Our Watershed

Students use data and models to make a difference in their own school yard

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Science becomes engaging when students know that what they learn in the classroom relates to their own lives and communities. This article describes a project in which students use field exploration and online software to design virtual solutions to improve the hydrology of their school yard. The project is called Teaching Environmental Sustainability—Model My Watershed (TES-MMW).

In the unit, students collect data to learn about land features that affect where water flows in their school yard. They also use a scientifically valid watershed model to learn more about their watershed and its current health. Using the Model My Watershed software application, students can virtually change land cover and implement conservation practices such as installing a rain garden, porous pavement, or a "green" roof, which involves installing a waterproof membrane over a traditional roof and covering it with a growing medium and vegetation. (A rain garden is a shallow depression near a runoff source that is planted with deep-rooted grasses and native plants.)

Armed with data from their school yard investigation and model outputs, students virtually redesign their school yard to improve watershed health. In this way, students use evidence-based reasoning to become engaged citizens.

Accessing the curriculum

Teachers and students can access the TES-MMW activities online in the High School Environmental Science section of the Innovative Technology in Science Inquiry (ITSI) portal at the Concord Consortium. The teacher creates a free, password-protected account (see "On the web") with a unique word code for each class. Students use the code to register and access activities assigned to them.

Learning objectives

In this unit, students

- explore their local watershed and describe the effects of land cover types and conservation practices on their watershed,
- gather and analyze scientific data from their school yard and an online watershed-modeling tool, and
- design a watershed plan for their school yard that maximizes the health of the watershed by implementing conservation practices and land-cover changes.

What is a watershed?

A 2003 article defined watershed as "an area of land in which all water drains to a common location or waterway. In some parts of a watershed, water is stored, at least temporarily. Water moves from one place to another by streams and rivers both above and below ground. Small watersheds make up larger watersheds, which in turn make up even larger watersheds" (McCallie 2003, p. 17).

Everyone lives and works in watersheds. Learning about watersheds helps citizens make informed decisions at individual, business, and governmental levels to protect the necessary resource we all depend on—water. The watershed can also serve as a context for teaching interdisciplinary science (physical, chemical, biological, Earth, environmental, agricultural), social studies, engineering, and mathematics knowledge and skills.

FIGURE 1

MODEL MY WATERSHED

For modeling activities, students can select their school site from anywhere in the continental United States.

The types of land cover (farmland, fields, parks, forests, parking lots, housing areas) in a watershed affect the amount and quality of water that infiltrates into groundwater and runs off into streams during rainstorms. Landfills, sewage treatment plants, farmland, and other human changes to the land can also greatly affect water quality. In cities and towns, storm drains pipe this water underground to the nearest stream.

Landowners, farmers, businesses, schools, and city planners can improve the water quality and quantity in their local streams by making informed decisions about land cover use and conservation practices.

Investigating your school yard

The first step in any scientific endeavor is to understand the problem. For this project, students go outside to explore their watershed. This can occur during a regular class period because by merely exiting the school building students are fully immersed in their watershed. The goal is to help students view the school yard through "watershed goggles," tracing the flow of water and identifying land-cover features and conservation practices.

To focus their exploration of the local watershed, each student is provided with a satellite map covering one-square-kilometer, including their school yard (Figure 1). Serving as an expert guide, the teacher leads a walk around the school yard, directing students' attention to the building and topographic and other features that affect runoff, infiltration, and evapotranspiration. These features include the slope of the school's roof, the location of drainpipes, water retention basins, plantings, parking lots, hills, athletic fields, and streams. (Teachers unsure of their knowledge can invite the school district's facility manager or a local land planner to lead the walk.) During the tour, students use their maps to trace the flow of water and to identify any areas of hydrologic concern that they or the guide identify.

