator File (ShockWave Component (SWC) 1kB Jun28 16)

- Missouri River, Vermillion, SD

Missouri River Example (Microsoft Word 2007 (.docx) 599kB Dec1 16)

Missouri River Location -- Stormwater Calculator File (ShockWave Component (SWC) 1kB Jul24 15)

Missouri River Subdivision -- image modified from Google Earth

- Williams Building Redevelopment / Red Butte Creek, Salt Lake City, UT

Williams Building Example (Acrobat (PDF) 591kB Nov30 16)

Williams Building Location -- Stormwater Calculator File (ShockWave Component (SWC) 1kB Jul30 15)

Each of the three examples has the same assessment schema in its description. A generalized assessment tool is included as Unit 2.3 Assessment (Microsoft Word 2007 (.docx) 20kB Sep4 16).

Williams Building Redevelopment along Red Butte Creek - image modified from Google Earth

Teaching Notes and Tips

Alternatives to LID Controls (10 min)

Prior to ending your last class session, you posed this question to your students: In planning the development of the expansion area, can you do so in such a way as to optimize natural ecosystem services to reduce the need for and cost of LID controls?

Ask the question again, prefacing it by saying that LID controls are not the only way to mitigate stormwater increases, and that before you proceed, you want to explore other ways. Solicit student responses to the question.

From a stormwater management link from the Center for Watershed Protection, there is a nice summary of LID controls as well as green infrastructure and environmental site design. You can follow the response period with a review of the website or by simply building a discussion off of the responses. The key here is being smart about the site. For example:

- Do not build in the low spots.
- Rearrange housing to follow contour or elevation.
- Move away from square lots to consume all of the space by creating common space with natural cover.

- If different soils are on the site, do not build on the most permeable or well-drained soils. Build on the high runoff potential soils, and let the other soils do what they do bestâ€”allow the infiltration of rainfall.
- Keep the steeper slopes in natural cover.
- Take advantage of natural features (e.g., swales and wetlands) and ecosystem services.

The National Stormwater Calculator can be manipulated in some ways to mimic these, but it suggests the limits of the model to students while providing alternative ways to think about the problem.

Assign the Land Use Change Example (remainder of class)

Ideally, students would investigate the impact of a local land-use change on stormwater runoff. Three examples, to be used as templates by the instructor for a developing a scenario for their locale, are provided. Alternatively, any of these examples could substitute for the local land-use change. The activity should be assigned to students in small groups of 2â€“4 students. They should use the remainder of the time developing a group plan for completing the work, finishing as much as possible during class. It may or may not be possible to hold a brief discussion of the groups' results. This can also happen within the context of the next and final unit of this module, Unit 3: Using an Ecosystem Services Approach for Civic Engagement. Alternatively, the students' work can be evaluated on the basis of a set of slides that might be presented to the university. A description of that assessment is included as Unit 2.3 Assessment (Microsoft Word 2007 (.docx) 20kB Sep4 16).

The assessment includes a summary slideshow to be turned in, geared toward the activity's objectives and designed for a university audience. Be clear that the final product is a 5-min slide presentation (suggest that it be 5 slides or fewer), submitted to you for review. Groups should include annotation on each slide or in the notes. This could be modified for a much broader audience in the next unit.

Assessment

The Unit 2.3 Assessment (Microsoft Word 2007 (.docx) 20kB Sep4 16) is generalized so that it is applicable to any exercise developed locally that follows the format of the example exercises presented above. A key is included: ▶ Unit 2.3 Assessment Key -- private instructor-only file
Unit 2.3 Assessment Key

This file is only accessible to verified educators. If you are a teacher or faculty member and would like access to this file please enter your email address to be verified as belonging to an educator.

Email Adress [ ] Submit

.

References and Resources

National Stormwater Calculator User's Guide Version 1.1

Description and download page for National Stormwater Calculator

Center for Watershed Protection

Teaching Themes

- Real-World Connections »
- Geographic Facility »
- Geoscience Methods »
- Authentic Data »

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Unit 3: Using an Ecosystem Services Approach for Civic Engagement

Developed by Ed Barbanell (University of Utah), Meghann Jarchow (University of South Dakota), and John Ritter (Wittenberg University)
Author Profiles
Profile Ed Barbanell, University of Utah
Profile Meghann Jarchow, University of South Dakota
Profile John Ritter, Wittenberg University

Summary

In this unit, students will explore the larger context in which ecosystem services are often utilized and real-world proposals for land-use change typically occur. Presented with a scenario for a proposed land-use change, students will consider both a broad range of ecosystem services as well as a variety of different stakeholder groups who benefit from those services. Students will then prepare group presentations, utilizing materials created in Units 1 and 2, describing a proposed land-use change, along with preferred mitigation strategies, from the perspective of particular stakeholders. Additionally, students will be prompted to reflect, individually, on an ecosystem services approach to natural resources management.

Learning Goals

Used this activity? Share your experiences and modifications

Overall Learning objective: Students will be able to evaluate the impact of land-use change on water resources utilizing an ecosystem services approach.

1. Students will be able to express the interests and values of identified stakeholder groups.
2. Students will create a presentation, supported by hydrologic data, that aligns with stakeholder groups' interests.
3. Students will assess an ecosystem services approach to land-use change.

Context for Use

This unit is designed to be used in conjunction with Unit 2 of this module. The example utilized by the instructor in Unit 2.3 should be extended/elaborated for the activities in this unit. This unit would be appropriate in a range of introductory courses, including courses in water resources, sustainability, ecology, environmental science, Earth science and geology, land-use planning, anthropology, and landscape design.

Class Size: This unit can be adapted for a variety of class sizes.
Class Format and Time Required: These activities are designed for at least three 50-minute lecture periods if students will be giving oral presentations. Students will work in groups of 4–5 students.
Special Equipment: Student groups should have a computer with access to the Internet as well as results from their work in Unit 2.3.
Skills or concepts that students should have already mastered before encountering the activity: This activity assumes mastery of basic concepts of ecosystem services and the hydrologic cycle through the completion of Units 1 and 2.

Description and Teaching Materials

This unit is divided into two sub-units:

1. Identifying the range of both ecosystem services and affected stakeholders associated with a land-use change.
2. Using stakeholder perspectives to create a group presentation describing a proposed land-use change along with a preferred mitigation strategy.

Either with the teacher leading the discussion or with the students working in groups, "mind maps" are created for considering a proposed land-use change (the same example used in Unit 2.3). Then through discussion, extract from the mind maps the range of (a) interests and (b) interested parties, from which students, organized into groups, will identify a range of both **stakeholders** and **ecosystem services** that need to be considered. Then, organized into stakeholder groups, students prepare a group presentation describing their preferred land-use change and mitigation strategy. Finally, at the conclusion of the unit and the module, students are asked to individually reflect on the efficacy of an ecosystem services approach for managing natural resources.

Assessment

The summative assessment for the module has two parts. Part I is a group presentation where students will develop a presentation describing a proposed land-use change and mitigation strategy from the perspective of a particular stakeholder group. Part II is a set of reflective questions that should be responded to individually. Both parts are contained in Module summative assessment (Microsoft Word 2007 (.docx) 28kB Sep4 16).

