Stormwater Curriculum

Grades 3-5

Developed by the University of Tennessee, Knoxville. Funding for this project is provided by the U.S. Department of Agriculture Forest Service, Urban and Community Forestry Program.

Developed by the University of Tennessee, Knoxville. Funding for this project is provided by the U.S. Department of Agriculture Forest Service, Urban and Community Forestry Program.

Portions of this curriculum were developed with the assistance of AI language model tools. All content was reviewed, edited, and approved by the human authors listed below, and some sections were written entirely without AI assistance. All materials were reviewed against Tennessee State Education Standards and current childhood development research.

- *Jaq Payne, National Director of the National Champion Tree Program & Research Associate at University of Tennessee, Knoxville*
- *Aoife Whitaker, Master's Candidate at the University of Tennessee, Knoxville*
- *Kayla Stuart, President of TreeCPR and Research Associate at University of Tennessee, Knoxville*
- *Dr. Sharon Jean-Philippe, Professor of Urban & Community Forestry Applied Science at the University of Tennessee, Knoxville*

Support and advice was provided by:
-Dr. Victoria Rexhausen
-Bradan Bruce
-Dr. Kay Bernard
-Dr. Kelsey Ellis
-Dr. Jon Hathaway

For feedback, questions, or assistance, please email Dr. Sharon Jean-Philippe at jeanphil@tennessee.edu or use the feedback QR codes at the end of each activity.

Stormwater Curriculum

Grades 3-5

Table of Contents

3-5 Activities

Water Cycle Relay Data Sheets & Reading Exercises

Soil on the Move Data Sheets & Reading Exercises

Investigating Our Stormwater System Data Sheets & Reading Exercises

Shape the Land, Watch the Water Data Sheets & Reading Exercises

Biofiltration Engineering Lab Data Sheets & Reading Exercises

Flood Prevention Engineering Data Sheets & Reading Exercises

Curriculum Introduction

This module is designed to help students understand one powerful and important idea: water moves, and how we manage that movement matters.

Across grade levels, students will explore what happens to rain after it falls. They'll investigate where water goes on their campus, explore how soil and plants change its path, and learn through hands-on activities how engineered systems like the Gravel Tree Stormwater System (GTSS) or rain garden help reduce flooding and support healthy, balanced ecosystems.

This module uses your school's outdoor infrastructure as a living laboratory. Rather than learning about stormwater from diagrams, slides, and videos, students will observe, measure, analyze, and evaluate a real system in their own environment.

BIG IDEAS OF THE STORMWATER MODULE:

- Water is constantly moving through Earth's systems (aka the Water Cycle).
- Land surfaces influence infiltration, runoff, and erosion.
- Plants play a critical role in managing stormwater.
- Engineered systems can reduce human impact on the environment.
- Data helps us evaluate and improve environmental solutions.

LEARNING PROGRESSION

In Kindergarten through Grade 2, students will build a foundational understanding. They observe rainfall, explore wet and dry soil, use simple measuring tools, and connect water to plant needs. They learn that water doesn't disappear when it hits the earth – it soaks in, it flows, and it collects.

In Grades 3 through 5, students begin investigating patterns and cause-and-effect relationships. They collect multi-day data, graph changes in water levels, compare surfaces, and explain how stormwater systems reduce runoff. They are introduced to the idea that this is an engineered solution, and we have great power and responsibility to come up with solutions to the human impact on or natural resources.

In Grades 6 through 8, students investigate stormwater with more depth and complexity, taking on the role of environmental engineers. They measure system performance, calculate infiltration rates, define design criteria and constraints, evaluate effectiveness, and propose improvements supported by evidence.

Throughout all grades, students engage in authentic scientific practices:

- Asking questions
- Collecting and analyzing data
- Constructing explanations
- Using models
- Designing and evaluating solutions

WHY DOES THIS MATTER?

Stormwater management is not abstract, and it impacts all of us in our day-to-day lives. It affects flooding, erosion, water quality, green and gray infrastructure, and urban tree health. By studying a system on their own campus, students see that environmental science is local, practical, and connected to their daily lives.

This module also strengthens cross-disciplinary skills. Students practice measurement and data representation in math, evidence-based writing in ELA, and systems thinking in science and engineering.

WHAT TO EXPECT

This curriculum prioritizes outdoor, hands-on learning whenever possible. Students will measure real rainfall, observe real infiltration, and track real tree growth. Schools without physical access to a GTSS will use rain gardens or visible infrastructure to conduct equivalent investigations.

Teachers should expect movement, observation, and discussion. Many lessons are designed to be revisited seasonally and annually, allowing students to build longitudinal understanding over time.