Students divide into groups of three or four, and then each group chooses two study sites in the school yard to explore further. One of the two study sites should have a conservation practice already in place, and the second site should be a place where the group believes a conservation practice may be needed. This could be an area where water pools after a rainstorm, for example, or which shows evidence of erosion. Students begin by taking detailed field notes, plus photographs and/or sketches of the study sites. Using probeware, students measure the light, ambient temperature, and relative humidity to compare their two study sites. Students collect the data using the Texas Instruments Sensor Tag and the free SimpleLink app on their smartphone or mobile device (Figure 2).

FIGURE 2

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Students use probeware (SensorTag or another brand) to collect data at their two study sites. The probeware transfers data to a smartphone app via Bluetooth connection.

Vegetation and sandy soils can greatly reduce the amount of runoff and increase infiltration and storage of precipitation. Soil moisture affects how much water plants can absorb through their roots. Relative humidity affects the rate of evapotranspiration. Plants grow best in certain temperature ranges and light levels, which affect rates of photosynthesis. These data plus observations of soil type provide insight into the runoff, infiltration, and evapotranspiration rates of the study sites. Ideally, students will collect data at their test sites over time, especially during or after rain.

Each student group enters their data into data tables and graphs in the online portal to compare the two study sites. The data and their aerial maps help students better understand the school yard's hydrology.

Using national hydrologic data and models

Next, students harness the power of large-scale scientific data sets to develop deeper understandings and apply their knowledge to modeling watershed improvement scenarios. Many national environmental data sets, such as the USGS NHDplusV2 Stream Network, the USGS National Landcover Database, the USDA National Hydrologic Soils groups, the USEPA National Climate Data, and ESRI satellite and Google terrain maps can inform our study of watersheds. While these public data are freely available, making sense of these complex databases can be challenging for high school classes. Fortunately, this data is embedded in the Model My Watershed (MMW) online application

The "analyze" screen provides a wealth of easily accessible watershed data. Students can explore both below and above the ground including land cover, hydrologic soil type, farm animals, permitted point sources of pollution, and basic water-quality data.

(see "On the web"). Any classroom with internet access and connected devices can explore watershed data using this free tool.

In the MMW application, students locate their school yard by typing in the school address (Figure 3). Then they can change the basemap to "satellite with roads" to see an aerial view of the school yard. Choosing the "draw area" tool, students can select a square kilometer area to further analyze. (This area matches the map students used earlier in their field study.)

The "analyze" screen provides a wealth of easily accessible watershed data. Students can explore both below and above the ground including land cover, hydrologic soil type, farm animals, permitted point sources of pollution, and basic water-quality data. The data contained in the MMW application is useful to scientists, watershed associations, and citizen scientists who build scientific models to describe and study watersheds as well as to city and other land-use planners when considering development or restoration projects (Figure 4).