References and Resources

Module summative assessment (Microsoft Word 2007 (.docx) 28kB Sep4 16)

Mind Mapping Video

Celebrating and Shaping Nature (Acrobat (PDF) 425kB Nov30 16)

MEA ecosystem services categories (Acrobat (PDF) 510kB Aug4 15)

Considering using these

Already used some of these materials in a course?

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Unit 3.1: Land-Use Change and Stakeholders

Developed by Ed Barbanell (University of Utah), Meghann Jarchow (University of South Dakota), and John Ritter (Wittenberg University)
Author Profiles
Profile Ed Barbanell, University of Utah

Profile Meghann Jarchow, University of South Dakota

Profile John Ritter, Wittenberg University

These materials have been reviewed for their alignment with the Next Generation Science Standards as detailed below. Visit InTeGrate and the NGSS to learn more.

Overview

Students identify several major stakeholder groups and several distinct ecosystem services. Students, organized into groups representing particular stakeholders, prepare, for Unit 3.2, a group presentation that utilizes those ecosystem services as much as possible.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information: Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. HS-P8.1:

Developing and Using Models: Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system HS-P2.3:

Cross Cutting Concepts

Systems and System Models: Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. MS-C4.1:

Structure and Function: Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. HS-C6.1:

Disciplinary Core Ideas

Biodiversity and Humans: Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on —for example, water purification and recycling. MS-LS4.D1:

Human Impacts on Earth Systems: The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. HS-ESS3.C1:

Human Impacts on Earth Systems: Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. HS-ESS3.C2:

Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. HS-ETS1.B1:

Defining and Delimiting Engineering Problems: Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities HS-ETS1.A2:

Performance Expectations

Ecosystems: Interactions, Energy, and Dynamics: Evaluate competing design solutions for maintaining biodiversity and ecosystem services. MS-LS2-5:

Engineering Design: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. HS-ETS1-4:

Engineering Design: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. HS-ETS1-3:

This activity was selected for the On the Cutting Edge Reviewed Teaching Collection

This activity has received positive reviews in a peer review process involving five review categories. The five categories included in the process are

- Scientific Accuracy
- Alignment of Learning Goals, Activities, and Assessments
- Pedagogic Effectiveness

- Robustness (usability and dependability of all components)
- Completeness of the ActivitySheet web page

For more information about the peer review process itself, please see https://serc.carleton.edu/teachearth/activity_review.html.

This page first made public: Dec 2, 2016

Summary

The example of a proposed land-use change that was used in Unit 2.3 is built upon here. The activities in this unit are meant to broaden the discussion beyond calculating quantitative run-off changes. Now we will also bring in consideration of a broader range of ecosystem services, as well as other ways in which a landscape can be valued, some of which may not be easily measured or even conceptualized as "services." Classroom time is devoted to the instructor and students exploring both (a) the stakeholders who have an interest in a particular place and (b) the various interests/uses those stakeholders may have for that place. By the end of the activity, the class should have identified several major stakeholder groups and several distinct ecosystem services. Students, organized into groups representing particular stakeholders, will then be tasked to prepare, for Unit 3.2, a group presentation, to be discussed on class on the last day of the module, that utilizes those ecosystem services as much as possible.

Learning Goals

Used this activity? Share your experiences and modifications

Overall Learning objective: Students will be able to express the interests and values of multiple stakeholder groups.

Specific learning objectives for this activity:

1. Students will be able to assess a proposed land-use change from a broad perspective, including multiple uses and multiple stakeholders.
2. Students will be able to express disparate stakeholder values in terms of discrete ecosystem services.
3. Students will be able to construct scenarios matching stakeholder values with ecosystem services.
4. Students will be able to evaluate the effectiveness of mapping stakeholder values onto ecosystem services.

Context for Use

This activity is intended to be used as an extension of the activity used in Unit 2.3 of this module. As such, it would be appropriate in a range of introductory courses, including courses in water resources, sustainability, ecology, environmental science, Earth science and geology, land-use planning, anthropology, and landscape design.

Class Size: This activity can be adapted for a variety of class sizes.

Class Format: This activity is designed for individual lecture sessions, but it is suitable for use in a lab setting or as a homework assignment as well. Students can work together, in groups of 4–5 students.
Time Required: This activity is designed to be completed in a 50-minute class period.
Special Equipment: Student groups should have a computer with access to the Internet as well as the results from their work in Unit 2.3.
Skills or concepts that students should have already mastered before encountering the activity: This activity assumes mastery of basic concepts of ecosystem services and the hydrologic cycle through the completion of Units 1 and 2.

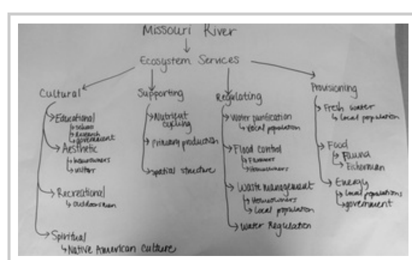
Description and Teaching Materials

In preparation for this activity, prior to class students should (1) watch the short YouTube Mind Mapping Video, and (2) read the short article by F. Stuart Chapin III Celebrating and Shaping Nature (Acrobat (PDF) 425kB Nov30 16). The video illustrates the process for creating a mind map, which will be the main tool for teasing out the ecosystem services and stakeholders involved in the proposed land-use change example. The Chapin article sets up a context for evaluating an ecosystem services approach to resource management, which should become an aspect of both the in-class discussion following the mind mapping exercise, as well as the reflective part of the module's summative assessment. (As a jump start to the in-class activity, students might be asked to come to class with a list of 4–5 potential interested parties and at least 3 uses/values of the land, in either its current or its re-developed state of affairs.)

During the first part of class, students will be put in groups of 4–5 individuals and asked to create mind maps whose main "topics" should be organized around either (a) people who have interests in the land and/or the land-use change or (b) uses to which the land is used or could be used under various land-use change scenarios (see the References and Resources section below for examples of actual mind maps created by student groups during the piloting phase of this module).

From these group mind maps, two consensus lists—one listing the major stakeholders, and one listing of the variety of uses of the land—should be created by the instructor on the board. At this juncture, the Millennium Ecosystem Assessment (MA) categorization of ecosystem services (MEA ecosystem services categories (Acrobat (PDF) 510kB Aug4 15)), which was described in Unit 1.1, should be reintroduced into the discussion. The discussion should then turn to translating the variety of uses listed on the board into discrete ecosystem services/benefits categories (i.e., Provisioning, Regulating, Cultural or Supporting) as identified in the MA.

In the context of this discussion, the difficulty of translating all of the uses identified in the mind map/list of uses into discrete ecosystem services as described in the MA will manifest itself, which will present an avenue for discussing the Chapin article.



Ecosystem Services, Uses, and Stakeholders for a Missouri River Landscape

Finally, students should organize into groups of 4–6 students representing major stakeholder groups. It is in these groups that they will create their presentations for the Unit 3.2

activity.

Teaching Notes and Tips

Below is a lesson plan for a 50-minute class period.

Discussion of the Chapin article (5 min)

In the Chapin article, he discusses how an ecosystem services approach tries to incorporate cultural and aesthetic values in services' trade-off calculations, but he also states that these values are more simply viewed as a "sense of place"—i.e., "the collection of meanings, beliefs, symbols, values and feelings that individuals and groups associate with a particular locality" (p.167). So, a question the students might consider before they began their mind-mapping exercise: is an ecosystem services approach capable of capturing/modeling all those thick-textured sense-of-place values?