STANDARDS ALIGNMENT

This module is vertically aligned for K-8 and meets Tennessee State Standards in:

- Earth and Environmental Science
- Engineering Design
- Measurement and Data
- Speaking and Listening
- Informational and Explanatory Writing

Each activity identifies specific grade-level standards addressed.

INSTRUCTIONAL APPROACH

This module follows a progression of increasing rigor:

- K-2: Observe and describe
- 3-5: Investigate and explain
- 6-8: Evaluate and redesign

The physical system remains constant, but the cognitive demand should evolve each year. The stormwater management systems that they started off observing in K-2 and investigating in 3-5 become systems that they build and redesign in 6-8.

Repeating the same activities with accumulating depth season-over-season or year-over-year provides students with repetition that deepens their understanding without feeling boring, gives them the opportunity to observe how their own understanding of the subject matter changes and grows over time and provides consistent through-lines across their entire elementary/middle school educational experience.

ASSESSMENT

Assessments are embedded within activities and include:

- Student observation records
- Data tables and graphs
- Written explanations
- Engineering proposals
- Class discussions

Teachers may use provided Performance Indicators or adapt assessments to fit classroom needs.

TEACHER PREPARATION

Before beginning the module, teachers should:

- Locate the GTSS or rain garden on campus (or the proposed site, if not built yet)
- Identify safe observation boundaries
- Familiarize themselves with the rain gauge and observation well (if present)
- Review measurement tools needed for their grade band
- Prepare communications to parents about required clothing for days where you and your students will be exploring the rainy, muddy, outdoors environment

Lessons can be implemented after rainfall events or during dry periods to compare conditions.

FLEXIBILITY

Activities are designed to be adaptable based on:

- Access to infrastructure and resources
- Weather conditions
- Available time
- Student readiness

Scripts are provided in places to help guide instruction, but they are recommendations only. Teachers are encouraged to use their own words and alter language to fit their own voice.

Indoor extensions are provided when weather or safety limits outdoor access. Although we encourage students to experience the rain first-hand, please keep in mind that the presence of lightning during a rainstorm constitutes a real danger and in case of a thunderstorm, lessons should be moved under shelter or indoors for student and instructor safety.

3-5 Activities

3-5 Section Introduction

Welcome to the 3-5 Stormwater Section!

In the intermediate grades, students move beyond noticing stormwater to investigating it. They begin asking deeper questions about patterns, causes, and system performance. At this level, students will explore how rainfall interacts with soil, plants, pavement, and engineered systems like the Gravel Tree Stormwater System (GTSS) or rain garden.

This section builds on the foundation ideas introduced in K-2 and shifts toward data collection, analysis, and explanation. Students measure rainfall, track water levels, compare surfaces, graph results, and look for patterns over time. They begin to understand stormwater management not just as something that happens, but as an intentionally designed solution to real environmental challenges.

Teachers continue to guide questioning and structure investigations, while gradually increasing student independence. Activities include structured data sheets and suggested discussion prompts, but teachers are encouraged to adapt pacing, depth, and emphasis based on student readiness and classroom goals. The aim is not simply to complete measurements and fill in forms, but to help students use evidence to explain what they observe.


Adobe Stock | #967390192

Guiding questions at this level include:

- What patterns do we notice between rainfall and water levels?
- Why does water behave differently on soil than on pavement?
- How does this system reduce runoff or flooding?
- How are plants, soil, air, and water connected here?

By the end of Grade 5, students should be able to explain how stormwater systems function as engineered solutions. They should understand that land surfaces influence infiltration and runoff, that Earth's systems interact, and that data can be used to evaluate environmental performance.
This section prepares students for middle school, where they begin evaluating system efficiency, defining design criteria and constraints, and proposing improvements supported by quantitative evidence.

LEARNING/ACTIVITY PROGRESSION

Water Cycle Relay: Embody the water cycle.

Soil on the Move: Understand erosion.

Investigating Our Stormwater System: Investigate how stormwater systems can help manage erosion.

Shape the Land, Watch the Water: Explore how land shape and human activity can impact erosion and watersheds.

Biofiltration Engineering Lab: Experiment with how different materials filter stormwater.

Flood Prevention Engineering (Intermediate/Advanced): Design a Stormwater Management System based on experiences throughout the year.

Water Cycle Relay

Grades: 3-5

Time: 1–2 class periods (Simulation Day; Data & Systems Analysis Day)

Lesson: Model how energy, temperature, land surfaces, and plants influence the water cycle by acting out system roles, tracking water movement, and analyzing how environmental changes affect storm intensity and runoff.

Introductions

TEACHER INTRODUCTION

By Grade 3, students have several years of accumulated observation behind them. They have measured rain, followed runoff, and built physical models. What they may not yet have is a systems-level framework, or a way of understanding how all the pieces connect. The Water Cycle Relay provides that framework in the most effective way available: embodied, physical experience.