Using scientific models to better understand watersheds

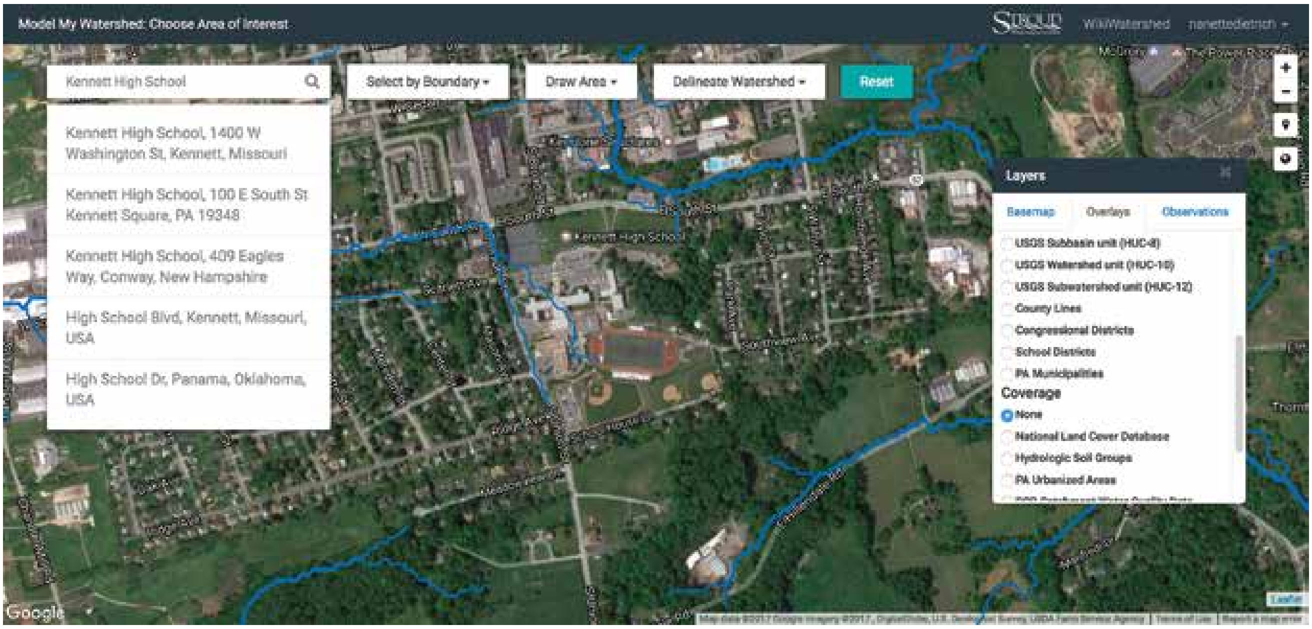
Models and simulations are useful for studying complex systems. Watersheds are complex, dynamic systems that can be studied with many scientific models, because each model deals only with a specific part of the system. The MMW site storm model (24-hour storm event) included in the curriculum uses a hybrid of models that scientists use to study watersheds. The site storm hybrid model addresses different land use areas across the continental United States (e.g., urban vs. rural), using a set of algorithms that addresses multiple factors to represent where surface water flows (runoff) and how much runs off into nearby streams after a rainstorm. Managing runoff is important for watershed health.

With the MMW application, students can run the site storm model over a defined area. By choosing the "model" button and selecting "site storm" model, complex calculations are completed behind the scenes almost instantaneously using the power of cloud computing. Students see an estimation of where precipitation from a storm goes, including runoff, infiltration, and evapotranspiration.

Taking action

Students can see how their school's current land use compares to its natural state (defined in this simulation as 100% forest cover; Figure 5). Then, students are challenged to improve their