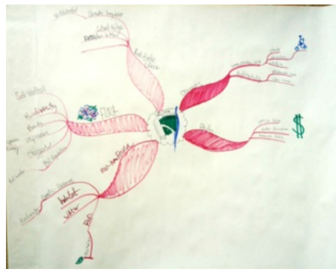
Mind Mapping (15 min):

Materials needed:

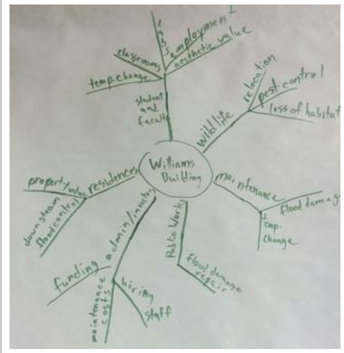
1. Enough (a) large sheets of unlined paper, or poster board, and—if you are going to have the students do a full-blown mind map, (b) sets of 4–5 different colored markers to accommodate groups of 4–5 students: one (a) and (b) for each group. (Using large sheets with a self-adhesive strip on the back is good, if you want to stick the completed group mind maps on the wall around the room afterward for folks to look at and reference.)
2. Copies of the land-use change exercise used in Unit 2.3 (enough so there is one for each group).
3. Write or project on the board the six main features of a good mind map:
    - Start in the center of a blank page turned sideways
    - Use an image or picture as your central idea
    - Use colors throughout
    - Connect your main branches to the central image, your second- and third-level

branches to the first, etc.
- Use one key word or phrase per line
- Use images when appropriate

Put the students in groups, and instruct them to use the picture of the site of the proposed land-use change as the center image of their mind map.



Full-Blown Mind Map (for Williams Building Redevelopment example)



Simple Mind Map (for Williams Building Redevelopment example)

Tell them that they are to create a mind map about the site, considering (1) all the kinds of **people** who might either **use** the site or have an **interest** in it (either in its current state or when it is developed in some fashion—maybe not the exact one proposed) and (2) all the different **ways** it might be **used** or **valued** (either in its current state or when it is developed in some fashion—again, maybe not the exact one proposed). They should use either (1) or (2) as the main branches of their mind map.

If time or inclination permits, a discussion of the pros/cons of using mind maps for this exercise could occur.

Ecosystem Services (5 min):

Project on the board or pass out copies of [MEA ecosystem services categories] (Acrobat (PDF) 510kB Aug4 15) from Unit 1.1. Have the students use their group's mind map (or the instructors, if s/he created one) to see which of the ways/uses/values identified on it can be translated into an ecosystem service that fits into a particular category.

Stakeholders and Ecosystem Services (10–20 min):

After clarifying that "stakeholder" merely means "someone who is involved in or affected by a course of action," the instructor at the board should extract from the groups two lists (1) Stakeholders and (2) Ecosystem Services. Additionally, stakeholders and ecosystem services can be paired or connected during this part of the discussion.

Ecosystem Services versus other values and interests (10–15 min):

Aspects of this part of the discussion will undoubtedly arise as students work through the above exercises, but the issue that not all "ways of using/valuing" can be easily or fruitfully translated into "ecosystem services" will be a cause of much frustration for students, and that is part of the point. Here, the instructor should refer to aspects of the Chapin article, particularly pp. 166–68, where he discusses all of this. How these non-ecosystem services values are characterized and utilized in public forum discussions is a vital question, and students should come away from the discussion with some ambivalence about the efficacy of ecosystem services as a comprehensive approach for making land-use change decisions.

Group Presentation Assignment and Groupings (10 min):

Students should be put in groups of 4–5 (or stay in the groups they have been put in), and each group should be assigned a main stakeholder or cluster of closely aligned stakeholders. Students will be working in these same groups for Unit 3.2.

Assessment

There is no assessment for this particular activity.

References and Resources

Mind Mapping Video

Celebrating and Shaping Nature (Acrobat (PDF) 425kB Nov30 16)

MEA ecosystem services categories (Acrobat (PDF) 510kB Aug4 15)

Mind map examples: Mind map examples from Barbanell course (Acrobat (PDF) 468kB Jun22 16), Mind map examples from Jarchow course (1) (Acrobat (PDF) 4.1MB Jun22 16), Mind map examples from Jarchow course (2) (Acrobat (PDF) 115kB Jun22 16), Mind map examples from Jarchow course (3) (Acrobat (PDF) 97kB Jun22 16), and Mind map examples from Jarchow course (4) (Acrobat (PDF) 67kB Jun22 16).

Teaching Themes

- Geographic Facility »
- Interdisciplinary Teaching »

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Unit 3.2: Presentation and Reflection

Developed by Ed Barbanell (University of Utah), Meghann Jarchow (University of South Dakota), and John Ritter (Wittenberg University)
Author Profiles
Profile Ed Barbanell, University of Utah

Profile Meghann Jarchow, University of South Dakota

Profile John Ritter, Wittenberg University

These materials have been reviewed for their alignment with the Next Generation Science Standards as detailed below. Visit InTeGrate and the NGSS to learn more.

Overview

Students present to a panel of faculty/students, or to a "board" representing some decision-making unit (Community Council, University Board of Trustees, City/County Planning Commission). Then they reflect, individually, on an ecosystem services approach to natural resources management.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information: Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). HS-P8.5:

Engaging in Argument from Evidence: Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions. HS-P7.3:

Engaging in Argument from Evidence: Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. HS-P7.4:

Constructing Explanations and Designing Solutions: Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. HS-P6.2:

Constructing Explanations and Designing Solutions: Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. HS-P6.3:

Cross Cutting Concepts

Systems and System Models: Systems can be designed to do specific tasks. HS-C4.1:

Cause and effect: Systems can be designed to cause a desired effect. HS-C2.3:

Disciplinary Core Ideas

Biodiversity and Humans: Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on —for example, water purification and recycling. MS-LS4.D1:

Human Impacts on Earth Systems: The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. HS-ESS3.C1:

Human Impacts on Earth Systems: Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. HS-ESS3.C2:

Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. HS-ETS1.B1:

Defining and Delimiting Engineering Problems: Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities HS-ETS1.A2:

Performance Expectations

Ecosystems: Interactions, Energy, and Dynamics: Evaluate competing design solutions for maintaining biodiversity and ecosystem services. MS-LS2-5:

Engineering Design: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. HS-ETS1-4:

Engineering Design: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. HS-ETS1-3:

This activity was selected for the On the Cutting Edge Reviewed Teaching Collection

This activity has received positive reviews in a peer review process involving five review categories. The five categories included in the process are

- Scientific Accuracy
- Alignment of Learning Goals, Activities, and Assessments
- Pedagogic Effectiveness
- Robustness (usability and dependability of all components)
- Completeness of the ActivitySheet web page

For more information about the peer review process itself, please see https://serc.carleton.edu/teachearth/activity_review.html.

This page first made public: Dec 2, 2016

Summary

In this activity, the student groups organized at the end of Unit 3.1 will prepare presentations representing different stakeholder positions. This artifact—Part I of the Module Summative Assessment (Microsoft Word 2007 (.docx) 25kB Sep4 16)—can be part of a presentation to the instructor, to a panel of faculty/students, or to a "board" representing some decision-making unit (Community Council, University Board of Trustees, City/County Planning Commission). At the conclusion of this unit, students will be prompted to reflect, individually, on an ecosystem services approach to natural resources management—Part II of the Module Summative Assessment (Microsoft Word 2007 (.docx) 23kB Sep4 16) .