The simulation structure of this activity is pedagogically well-grounded. When students physically inhabit a role (as a water molecule, as the Sun team, as the Land team directing flow toward Soil or Pavement) they internalize the relationships between system components in a way that passive observation cannot replicate. Research on embodied cognition consistently shows that movement and role-play accelerate conceptual understanding of abstract systems.

Several teaching points deserve attention:

- The contrast between the Normal Round and the Urban Round is the conceptual heart of the activity. The question students should carry out of this simulation is: why does the same amount of rain cause a flood in one scenario and not the other? The answer (land cover and surface permeability) is the foundation of everything that follows in 3–5 stormwater investigation.

- The Runoff Zone filling up is a feature, not a problem. When students standing there realize they cannot move (they are “flooded”) that experience of system failure is more memorable than any diagram.

- Role rotation is essential. Students who spend the entire simulation as a water molecule have a different and incomplete understanding compared to those who also served as the Land team making routing decisions.

- For Grade 5 students, push toward systems analysis: what would happen if we added a Plant team that absorbs more? What if the Cloud threshold were lower, with more frequent but smaller storms?

This activity is most powerful when it immediately precedes or follows outdoor investigation. Running the simulation and then going outside to observe real water movement on campus creates a tight feedback loop between model and reality.

GRADE 3 INTRODUCTION

You already know the basics of the water cycle: water evaporates, forms clouds, falls as precipitation, and starts the cycle again. But knowing the steps is different from understanding how the system works and how the parts interact, how changes in one part affect everything else.

Today you are going to become part of the water cycle.

You and your classmates will take on roles: water molecules, the Sun team, the Cloud team, the Land team, the Plant team. Together, you will run the cycle through multiple rounds and you will see what changes when land surfaces change.

Pay attention to this question as you go: what happens in the Urban Round that does not happen in the Normal Round? Something fills up. Something stops moving. That observation is the beginning of understanding why stormwater management matters.

GRADE 4 INTRODUCTION

The water cycle is a system, or a set of parts that interact with each other according to rules. When one part changes, the whole system responds.

Today's simulation is a model of that system: simplified, but real enough to produce genuine patterns we can analyze.

As you participate, track the system's behavior, not just your own role. When the Runoff Zone fills up, what caused that? When transpiration returns water to the Cloud team, how does that change the pacing of the cycle? These are the questions that systems thinkers ask.

Adobe Stock | #407477174

After the simulation, you will have the chance to propose a modification: what would you change about the Urban Round to reduce flooding? Your proposal should be based on what you observed in the simulation with supporting evidence, not just intuition.

Think about East Knoxville as you work. What would the Land team's routing decisions look like for Magnolia Avenue after a heavy summer storm? What surfaces are most common there? How does that affect where the water goes?

