

## Unit Objectives

- Matter is made of particles; this includes soil and water.
- Matter is conserved. In other words, matter, and the particles that make it up, can neither be created nor destroyed.
- Mass provides us with a measurement of the amount of matter, or “stuff”, in an object.  
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- An increase in the mass of an object indicates that particles were added whereas a decrease in the mass of an object indicates that particles were removed. \*\*
- The known density of water (amount of mass in given volume) allows us to make mass or volume measurements and convert between the two. \*\*
- For convenience, measurements of volume rather than mass are often used by Earth scientists to monitor quantities of water in natural systems. (For this unit, we will ignore volume changes that occur due to changes in temperature.)
- Volumes of water added to a system or removed from a system are calculated by measuring and multiplying the length, width, and depth of water (volume = length x width x depth). A rain gauge provides a measure of depth (of precipitation that falls into the rain gauge), but the length and width of an area must also be measured. In a lake or reservoir, the volume of water can be calculated by the width and length of the water body multiplied by its average depth.
- Measurements made with rain gauges and flow gauges best represent events happening nearby rather than events happening over large geographic areas.
- In a soil and water system, where soil particles are assumed to be fixed, measuring the volume of water added to a system and the volume of water that leaves a system provides a way to estimate the volume of water that remains within a system.
- While water particles are most commonly added to a soil-water system via rain, they can be removed via evaporation, uptake by plants, surface runoff, and subsurface runoff. Water particles can also be stored in the system.
- Humans can alter evaporation, uptake by plants, surface runoff, and subsurface runoff through land use patterns (paving surfaces, re-grading slopes, or changing vegetation cover, for instance).
- Water naturally drains downhill (from a higher elevation to a lower elevation) due to gravity.
- A watershed is a region from which water drains to a common location.

- Scientists can create complex mathematical models that allow them to adjust many factors and predict the effect on storage, surface runoff, and subsurface runoff.
- Computers allow scientists to design more complex models and use the models over larger geographic areas or longer time scales than would otherwise be possible.
- As scientists collect additional data and improve their understanding of the Earth System, mathematical models are improved and more accurate predictions are made.
- Geoscientists are working on topics that have applications in everyday life.
- Geoscientists need to apply their content knowledge in innovative ways while working with a diverse range of partners to solve complex problems.

**\*\*** While these three objectives are not explicitly taught in this unit, they are fundamental concepts that should be understood by the teacher in order to connect what students learn to other disciplines, such as physics and chemistry.

### **Instructional Strategies**

A deliberate effort has been made to use best practices in science education when designing this unit. The unit is based around the 5E Learning Cycle and each investigation is an exercise in guided inquiry. Topics are introduced conceptually in qualitative ways before engaging in extensive quantitative measurements and calculations. While lectures can be used to quickly communicate the information contained in the unit, an explicit goal is to provide ways for major objectives to be “uncovered” and discussed in context of content-rich learning experiences. Hopefully, this will engage students, link content with real-world situations, and support deep understanding and long-term retention of knowledge. This unit is best delivered with a connection to one or two local watersheds. Many online resources referenced in this unit allow teachers to tailor instruction to their local environment and identify local professional who can offer instructional support and serve as guest speakers or site visit coordinators.

The unit includes introductory investigations that are based around basic laboratory equipment, measuring tools, maps, paper, and writing instruments. More advanced investigations involve access to computers to retrieve data sets from government agencies’ websites, access Google Earth, and use a HydrologyWebApp. The extent to which more advanced components of the unit are included in a course is dictated by the overall course curriculum, grade level, and access to technology. Please note, to be successful, teachers need not implement the entire curriculum, but should rather select those investigations that support their needs. A number of background readings are provided at the end of this document that provide information about scientific content, student understanding, pedagogy, and classroom management.

## **Sequence**

### **Exercise 1: Soup Can Water Balance**

- 1.1 Measurements of Water Entering, Leaving, and Being Retained Within a Soil-Water System
- 1.2 Impact of Types of Soil Movement of Water Through a Soil-Water System

### **Exercise 2: Sandbox Water Balance**

- 2.1 3D Observations & Descriptions of a Watershed and Water Budget of Precipitation, Surface Runoff, and Subsurface Runoff

### **Exercise 3: Schoolyard Watershed**

- 3.1 Schoolyard Watershed – Part A
  - 3.1 Schoolyard Watershed – Part B
  - 3.2 Intermediate Watershed
- Additional Support Materials