Learning Goals

Used this activity? Share your experiences and modifications

Learning objectives:

1. Students will create a presentation, supported by hydrologic data, that aligns with the interests of their stakeholder group.
2. Students will assess an ecosystem services approach to land-use change.

Context for Use

This activity is intended to be used to create an artifact that constitutes Part I of the Module Summative Assessment (Microsoft Word 2007 (.docx) 25kB Sep4 16). The activity gives students the opportunity to integrate the knowledge gained throughout the module. It is highly adaptable and can be modified for a wide variety of uses; it could be expanded to include other topics that might be discussed in a civic forum. The amount of structure provided by the assessment can vary based on the level of course, from being highly structured to largely determined independently by the individual student groups.

Class Size: This activity can be adapted for a variety of class sizes.
Class Format and Time Required: This activity is designed for at least two 50-minute lecture periods if students will be giving oral presentations. During the first class period

(and likely out-of-class time), the students will work in groups of 4–5 students to develop their group presentations. During the second class period, each group will give a presentation regarding their stakeholder group's position on the proposed land-use change. Instructors will need to consider the size of the class and the individual group sizes in terms of structuring the presentations. Ideally, the instructor should assemble a panel of 2–5 individuals, representing a range of the stakeholder groups presented in the activity, to whom the student groups should give their presentations.
Special Equipment: Student groups should have a computer with access to the Internet as well as results from work in Unit 2.3.
Skills or concepts that students should have already mastered before encountering the activity: This activity assumes mastery of basic concepts of ecosystem services and the hydrologic cycle through the completion of Units 1 and 2.

Description and Teaching Materials

Class Period 1

Students should use the whole class time—and likely some out-of-class time, too—to prepare their group presentation. If students completed the Unit 2.3 Assessment (Microsoft Word 2007 (.docx) 20kB Sep4 16), they should be encouraged to use components of that presentation.

Presentation Guidelines

The purpose of the group presentation is to provide students the opportunity to role-play the likely responses of a particular stakeholder group to the proposed land-use change. In their group presentations, students evaluate a proposed land-use change and offer a strategy to mitigate the hydrologic impacts of the change. Because the focus of this module is on ecosystem services, each group's presentation should focus on how the proposed change will or will not affect the production of ecosystem services most important to the stakeholders they are role-playing/representing. [Note: Students may find that focusing on ecosystem services constrains their ability to make their arguments. The reflective questions in Part II of the Module Summative Assessment (Microsoft Word 2007 (.docx) 23kB Sep4 16) provide students an opportunity to reflect on the limits of an ecosystem services approach.]

In the presentation, each group will:

1. Provide an introduction that frames the proposed land-use change within the broader context of water resource challenges,
2. Identify themselves (i.e. their stakeholder group), including stating their organizational mission or objectives,
3. Describe the proposed land-use change from the perspective of their stakeholder group and propose a mitigation strategy,
4. Quantify the hydrologic impacts of the proposed land-use change and mitigation strategy,
5. Create a visualization to contextualize the stormwater calculator results in terms of the broader system in which the site exists, and
6. Describe impacts of the mitigation strategy from environmental, social, and

economic perspectives of their stakeholder group.

Additional guidelines/instructions for each of these components are described in Part I of the Module Summative Assessment (Microsoft Word 2007 (.docx) 25kB Sep4 16).

Class Period 2

If a review panel or "board" representing some decision-making unit (Community Council, University Board of Trustees, City/County Planning Commission) is present for the class period, the panel should be introduced to the students. Most of the class period should be dedicated to the group presentations. The group presentations should be evaluated along the lines of the rubric supplied as part of the Part I of the Module Summative Assessment (Microsoft Word 2007 (.docx) 25kB Sep4 16). If time is available after the presentations, the panel and students should engage in a discussion about the proposed project. The panel members could bring up aspects of the proposed land-use change that were not addressed in the group presentations.

At the end of the class period, students should be assigned to individually complete for homework the reflective questions in Part II of the Module Summative Assessment (Microsoft Word 2007 (.docx) 23kB Sep4 16). This assessment will allow the students to broadly reflect on an ecosystem services approach, particularly regarding its strengths and weaknesses as a decision-making tool for natural resources management.

Teaching Notes and Tips

none

Assessment

The group presentations should be assessed with Part I of the Module Summative Assessment (Microsoft Word 2007 (.docx) 25kB Sep4 16).

The reflective questions should be assessed with Part II of the Module Summative Assessment (Microsoft Word 2007 (.docx) 23kB Sep4 16).

References and Resources

Part I of the Module Summative Assessment (Microsoft Word 2007 (.docx) 25kB Sep4 16)

Part II of the Module Summative Assessment (Microsoft Word 2007 (.docx) 23kB Sep4 16)

Teaching Themes

- Interdisciplinary Teaching »
- Authentic Data »

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Assessment of Module Goals

Below you will find a list of the assessments for each activity (e.g. Units 1.1, 1.2, and 1.3) in the module as well as the assessment for the module as a whole. Each activity has associated with it formative assessments to measure student progress toward individual activity learning outcomes. To assess overall learning in this module, you will find a summative assessment project that integrates the learning outcomes of the module.

Overall Module Assessment

The summative assessment for the module has two parts. The first part is a group presentation where students will develop a presentation describing a proposed land-use change and mitigation strategy from the perspective of a particular stakeholder group. The second part is reflective questions that should be completed individually (Module summative assessment (Microsoft Word 2007 (.docx) 28kB Sep4 16)).

Unit Assessments

Unit 1 Assessments

Unit 1.1

- Assessment of before-class preparation material: Worksheet on "An Introduction to Ecosystem Services" (Microsoft Word 2007 (.docx) 15kB Nov30 16); Assessment key for Worksheet on "An Introduction to Ecosystem Services" -- private instructor-only file
  Assessment key for Worksheet on "An Introduction to Ecosystem Services"

  This file is only accessible to verified educators. If you are a teacher or faculty member and would like access to this file please enter your email address to be verified as belonging to an educator.

  Email Adress [ ] Submit
- In-class formative assessment: Instructors should provide oral feedback to each group on their presentations (see Unit 1.1 Presentation (PowerPoint 2007 (.pptx) 5.6MB Nov30 16) for a description of the in-class presentation guidelines). Instructors can also utilize the "additional practice" exercises in the PowerPoint file as an assessment.