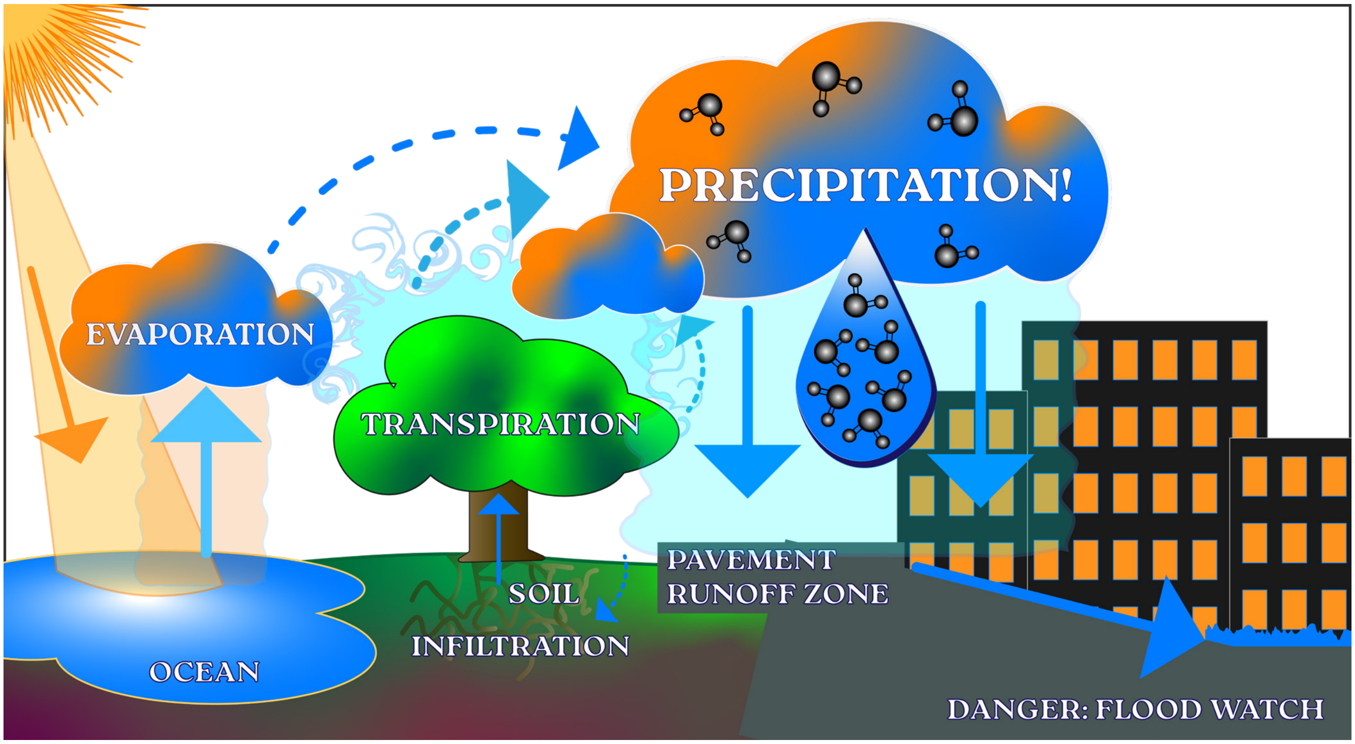
GRADE 5 INTRODUCTION

You are about to run a physical model of the water cycle and then analyze it the way an environmental scientist would.

A model is always a simplification. The real water cycle is enormously complex: it involves solar radiation, atmospheric pressure, soil chemistry, plant physiology, and hundreds of other variables. This simulation captures the essential logic: energy drives evaporation, clouds release precipitation, and land surface determines what happens next.

Your task is not just to participate, but to evaluate the model. After the simulation: what did it capture well? What did it leave out? If you were redesigning the simulation to better represent what happens in Knoxville's watershed including the urban surfaces, the green infrastructure, the creeks flowing toward the Tennessee River, what would you add?

That kind of thinking (using a model, critiquing it, and improving it) is one of the most important scientific practices there is. It is also exactly what engineers do when they design systems like the GTSS.



A diagram showing the water cycle, as students will experience it in the Water Cycle Relay. The sun warms water in the ocean, which evaporates into a cloud. The cloud then rains precipitation down on the land. Some rainwater infiltrates into the soil, is taken up by plants and trees, and through transpiration, heads back to the cloud. Some rainwater becomes runoff on the pavement, leading to a flood in the city.

Crosscutting Concepts & Connections

- Systems and system models
- Energy and matter
- Cause and effect
- Patterns
- Human impact
- Scale and proportion

TN Academic Standards

GRADE 3	GRADE 4	GRADE 5
3.ESS2, 3	4.ESS2-3	5.ETS1, 2
3.ETS1	4.RI.KID.1-3	5.NBT.B.7
3.MD.B.3	4.RI.CS.4, 5	5.RI.KID.1-2
3.RI.KID.1-2	4.RI.IKI.7, 8	5.RI.CS.4
3.RI.CS.4	4.RI.RRTC.10	5.RI.IKI.8
3.RI.IKI.7-8	4.SL.CC.1-3	5.RI.RRTC.10
3.SL.CC.1-3	4.SL.PKI.4 , 6	5.SL.CC.1-3
3.SL.PKI.4	4.W.TTP.2	5.SL.PKI.4, 6
3.W.TTP.2	4.W.PDW.4	5.W.TTP.2
3.W.PDW.4, 5	4.W.PDW.5	5.W.PDW.4, 5
3.W.RBPK.9	4.W.RBPK.9	5.W.RBPK.9
	4.W.RW.10	5.W.RW.10

Disciplinary Core Idea Progression

- Grade 3: Energy from the sun drives the water cycle. Water moves between the atmosphere, land, and oceans through evaporation, condensation, and precipitation. Students model these interactions across Earth's spheres.
- Grade 4: Organisms, including plants, affect the physical characteristics of their regions. Paved surfaces increase runoff; plant roots and vegetation alter how water moves through a landscape. Students connect land cover to water behavior through observation and data.
- Grade 5: Engineering design solutions can be tested, evaluated, and improved based on performance data. Students apply understanding of the water cycle and land-surface interactions to evaluate how system design changes affect runoff and infiltration outcomes.