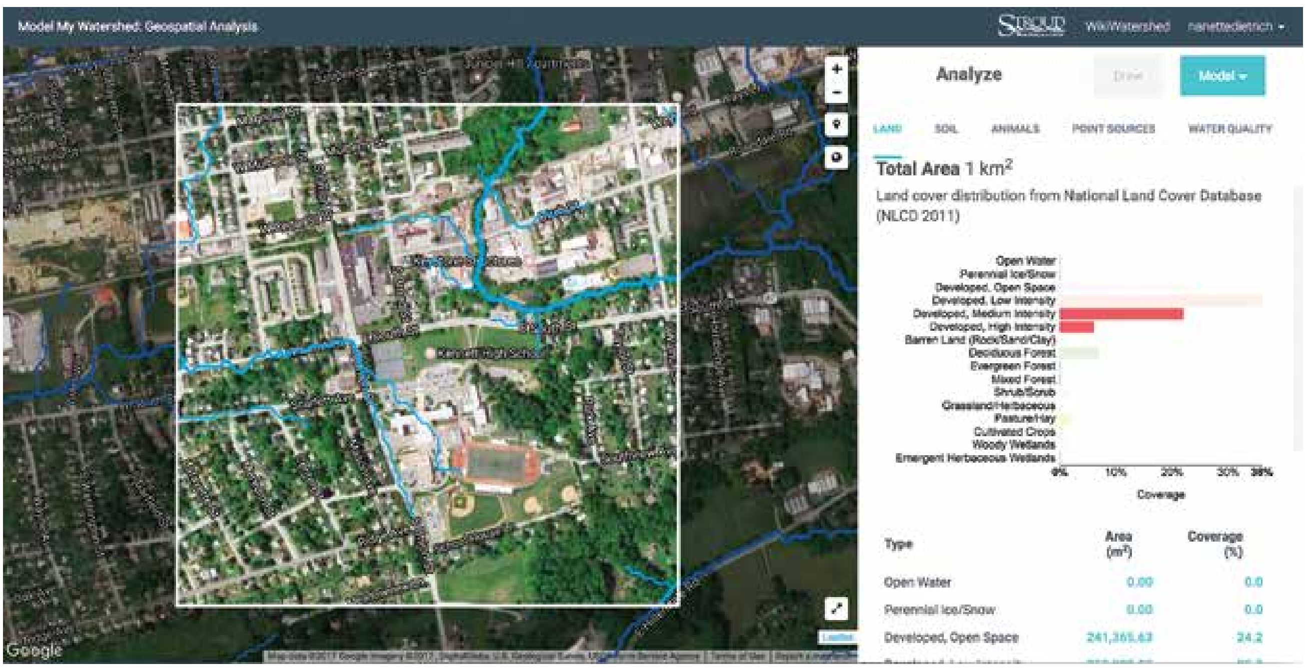
FIGURE 3



MODEL MY WATERSHED

Students can zoom into their school site on the web and view different basemap layers, overlays, and hydrology data. This example shows a satellite image with a roads basemap and stream overlays.

FIGURE 4



MODEL MY WATERSHED

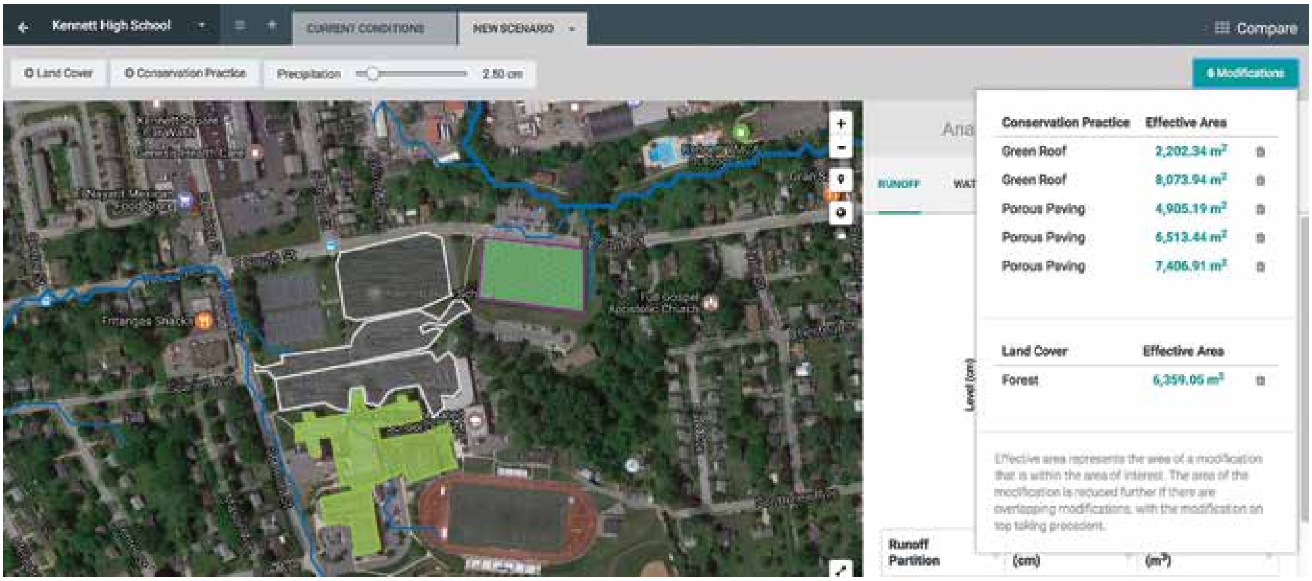
After selecting a square kilometer around their school, students analyze watershed and water-quality data from national databases. This example shows land-cover types.