- Post-activity formative assessment: Unit 1.1 Assessment (PowerPoint 2007 (.pptx) 2.7MB Nov30 16); Unit 1.1 Assessment key -- private instructor-only file
  Unit 1.1 Assessment key

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Unit 1.2

- A Watershed Hydrology Literacy Assessment (Microsoft Word 2007 (.docx) 14kB Dec1 16) can be assigned as a follow-up assessment or exercise to the Watershed Hydrology Literacy reading or it can be assigned as homework following completion of Unit 1.2.
- Post-activity formative assessment: Unit 1.2 Assessment (Microsoft Word 2007 (.docx) 18kB Sep3 16); Unit 1.2 Assessment Key -- private instructor-only file
  Unit 1.2 Assessment Key

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Unit 1.3

- Post-activity formative assessment: Unit 1.3 Assessment (Microsoft Word 2007 (.docx) 20kB Sep3 16); Unit 1.3 Assessment Key -- private instructor-only file
  Unit 1.3 Assessment Key

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Unit 2 Assessments

Unit 2.1

- In-class formative assessment: Unit 2.1 Assessment (Microsoft Word 2007 (.docx) 16kB Sep4 16); Unit 2.1 Assessment Key -- private instructor-only file
  Unit 2.1 Assessment Key

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Unit 2.2

- In-class formative assessment: Unit 2.2 Assessment (Microsoft Word 2007 (.docx) 21kB Sep4 16); Unit 2.2 Assessment Key -- private instructor-only file
  Unit 2.2 Assessment Key

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Unit 2.3

- Post-activity formative assessment: Unit 2.3 Assessment (Microsoft Word 2007 (.docx) 20kB Sep4 16); Unit 2.3 Assessment Key -- private instructor-only file
  Unit 2.3 Assessment Key

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Unit 3 Assessments

Unit 3.1

- Post-activity formative assessment of group mind maps, per the features of a good mind map, as outlined in the Unit 3.1 Teaching Tips and Techniques.

Unit 3.2

- Module summative assessment: Module summative assessment
  (Microsoft Word 2007 (.docx) 28kB Sep4 16)

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How to Use »

Instructor Stories and Adaptations

These resources describe how the module was adapted for use in different settings. We hope these stories inspire your own use of the module and give you insight into how to adapt the materials for your classroom.

Ed Barbanell: Environmental Ethics at University of Utah. This module was used in an intermediate-level environmental ethics course, which fulfills major requirements for both philosophy and environmental/sustainability studies, as well as fulfilling a humanities general education requirement. The course had 40 students, and the module was taught over three weeks—two 80-minutes sessions per week— toward the latter part of the semester.

Meghann Jarchow: Sustainability and Society at University of South Dakota. This module was used in an introductory sustainability course with 25 students. The module was taught for three weeks as the third of four modules in the course. The course met three times per week for 50 minutes per class.

John Ritter: Environmental Geology at Wittenberg University. I used this module in an introductory environmental science course taken by both science and non-science majors. The course consists of three hours of lecture and one three-hour lab each week. The module was taught over a three-week period, using both lecture and lab sessions but interspersed with other lecture content and lab activities associated with water resources. In all of my courses, I attempt to make the content relevant locally; the module provides an opportunity to examine a local impact on stormwater generation and its mitigation by maintaining or enhancing ecosystem services. It will be modified this year for use in a course on the hydrologic cycle for non-science majors.

Learn more about using InTeGrate modules and courses

Additional Instructor Stories

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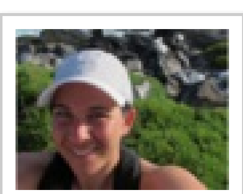

Dr. Kristen Cecala: Using An Ecosystem Services Approach to Water Resources in Biology 210 at Sewanee: the University of the South
Kristen Cecala, Sewanee: the University of the South
Ecology regularly integrates expertise developed in other disciplines to allow us to understand interactions in the natural world. Teaching concepts in ecosystem ecology that require rudimentary comprehension of chemistry for nutrient cycling and availability can be challenging for

two reasons: 1) students have the misconception that scientific disciplines don't inform one another, and 2) nutrient cycling can seem abstract.

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Ed Barbanell: Using An Ecosystem Services Approach to Water Resources in Environmental Ethics at University of Utah

About this Course

This is a 3000-level course that serves a variety of purposes and audiences. For philosophy majors and minors, it satisfies an area requirement in ethical theory, and it satisfies a similar area requirement for environmental and sustainability studies majors. It is also designated as a humanities general education course, so it also regularly attracts students from all levels and from across the curriculum.

40
students

Two 80-minute lecture sessions

Syllabus for Environmental Ethics (Phil 3530) (Acrobat (PDF) 950kB Jun23 16)

Basic theories of environmental ethics, issues in environmental ethics (e.g., wilderness/species preservation, animal rights, pollution control, development vs. preservation) distributive justice in relation to the environment.
By the end of the semester, students should be able to:

- Understand a range of approaches to and standpoints about environmental ethical issues;
- Integrate such approaches/standpoints into their own thinking about such issues;
- Formulate their own conceptions and informed positions about such issues;
- Express those positions in reasonable, forceful and well-structured written arguments;
- Evaluate (describe and analyze) others' arguments/concepts/positions about such issues;
- Engage directly and effectively with others in informed discussions about such issues.

Provocative Expansion of the Typical Environmental Ethics Course

The narrative of environmental ethics is currently in flux, inexorably shifting away from an almost exclusive emphasis on justifying the protection of "nature," understood primarily as "wilderness," to exploring a broader range of human/nature relationships. With discussion of the Anthropocene quickly gaining traction and momentum across the curriculum, conceptualizing nature as just so many discrete services supporting and sustaining human life and well being is fast emerging as the dominant viewpoint. In such a state of affairs, the main ethical questions concern what, if any, limits we might have in altering "nature" in the name of improving its services to us. Accordingly, introducing this module in an environmental ethics course is a timely and necessary expansion of the discussion.

The exercises in this module thoroughly engaged and animated the students. Several of them explicitly referenced the module in their course evaluations, e.g., "Ed's three-week module on water resource management was the highlight of the semester for me. I learned a lot, and it opened my eyes to the considerable amount of planning that goes into low-impact development."

My Experience Teaching with InTeGrate Materials

I was able to use module effectively just as we designed it. I did not administer some of the formative assessments, and in a few places I combined PowerPoints because we designed the module for nine 50-minute class sessions but I taught it in six 80-minute ones.

Relationship of InTeGrate Materials to my Course

This was a standard 16-week spring semester course, and I implemented the module during weeks 11–13, right after spring break. Prior to introducing the module, we had worked progressively through a serious of ethical viewpoints, starting from eco-centric ones and moving inexorably toward more eco-humanist and anthropocentric ones. The module served as a useful bridge leading to an end-of-semester discussion of an emerging eco-modernist ethic. Since eco-modernism evaluates nature primarily through a ecosystem services lens, it was quite useful to have actually gone through an ecosystem services modeling exercise.

Unit 1:

I implemented Unit 1 in two class sessions, rather than the three for which it was originally designed. So on the first day, I worked through all of Unit 1.1, and about halfway through Unit 1.2, through the introduction of the water balance equation and stream hydrograph. Accordingly, I added the first seven slides from the Unit 1.2 PowerPoint to the end of the Unit 1.1 In-class PowerPoint.

Prior to the first class, I had the students go through the Unit 1.1 Before-class Introductory PowerPoint and do the associated assessment (I spent just a few minutes at the beginning of class making sure there was a general understanding of the material). Also, for use as a reference document during this class and the rest of the module, I made copies of the Ecosystem Services Chart (slide #8 from the Before-class PowerPoint) for each student (this proved quite useful as a ready reference throughout the module).

Prior to the first class, I had also identified students with PC laptops who were willing to bring them to class throughout the module. I made sure that these students had downloaded both (1) Google Earth Pro and (2) the EPA Stormwater Calculator. All the students had then been put in groups of 4–5, with each group having a student with a laptop that had the necessary software installed.