Learning Objectives

Students will be able to:

- Explain how energy drives evaporation.
- Describe how transpiration and precipitation occur.
- Model interactions between atmosphere, land, and plants.
- Collect and graph simulation data.
- Analyze how surface changes affect runoff and infiltration through data collection, writing, and verbal communication with peers

Adobe Stock | #2420610

Materials

1. Station signs labeled Ocean, Cloud, Land, Soil, Pavement, Runoff Zone
2. Beanbags, soft balls, or poker chips to serve as energy tokens
3. Floor markers, cones, and/or masking tape
4. Clipboards and student recording sheets
5. Graph paper
6. Student Instruction Sheets (see activity printables)
7. Optional stopwatch

Vocabulary

GRADE 3	GRADE 4	GRADE 5
evaporation	*transpiration*	*model*
condensation	*runoff*	*variable*
precipitation	*system*	*relationship*
runoff	*energy*	*watershed*

Activity Introduction

1. Ask students:
   a. "What gives water the energy to evaporate?"
   b. "Does land change what happens after rain falls?"
   c. Explain that students will act out different parts of the water cycle and test how heat and land surfaces change the system.

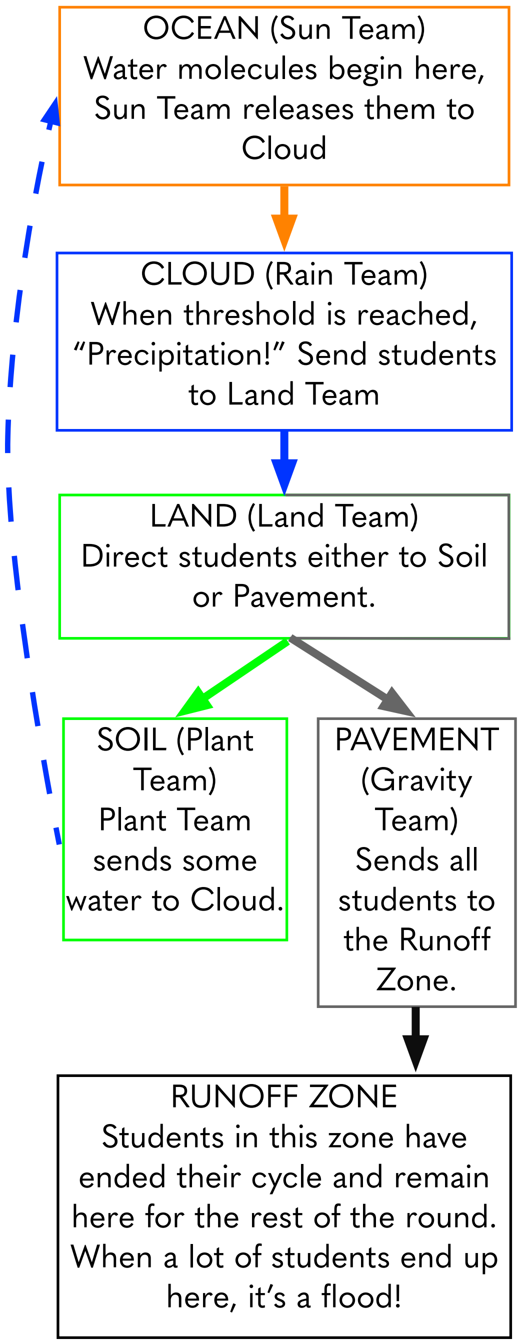
Adobe Stock | #301116107

Activity Instructions

1. Structure and Roles
   a. There are two types of roles: water molecules and system controller teams.
   b. Water Molecules
      i. These students move through the system. This should be the largest group.
      ii. They begin in the Ocean zone.
      iii. They only move when directed by a system team.
      iv. They will cycle through the stations as directed by the Teams, but when they reach the Runoff Zone they must stay there until the end of the round.
   c. System Controller Teams
      i. Sun Team
         1. Controls evaporation.
         2. When ready, the Sun gives an energy token to a water molecule in the Ocean, representing the energy needed for evaporation.
         3. Tokens are returned to the Sun Team by the Rain Team when it rains.
      ii. Rain Team
         1. Collects water molecules (and their tokens) that evaporated in the Cloud.
         2. When the Cloud reaches the chosen threshold (for example, 5 students), the Rain Team shouts "Precipitation!" and all water molecules are released at once as precipitation to the Land Team.
            a. This threshold can greatly change the intensity of the game. For more frequent rain, lower the threshold. For less frequent but more intense rain, raise the threshold.
         3. Returns energy tokens to the Sun Team when it rains.
      iii. Land Team
         1. Directs water molecules to either Soil or Pavement areas when precipitation occurs.