### **Optional: Topographic Mapping Underpinnings**

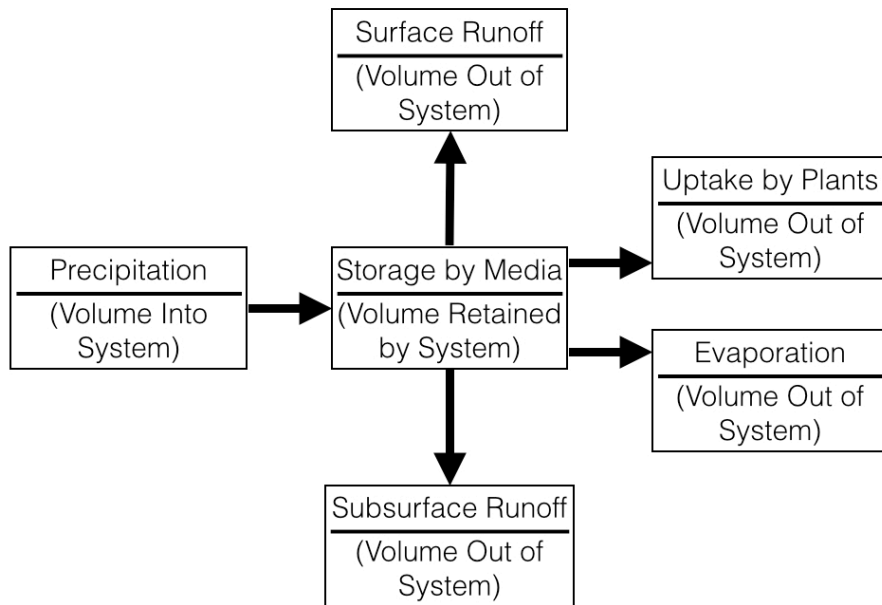
### **Exercise 4: Large Scale Watershed**

- 4.1 Examination of Historical Aerial Photographs
- 4.2 Examination of Differences in Land Use and Hydrology
- 4.3 Large-Scale Watershed Hydrology
- 4.4 Government and Planning Documents Related to Land Use
- 4.5 Media Coverage of Changing Land Use
- 4.6 Land Use Changes in a Large-Scale Watershed

### **Exercise 5: Land Use Change**

- 5.1 Runoff and Flooding
- 5.2 Water Quality Impacts

The following diagram captures the major concepts of this unit in graphical form.



## **Standards Addressed**

### **NGSS**

#### **HS. Earth's Systems**

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

**HS-ESS2-5.** Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

#### **HS. Human Sustainability**

**HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural 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.

## **NRC Framework**

### ***Science and Engineering Practices***

#### **Planning and Carrying Out Investigations**

Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

#### **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.

#### **Engaging in Argument from Evidence**

Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

#### **Engaging in Argument from Evidence**

Construct an oral and written argument or counter-arguments based on data and evidence.

#### **Using Mathematics and Computational Thinking**

Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.

#### **Constructing Explanations and Designing Solutions**

Construct 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.

#### **Developing and Using Models**

Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

#### **Connections to Nature of Science: Scientific Knowledge is Based on Empirical Evidence**

Science knowledge is based on empirical evidence.

### ***Disciplinary Core Ideas***

#### **ESS3.A: Natural Resources**

All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

#### **ESS3.C: Human Impacts on Earth Systems**

The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

### ***Crosscutting Concepts***

#### **Stability and Change**

Much of science deals with constructing explanations of how things change and how they remain stable.

#### **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.

#### **Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World**

Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

New technologies can have deep impacts on society and the environment, including some that were not anticipated.

#### **Connections to Nature of Science: Science Addresses Questions About the Natural and Material World**

Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

### **Common Core State Standards Connection**

#### ***Literacy/ELA***

**RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

**WHST.9-12.1** Write arguments focused on discipline-specific content.

#### ***Mathematics***

**MP.2** Reason abstractly and quantitatively.

**MP.4** Model with mathematics.

**HSN.Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

### Background Reading of Interest

- Arons, A. (1997). *Teaching Introductory Physics*. New York, NY: Wiley. (Chapter 1 – Underpinnings)
- Ben-zvi-Assarf, O., & Orion, N. (January 01, 2005). A Study of Junior High Students' Perceptions of the Water Cycle. *Journal of Geoscience Education*, 53, 4, 366-373.
- Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (July 2006). *The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications – Executive Summary*. Colorado Springs, CO: BSCS. Available online at [http://bscs.org/sites/default/files/legacy/BSCS\\_5E\\_Instructional\\_Model-Executive\\_Summary\\_0.pdf](http://bscs.org/sites/default/files/legacy/BSCS_5E_Instructional_Model-Executive_Summary_0.pdf).
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- Shepardson, D. P., Wee, B., Priddy, M., Schellenberger, L., & Harbor, J. (July 01, 2007). What is a watershed? Implications of student conceptions for environmental science education and the National Science Education Standards. *Science Education*, 91, 4.