Working through the first class was straightforward, and the students seemed really engaged and fascinated by Google Earth, most never having thought of the software as a research tool (!?). I added in demonstrations of two Google Earth tools that are not discussed in the PowerPoint: street view (which came in handy for Unit 2.3) and save (which is useful when the students are preparing their presentations in Unit 3.2.)

I did not do the water hydrology literacy assessment, as it would have taken me too far afield and used up too much class time.

As homework before the second class period, I assigned them to read the USGS "Effects of Urban Development on Floods." The second class period covered the second part of Unit 1.2 and all of Unit 1.3. Here is a detailed script of how we moved through the materials:

1. Using Google Earth, showed Salt Lake Valley, discussed bulleted questions under Introduce the Rock creek watershed in 1.2 Description and Teaching Materials. Particularly focused on (a) how precipitation is measured and (b) where output, or runoff, is measured.
2. Zoomed to U. of U. campus, and discussed the sub-watershed for our campus, which is Red Butte Creek.
3. Then switching to Surf Your Watershed, typed in the UofU zip code, and then looked at gauging data for Red Butte Creek—propitiously, we had just had a big rain/snow event the day before, and this was quite evident on the stream hydrograph. Discussed this for a few minutes.
4. Handed out rainfall/runoff data for Rock Creek and Big Creek, with only the Rock Creek data already plotted.
5. Asked the groups to plot out the Big Creek data and calculate the average rainfall and runoff, and plot the average runoff. (10 min) Discussed how independent/dependent data are typically plotted.
6. After coming up with the figures, used Google Earth, via the Rock Creek and Big Creek watersheds .kmz file), to show these two watersheds. Just from the Google images, asked them, in thinking about the disparity in runoff figures, which watershed was which, and that was fairly straightforward.
7. Spent the rest of class working through the Unit 1.3 Presentation PowerPoint.

Unit 2:

Prior to class, for homework, I had the students do the pre-Unit 2 assessment wrapper (and then had them do this again as a post-Unit 2 assessment wrapper at the end of the next class period). I worked through Units 2.1 and 2.2 in one class period, with plenty of time, and then worked through Unit 1.3 in one class period. The whole unit worked great. The first class period for Unit 2 went like this:

1. As a refresher from last time, went through PowerPoint 2.1, stopping on slide 6.
2. Discussed the other ecosystem services, beyond flood control, that are affected by urbanization and increased runoff.
3. Handed out Science in Action sheet and watched short intro to the Stormwater Calculator.
4. Handed out Assessing the Impact of Land Use Change on Stormwater Runoff tutorial and assessment & table for charting results.
5. Went through scenarios 1 & 2—walked around and helped groups. Went through it myself, periodically pointing out various aspects of the SWC as I overheard groups talking or was asked questions. Took about 30 minutes. Discussed the major things that changed between baseline and new scenario—runoff contained, days of flooding, change in how much rain would cause a flooding event.
6. Handed out Reducing the Impact using LIDs—went through this scenario, showing them how to get more information about particular LID controls by clicking on links in the stormwater calculator.
7. Had each group fill out the Unit 2.2 Assessment (should have allowed a little more time).
8. I wanted the students to have a little better sense of LIDs prior to doing Unit 2.3, so I assigned them for homework to watch the first 21 minutes of the YouTube video "Stormwater Management: Low impact Development and Greening Corporate Grounds."

I did not administer the Unit 2.1 Assessment because it significantly overlaps with the Unit 2.2 Assessment wrapper.

I spent the entire fourth class period having the students work through Unit 2.3, using the Red Butte Creek / Williams Building example.

At the beginning of class, for about 10 minutes, I used the street view feature of Google Earth to give the class a virtual tour of several LIDs around the University of Utah campus (which included bioswales, green roofs, catchment basins, planters and porous concrete). This was a successful enterprise, as evidenced in the students' responses for the Post-Unit 2 Assessment wrapper. When administered as a pre-unit wrapper, it showed that most students knew very little about stormwater generation and mitigation on our campus. When administered again as a post-unit wrapper, almost every student was fairly conversant about this topic!

Unit 3:

I did Unit 3.1 essentially as laid out in the Teaching Notes and Tips:

1. Did a brief overview of what we were going to be doing this week—building on the evaluation of the Williams building redevelopment, to consider ecosystem services more broadly.
2. Discussed the Chapin article, which had been assigned as homework, particularly pp. 167–68: he discusses how an ecosystem services approach tries to

incorporate "values" in trade-off calculations, but he later says that cultural or aesthetic values are more simply viewed as a "sense of place—the collection of meanings, beliefs, symbols, values and feelings that individuals and groups associate with a particular locality." So, the question posed to the students from this, before they began their mind-mapping exercise, was: is an ecosystem services approach capable of capturing/modeling those thick-textured sense-of-place values?

3. Handed out markers and big Post-it pads, and had them do mind maps (25-30 min):
   a. Showed them a mind map I had done for something else, a UofU water system mind, and I also showed them a pseudo-mind map I had done for the Williams building, but in only one color.
   b. After about 15 minutes, also handed out the sheet with the MA ecosystem services categories, and asked them to incorporate that into their mind maps.
   c. We posted the mind maps on the wall and had folks look over each others' for a few minutes.
4. Went around the room and extracted from the students a variety of stakeholders and a variety of uses, and we discussed these for a few minutes (15).
5. Handed out the instructions for the summative assignment for the module.
6. Rather than assign stakeholders to the various groups, I gave them a few minutes to choose themselves what stakeholder group they wanted to represent in their position reports.

On the last day of the module, students spent about an hour working on their presentations. Due to the size of the class and number of stakeholder groups, it was not possible for the groups to present them to the class. Instead, each group was asked to briefly summarize the main aspects of their proposal. The second part of the summative assessment was assigned for homework.

Assessments

I used/graded the Unit 1.1 Before-class Preparation Assessment to make sure they had gone through the module introductory PowerPoint, so that we could start off the first day of the module with a working knowledge of ecosystem services. I used/graded the Unit 2.2 Assessment to "reward" the students for all of their in-class hard work on using and mastering the EPA Stormwater Calculator. I used the pre- and post-Unit 2 wrapper to gauge the students' knowledge of campus features related to water generation and mitigation before and after our discussion on the topic. Regarding the module summative assessment, the reflective piece was of more interest to me than the presentation piece, in terms of gauging how the students were doing via-a-vis the learning outcomes for the course.

Outcomes

My intent was to expose the students to an anthropocentric, quantitative approach to environmental ethical decision-making, as opposed to the non-anthropocentric, qualitative approaches typically discussed in environmental ethics courses. I wanted them to be able to weigh the pros and cons of these two different approaches, and to consider which seemed a more promising approach to such matters. Based on the tenor of the classroom discussions and the content of their responses to assessments, particularly the reflective piece of the summative assessment, this vision was borne out to great effect.

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Meghann Jarchow: Using An Ecosystems Services Approach to Water Resources in Sustainability and Society at University of South Dakota

About this Course

One of two core, introductory courses (200-level) for a sustainability major and minor; course also fulfills a social science general education requirement.