            2. During Normal Round, most water goes to Soil.
            3. During Urban Round, most water goes to Pavement.
        iv. Plant Team
            1. Receives water molecules from Soil (infiltration).
            2. After a short delay, sends some water molecules back to the Cloud Team to represent transpiration.
        v. Gravity Team
            1. When students arrive on the Pavement, immediately sends them to the Runoff Zone.
            2. Pays attention to how many students are in the Runoff Zone. If more than half of the water molecules are in the Runoff Zone, whisper loudly "Flood!"
    d. Runoff Zone
        i. Water molecules sent to Pavement are sent here by the Gravity Team and stay until the round ends.
        ii. If this area fills up quickly, it represents a flood!

2. Role Rotation
    a. After each round, rotate roles so students experience both moving and controlling parts of the system.
3. Simulation Round: Normal Conditions
    a. Water molecules begin in Ocean.
    b. Sun distributes energy tokens at a steady pace.
    c. Water molecules evaporate to Cloud.
    d. Cloud releases precipitation when threshold is reached.
    e. Land directs water to Soil or Pavement.
    f. Soil/Plant Team returns some water to Cloud.
    g. Pavement/Gravity Team sends all water to the Runoff Zone.
    h. Continue for several cycles.
4. Simulation Round: Hot Conditions
    a. Sun distributes energy tokens more quickly.
    b. Observe changes in evaporation and precipitation frequency.
5. Simulation Round: Urban Conditions
    a. Land Team directs most precipitation to Pavement.
    b. Observe increase in runoff and decrease in infiltration.
6. Data Collection and Graphing
    a. Water Molecule students record for each round:
        i. Which stations they visited
        ii. How many times each station was visited
    b. Students create graphs comparing Normal, Hot, and Urban rounds.
    c. Students explain graphs in written text. Students hypothesize results and reasoning for results, using evidence from activity to support their conclusions.
    d. The Student Data Sheets contain space for calculations, graphing, and written responses to prompts.



OCEAN (Sun Team)
Water molecules begin here, Sun Team releases them to Cloud

CLOUD (Rain Team)
When threshold is reached, "Precipitation!" Send students to Land Team

LAND (Land Team)
Direct students either to Soil or Pavement.

SOIL (Plant Team)
Plant Team sends some water to Cloud.

PAVEMENT (Gravity Team)
Sends all students to the Runoff Zone.

RUNOFF ZONE
Students in this zone have ended their cycle and remain here for the rest of the round. When a lot of students end up here, it's a flood!

Sharing and Speaking

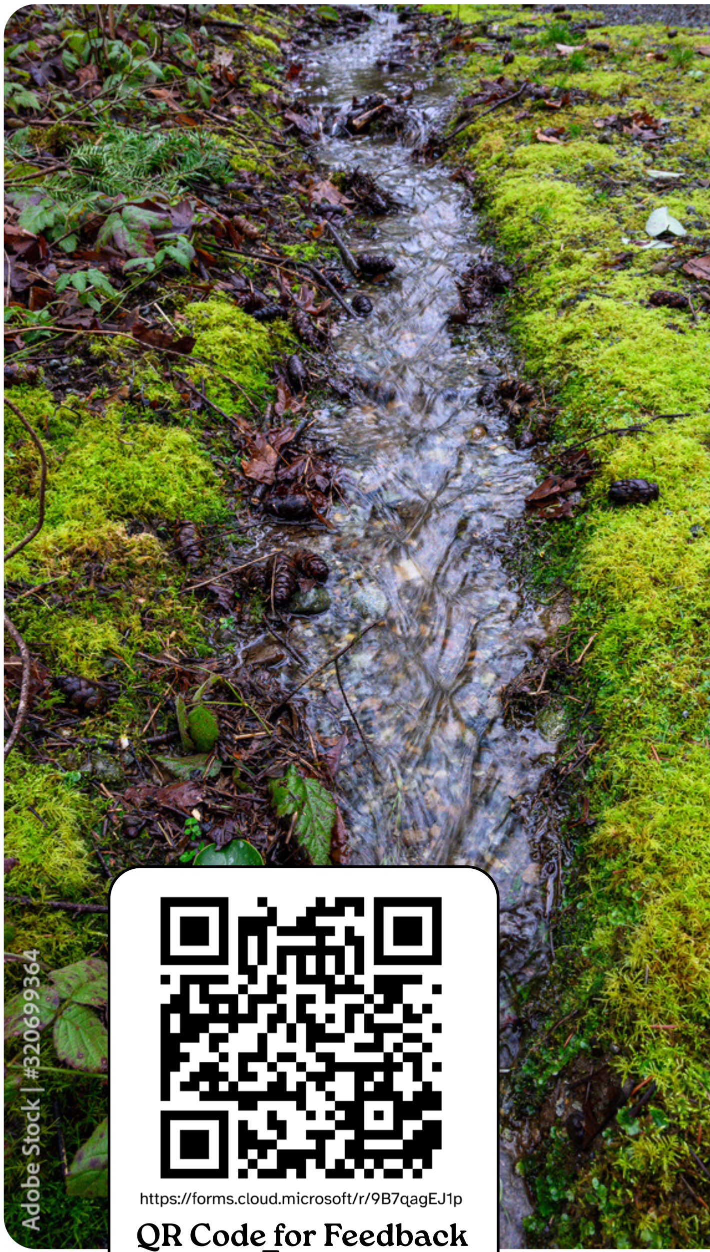
a. Ask:
  i. “How did increasing energy affect evaporation?”
  ii. “How did pavement affect runoff?”
  iii. “What role did plants play?”
  iv. “How does this connect to stormwater systems like our GTSS?”