FIGURE 5

MODEL MY WATERSHED

In this view, students can compare conditions at their school site to runoff amounts that would occur if the same area were covered by forest.

FIGURE 6



MODEL MY WATERSHED

Students can model changes in runoff and water quality as a result of changes in land cover and conservation practices.

watershed, virtually redesigning their school yard by changing the land cover and/or implementing appropriate conservation practices.

For example, students can reforest a lawn, add a green roof to the school gym, or repave the parking lot with porous paving. Students use evidence from the model to redesign their schoolyard with land cover changes and conservation practices to minimize runoff while maintaining the property's current use. (Students cannot, for example, demolish the school and replace it with a forest.) Simple and purposeful design changes such as replacing a large manicured lawn with a grassland or woodland and using porous pavement for the parking lots make measurable differences to the health of a school's watershed. Such improvements can mean that less soil and pollutants will run off into streams, fewer, less severe, flash floods will occur, and more water will be naturally cleaned by slowly moving through the ground before it enters streams.

One student used the simulation to model the impact of paving the school's front lawn for additional parking, which the district planned to do. She then considered how the school could mitigate the runoff from the new parking lot with conservation practices. On her own, she researched the cost of a green roof and used the MMW program to determine how much of the school roof would need to be made green to offset the effects of the new parking lot. She presented the data and her design proposal to the school administrator (Figure 6).

Other students have modeled scenarios of installing new rain gardens to promote infiltration and minimize runoff. Some students have looked beyond their school yards to explore the effects of building a new shopping center in their town. Still others have applied the watershed modeling tool to their own family property to see if they could improve the watershed at home.

Conclusion

Giving students access to scientific tools and authentic data to make informed decisions about real places galvanizes learning and motivates students to apply their knowledge to solve local problems. The Teaching Environmental Sustainability: Model My Watershed project enables students to make evidence-based decisions, encouraging them to become environmentally engaged citizens now and in the future. ■

REFERENCE

McCallie, E. 2003. Science 101: What is a watershed? *Science and Children* 70 (4): 17.

ON THE WEB

Model My Watershed: *https://app.wikiwatershed.org*
ITSI portal: *http://itsi.portal.concord.org*
Teaching Environmental Sustainability. Model My Watershed project: *https://concord.org/projects/teaching-environmental-sustainability*

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Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Standards

HS-ESS2 Earth's Systems

HS-ESS3 Earth and Human Activity

Performance Expectations

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

HS-ESS2-2. Analyze geoscience data to make a claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

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

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practices	
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.	Students use an online watershed modeling tool to analyze water quality data and runoff rates of different scenarios they propose and compare.
Constructing Explanations and Designing Solutions Design and evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	Students design and evaluate solutions to minimize runoff in their local watershed system using data collected from their school yard investigations and an online watershed modeling tool.
Disciplinary Core Ideas	
ESS2.C: The Roles of Water in Earth's Surface Processes The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.	Students gather data from their school yard investigations and the online watershed modeling tool about the ability of different surfaces to produce runoff that dissolves and transports pollutants and soil.
ESS3.B: 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.	Students propose and evaluate solutions to improve their local watershed while considering many factors.
Crosscutting Concepts	
Systems and System Models When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.	Students use an online watershed modeling tool to create scenarios for 24-hour storm events in which they change land cover and conservation practices and compare those scenarios to known current conditions.
Structure and Function The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.	Students model the implementation of designed objects such as rain gardens, green roofs, retention basins, etc.