22
students
Three 50-minute lecture sessions per week

Sustainability & Society syllabus (Acrobat (PDF) 454kB Jun21 16)

This course will examine how science seeks to answer questions and how it can be used to address sustainability-related issues including climate change as well as energy production and use.
Course learning outcomes:

- Students will describe what climate change and ecosystem services are.
- Students will describe how climate change, ecosystem services, energy, and the built environment are related to sustainability.
- Students will utilize a systems-thinking approach in assessing sustainability topics.
- Students will appraise group/team dynamics and personality styles better.
- Students will identify an area of sustainability about which they are passionate.
- Students will identify opportunities for how they can effect change.
- Students will identify appropriate sources of information for sustainability issues.

Using models to frame public discussions

My course is one of two introductory, core courses for a sustainability major and minor. The course focuses on the environmental aspects of sustainability and is taught using team-based learning methods. My goals for the course include teaching students how to use some of the many scientific tools that have been developed for the public and teaching students how to translate the output from those tools into forms that can be used to effect positive environmental change. This module was an effective way to combine these two goals.

Watersheds and the hydrologic cycle are especially clear examples of systems. Through this module my students learned basic systems terminology and how systems can be modeled.

My Experience Teaching with InTeGrateMaterials

I made only limited modifications to the module. My primary modifications were editing the PowerPoint presentations to fit my presentation style and reinforce content previously discussed in the course.

Relationship of InTeGrate Materials to my Course

My course was arranged into four modules. This module was taught as the third module of the course, after the climate change and energy modules and before the built environment module. This module built upon systems terminology introduced earlier in the course and built upon the summative assessments of the previous two modules where the students gave group presentations to the class.

I implemented this module very closely to our instructor descriptions. Below are descriptions of specific changes that I made to each module.

Unit 1

- Unit 1.1: In the In-class PowerPoint, I did not use the from-the-ground pictures that corresponded to the Google Earth imagery. I did not think that I would have enough class time to get through all of the material (which ended up being correct), so I decided to cut these slides out. I did not do either of the "additional practice" slides. I did not have as much time as I would have liked for the students to present back to the class for the summary/wrap-up. Because of this, I did not provide much oral feedback to the teams about their presentations or findings.
- Unit 1.2: I modified the PowerPoint to better fit my presentation style and the previous course material. We had previously discussed systems, so I presented the hydrologic cycle and watersheds using the systems terminology that we had discussed previously in the course. I also focused on how we would be modeling the hydrologic cycle. For the assessment, rather than doing a one-minute paper and the homework, I included the one-minute paper as a question on the homework. I also did not require the students to use Excel to graph the rainfall-runoff data for Big Creek watershed because we had not used Excel in the course previously. I provided them with the graph and asked them to calculate the amount of water stored in the soil or evapotranspired.
- Unit 1.3: I modified the PowerPoint to better fit my presentation style. I did not go into detail about the land-cover classes.

Unit 2

- Unit 2.1: I modified the PowerPoint to better fit my presentation style and the previous course material (i.e. I focused on the modeling and understanding systems). I will describe this more below, but I had problems with the students downloading the EPA Stormwater Calculator. I had intended for the students to do this unit in class, but instead I ended class early and told them to do the "Stormwater calculator tutorial 1" outside of class. This did not go well because most students did not do it, so then they had a poorer understanding of the stormwater calculator when we used it the next class period. Because I had planned on having the students complete the tutorial in class, I did not require them to turn in Table 1 from the tutorial.
- Unit 2.2: I modified the PowerPoint to better fit my presentation style. I did not do the "think-pair-share" question about campus because I spent more time catching the students up from what we would have done as wrap up/summary in class at the end of class for Unit 2.1. Rather than requiring students to complete the Unit 2.2 assessment, I offered them extra credit for completing it. Therefore, fewer students completed it.
- Unit 2.3: I had the students complete the assessment (Unit 2.3 assessment) in class as a team. Due to time limitations, most of the assessments were not complete.

Unit 3

- Unit 3.1: I created a PowerPoint to frame the mind mapping in terms of previous course material (and material from my course last semester, which at least one student in each team had taken).
- Unit 3.2: I did not modify this unit.

Assessments

I had my students complete almost all of the formative assessments described in the module, which ended up being a lot of assessments for the students to complete and for me to grade. In the future, I would not assign all of the formative assessments. I assigned the summative assessment as described. Because my students had been doing similar summative assessments for previous modules, this assessment worked well in my course.

Outcomes

Students often think that modeling is necessarily abstract and mathematically complex. Through this module, I hope that my students were able to realize (1) that there are many different ways to do modeling and (2) that there are many tools that have been developed to allow the public to use relatively complex models to quantitatively evaluate environmental processes.

Classroom Context

- Intro Courses »

John B. Ritter: Using An Ecosystem Services Approach to Water Resources in Environmental Geology at Wittenberg University

About this Course

An introductory course for both science and non-science majors; not required for the geology major but may be the gateway course for a major.

30
students
Three 60-minute lectures and one three-hour lab per week

Ritter Syllabus for Environmental Geology (Microsoft Word 69kB Jun21 16)

Introduction to applied geology for science and non-science students. The geologic basis for natural processes that are hazardous to humans and cause environmental problems associated with use of the natural or modified environment is discussed. Topics include flooding, mass wasting, soil erosion, water supply use, and pollution and waste disposal. Every year.
Students in this course evaluate hazardous geologic processes (e.g. volcanism, flooding, mass wasting) and natural resources (e.g., water resources, soils, wetlands) in a data-intensive way, the circumstances of their occurrence, and the impact humans have on them, and apply this understanding to hazard mitigation and resource conservation.

A Success Story in Building Student Engagement

My course is an introductory environmental geology course taken by science and non-science students with content split between natural hazards and natural resources. The course is data-driven, using locally-available data or data from the U.S. Geologic Survey and state surveys, to analyze hazards and resources and their mitigation. This module was used to cover water resources but from the context of ecosystem services which, in my opinion, tended to broaden the interest among the biology majors in the course. Students went from focusing on the generalities of ecosystem services that they mostly understood in a biotic context to using them to contextualize changes in the hydrologic cycle due to land-use change. They used streamflow data from watersheds under different land uses to quantify changes in runoff with development and impervious surfaces, they used a national model to assess changes in runoff, infiltration, and evaporation with land-use change, and they applied that information to a local, campus issue associated with planned construction on campus. The module culminated in a presentation to, and discussion with, members of the university administration who were actively engaged in decisions on how to handle stormwater from the planned facility.

Students actively participated in a discussion of how new stormwater generated by an athletic practice facility, the groundbreaking of which is planned for our campus next year, will be mitigated. Our community is aggressively addressing stormwater issues, so the interplay between students, the university, and the city's urban stormwater coordinator was an invaluable learning experience.

My Experience Teaching with InTeGrateMaterials

I substituted the module for content I normally would have covered concerning water resources. I dropped some lecture content on groundwater and several lab activities associated with surface water and groundwater resources. While the module was decidedly different in approach and some content, it allowed me to experiment with a different way of teaching and to evaluate the potential for using other modules on natural hazards and resources from the SERC InTeGrate site in my course.

Relationship of InTeGrate Materials to my Course

My environmental geology course is a semester-long course, divided into two halves, the first half covering natural hazards (e.g., volcanism, earthquakes, mass wasting) and the second half covering natural resources (e.g., surface water and groundwater resources, soils, wetlands). It consists of three hour-long lectures and a three-hour lab each week. The module is designed to be completed in three weeks, in three lecture periods per week.