Performance Indicators

- Student explains that energy from the sun causes evaporation.
- Student describes how land surface changes water movement.
- Student accurately records and graphs simulation data.
- Student connects the model to real-world stormwater systems.

Extensions & Variations

- Simulate an area with more green infrastructure than gray infrastructure by having the Land Team send more water molecules to Soil, and put more students on the Plant Team.
- Simulate a drought by increasing the Cloud threshold beyond the number of students in the class. What happens to the plants? Simulate a flood by suddenly reducing the Cloud threshold. What happens to the plants?
- Tie into the Flood Prevention Activity to highlight how human engineering can affect the way water moves through our landscapes.


Adobe Stock | #320699364

https://forms.cloud.microsoft/r/9B7qagEJ1p

QR Code for Feedback Form

Conclusion

Debrief the simulation before students disperse. The most important question is the one that cuts across both rounds: what was different, and why? Students should be able to name, in their own words, that directing water toward pavement produced faster, higher runoff, and that the consequence of that was the Runoff Zone filling up.

Press further for Grade 4 and 5 students: what did the Plant team do to the system? What would happen if we removed them? Students who grasp that vegetation slows the cycle by absorbing water and releasing it gradually through transpiration are ready to understand why green infrastructure works.

In **Soil on the Move**, students will investigate the physical consequences of runoff that moves too fast over unprotected surfaces. The flooding they simulated today becomes, in the next activity, something visible: soil eroding, particles carrying downstream, land changing shape under the force of moving water. The connection is direct and worth naming explicitly as you close today’s session.

Soil on the Move

Grades: 3-5

Time: 45-60 minutes; optional follow-up analysis day

Lesson: Investigate how water causes erosion and evaluate how ground cover and design choices reduce soil loss.

Introductions

TEACHER INTRODUCTION

East Knoxville sits in a landscape shaped by erosion. The ridges and valleys of Knox County were carved by water over millions of years, and that process continues today (most visibly during the heavy rainfall events that are a consistent feature of Knoxville's climate).

When First Creek and Loves Creek run brown after a storm, the color comes from eroded soil. When bare construction sites in rapidly developing East Knox County dump sediment-laden water into drainage channels, it is the same process operating on a human timescale.

This activity makes erosion visible, measurable, and manipulable. That is its central power. Rather than watching a video of a mudslide, students pour water onto soil trays and watch sediment move. They measure it. They compare conditions. They test interventions.

A few things to anticipate:

- The contrast between bare soil and vegetated soil is reliably dramatic. Students who doubt that grass makes a difference will be convinced by their own data.

- The GTSS tray, deep gravel with some vegetation, often produces the least sediment-laden runoff. This is a concrete, data-based demonstration of why the system was designed the way it was.

- Encourage precision in the measurement phase. The value of this activity as a science experience is multiplied when students collect data systematically enough to make genuine comparisons. Sloppy measurements produce ambiguous results and weaker learning.

- For Grade 5, push toward cause-and-effect explanations that reference particle size, ground cover, and flow rate. "The gravel slowed the water down" is a start; "the gravel reduced flow velocity, which reduced the water's carrying capacity for sediment" is the target.

The agricultural context is worth making explicit for students. The Appalachian region that surrounds East Tennessee has a long history of managing erosion on hillside farmland. Many of the traditional practices (contour farming, living ground cover, check dams) are analogs of the engineering interventions students will evaluate in this activity.

GRADE 3 INTRODUCTION

After a big rainstorm in East Tennessee, rivers and creeks often run brown. The water is carrying something: tiny particles of soil picked up from the land as water flowed across it. This process is called erosion.

Erosion is not always bad. Over millions of years, it is how rivers carve valleys. But when erosion happens too fast on construction sites, on bare hillsides, or in places where pavement sends water rushing across exposed soil, it becomes a problem. Soil ends up in waterways where it does not belong.

Today, you will investigate what causes erosion and what reduces it. You will test different surface conditions and measure how much soil moves. Your results will show, in real data, why some landscapes lose soil and others hold onto it.