The additional time associated with the lab allowed me to break up module work to include lab and field activities associated with water resources. In some cases, these activities were modified from existing activities so that they could be related to the module (i.e., a stream table lab was modified to illustrate regulating and supporting ecosystem services of floodplains and meandering rivers) and created new activities directly related to the module (i.e., a walking tour of campus structures designed to handle stormwater runoff and an off-campus field trip in association with our city's urban stormwater coordinator to examine other stormwater structures in our combined sewer overflow system).

I did not introduce related concepts or material prior using the module, though in hindsight I wish I had introduced systems and associated terms and concepts more deliberately during the course introduction. Following the module, I was able to use the ecosystem services framework and the information on water resources as the class shifted to soil resources and wetlands. Between these two topics, I could fully incorporate provisioning, cultural, and supporting services. They dovetailed nicely with content and activities, providing an overarching framework for natural resources that I will incorporate in the second half of my course in the future.

Unit 1: Recognizing Ecosystem Services and their Relation to the Hydrologic Cycle

This introductory unit is the most instructor-intensive, in my opinion. It sets up the final two units that are largely student-driven and time on task.

The conceptual framework for ecosystem services is introduced in the beginning through a visual-rich introduction of land use and cover and their change over time. Google Earth (and its historical imagery) is an invaluable tool for the introduction and can be used interactively with the PowerPoint presentation. In the future, I will modify this presentation to include the local setting as much as possible, including incorporating changes on campus that will be important to Units 2 and 3, including the final presentation. I handed out a table from the Millenium Assessment organizing and describing ecosystem services so we were working from a common framework and language.

The transition to the hydrologic cycle should stress the relation between terms associated with the hydrologic cycle and mostly known to students on a certain level (e.g., precipitation, runoff, evaporation, transpiration) with ecosystem surfaces. By referring to land use and land cover and its impact on say, runoff or infiltration and their relation to regulating ecosystem services, this will go smoothly. The rainfall-runoff data from the two watersheds is critical evidence demonstrating that land use impacts runoff. Rainfall-runoff data were collected from available data from watersheds that are as similar in area, slope, and other relevant watershed characteristics and hydrologic variables like annual precipitation as possible. The only exception is land use, dominated by agriculture in watershed and urban development in the other. Using this information to set up some of the habits of science (i.e., controls, variables) will help students brainstorm and understand potential reasons for the difference in runoff. Again, referencing specific ecosystem services (e.g., water regulation, natural hazard regulation) is critical here to maintain the integrity of the ecosystems approach.

The PowerPoints and instructor teaching notes and tips in general are extensive and contain more information and activities than are necessary to include in your course to make it successful. This is particularly true in Units 1.2 and 1.3. I would encourage adopters to tailor these materials to their expertise and their course needs to make them most successful. In the future, I will eliminate some of the slides on land use classification and land use change and rely on Google Earth for this. Working with the rainfall-runoff data was critical, but in the future I will have students do some of this as homework, entirely in Excel, and bring their results to class for group discussion.

Unit 2: Measuring and Modeling Ecosystem Services

I followed the activity outlined in the instructor notes and tips fairly closely in Units 2.1 and 2.2. The units are dominated by tutorial work associated with the EPA's Stormwater Calculator. The activities rely on the Calculator, and use of the Calculator is restricted to Windows-based systems. To alleviate the problems associated with this, I had the software loaded on computers in a campus computer lab. I introduced the software to students while in the lab, and they worked on the first two tutorials (Units 2.1 and 2.2) during class time. Because they worked in groups of two and three around computers, this facilitated the transition to larger group work (i.e., groups of 5–6) in Unit 2.3. Part of the work in Unit 2.3 was completed during a lab session, which helped facilitate organization of tasks within student groups related to the model simulations and creation of the presentation.

Three critical tips here:

- Unit 2.1. In introducing the Stormwater Calculator model to students in Unit 2.1, illustrate (or even map) the processes modeled to the hydrologic model presented in Unit 1.2. The input for the model is related directly (e.g., precipitation) or indirectly (e.g., soils or slope and their control on infiltration and runoff) to the hydrologic cycle.
- Unit 2.2. Low Impact Development (LID) controls are introduced in Unit 2.2. The relationships between LID controls and processes or reservoirs in the hydrologic cycle and ecosystem services are important. General discussion of these relationships can and should occur in class, but the assessments for these units explicitly ask students to make these relationships and will help the instructor evaluate student understanding of them. What may be important here is illustrating examples of LID controls to students. Table 2 in the National Stormwater Calculator User's Guide Version 1.1 is a good introduction. On three occasions, I did short walks on campus and an off-campus field trip to introduce some examples of LID controls, discuss their pros and cons relative to ecosystem services, and interact with the city's stormwater coordinator. Other community officials who might be appropriate to involve include watershed coordinators, members of local environmental and land preservation groups, and technicians or administrators of the county soil and water conservation district.
- Unit 2.3 Incorporate a local land-use change here, a real or hypothetical (but realistic) change that engages students. The examples in the Description and Teaching Materials section demonstrate a common template for creating these that can be adapted locally. In my case, the proposed change involved an indoor athletic practice facility being constructed on what is currently a practice field, albeit a green space. It is costly but will attract students, impacts some students (i.e., student athletes) more than others, and has some community interest relative to hosting some indoor events. It also requires that new stormwater generated is dealt with. So there are many facets to it. This was rich from a student perspective and engaged them directly.

Unit 3: Using an Ecosystem Services Approach for Civic Engagement

After going over the final student presentations, I talked to the class about making a presentation to an outside stakeholder group—members of the university administration who were directly involved in the planning and fundraising for the athletic practice facility. I suggested that I would select one presentation to present our class group work, but that the remainder of the class would be involved in the broader discussion that followed. The stakeholder group included the athletic director and two members of advancement, one of them charged with fundraising for the facility and having recently come from Oberlin College with its state-of-the-art environmental science building (runoff neutral, green roof, recycled water, LEED Gold-certified, etc). Following the presentation, there was back and forth discussion between students and our guests, founded on modeled data of the facility's impact on the rainfall-runoff relationship using different scenarios. This was about as engaged as I have ever seen students in a normal class of 24–30 members, and especially so with the athletes in the room.

Assessments

I used the assessments that we originally designed for the module. There were many of them. It was difficult for students from the perspective that it involved so much more activity inside and outside of class than came before the introduction of the module. In some respects, if I include other modules prior to this, the change will not be so dramatic. I felt each was useful for my assessment of their participation and understanding, so I am not ready to eliminate any of them. I actually added an additional quiz during Unit 1.2 to emphasize the need to read materials prior to class.

We included a reflective essay in Unit 3.2. I did not use it because of the preparation for the presentation, but I will in the future. Other members of the module team used it, and their results convinced me of its value. In fact, in our modifications of the module, we have incorporated it into the final summative assessment.

Outcomes

My primary goal, both in design and implementation of the module, was to become more acquainted with best practices associated with active teaching. In hindsight, I would add to that list backward design of course activities for assessment purposes and effective assessment of student learning in general. For my students, I hoped for more active engagement by students with material in class and its relation to their daily lives. Student participation in the final presentation and discussion demonstrated to me success in this goal. And the module itself presented them with a tool which they can use in the future if they become in involved land use and land-use change issues.

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