Look for patterns in your data. Which conditions produced the most erosion? Which produced the least? Why?

GRADE 4 INTRODUCTION

Erosion is a force and a process. It is how landscapes change over time and how human decisions speed that change up or slow it down.

In Knox County, rapid development has meant more bare soil exposed to rainfall, more impervious surfaces directing water at higher velocities, and more sediment entering creeks and rivers. First Creek in East Knoxville has been affected by this kind of upstream change.

Today you will investigate erosion experimentally. You will control variables by keeping water volume constant across tests and measure outcomes: how much soil moved, how far it traveled, how turbid the runoff water became.

As you analyze your results, think about cause and effect: what specific properties of each surface condition explain the erosion you observed? Ground cover, particle size, slope, and water velocity all play a role. Try to name which factor was most influential in each comparison.

GRADE 5 INTRODUCTION

Soil erosion sits at the intersection of geology, hydrology, and land-use planning. It is one of the most consequential environmental processes humans have to manage.

In this investigation, you will approach erosion as a scientist: forming hypotheses, controlling variables, collecting quantitative data, and constructing evidence-based explanations. You will test conditions ranging from bare soil to vegetated cover to a model of the GTSS, and you will measure the erosion outcomes with enough precision to compare them meaningfully.

After the data collection, you will be asked to do something harder: explain why. Not just “the vegetated tray had less erosion”, but identifying what physical mechanism produced that result. Your explanation should reference the properties of the materials, the behavior of water under different conditions, and the relationship between flow velocity and sediment transport.

Consider also: what are the design implications? If you were advising a construction company about to break ground on a new development in East Knox County, what would your data tell them about how to protect nearby waterways?

Adobe Stock | #176270862

Crosscutting Concepts & Connections

- Cause and effect (water flow causes soil movement)
- Systems (water, soil, vegetation, slope, and human design interacting)
- Stability and change (landforms changing over time)
- Engineering design (testing and improving erosion control methods)
- Math (measurement, graphing, data analysis)
- Communication (evidence-based explanation and argument)

TN Academic Standards

GRADE 3	GRADE 4	GRADE 5
3.ESS2	4.ESS2	5.ETS1
3.ESS3	4.ESS3	5.MD.B.2
3.MD.B.3	4.MD.B.4	5.W.TTP.1
3.W.TTP.2	4.W.TTP.1	5.W.TTP.2
	4.W.TTP.2	

Disciplinary Core Idea Progression

- Grade 3: Water shapes land through erosion and deposition. Students develop models to describe how Earth's spheres interact, including how flowing water moves soil and sediment across the landscape.
- Grade 4: Rocks, soils, and sediments are broken into smaller pieces through mechanical weathering and transported by water, ice, wind, and gravity. Students collect and analyze data to show how these processes operate and how organisms — including plants — can slow or accelerate erosion.
- Grade 5: Prototypes are tested under controlled conditions; failure points inform redesign. Students apply this process to erosion-control designs, using measured soil loss as performance data to evaluate and improve their solutions.

Adobe Stock | #257292428

Learning Objectives

Students will be able to:

- Explain how flowing water causes erosion.
- Measure and compare soil loss across different conditions.
- Analyze data to identify patterns in erosion.
- Design and test methods to reduce erosion.
- Construct a written explanation supported by evidence.

Materials

1. Shallow trays or plastic bins
2. Potting soil
3. Small rocks or gravel
4. Grass clippings, sod, or plant material
5. Watering cans or graduated containers
6. Measuring cups
7. Rulers
8. Scale (optional for measuring soil mass)
9. Books or blocks to create consistent slopes
10. Paper, pencils, and graph paper

Vocabulary

GRADE 3	GRADE 4	GRADE 5
erosion	*erosion*	*flow velocity*
sediment	*sediment*	*sediment transport*
particles	*deposition*	*carrying capacity*
ground cover	*turbidity*	*erosion*

Activity Introduction

1. Ask students:
   a. "What happens to soil during heavy rain?"
      i. Does the soil move when it rains? Where does the soil go when it rains?
   b. "Why do some areas lose more soil than others?"
   c. Does runoff water look the same as rainwater? What about water changes after it travels across the land?
2. Explain:
   a. "When water flows downhill, it can carry soil with it. This process is called erosion. Today, you will investigate what factors increase or reduce erosion."

TRAY DIAGRAMS
Showing tray setups with book underneath tray to create slope, different materials, measuring up setup

Observation & Discussion

1. Fill trays with the available materials. Examples:
   a. Bare soil
   b. Soil with grass or plant cover
   c. Soil with gravel
   d. Soil with a small barrier (rocks or sticks)
   e. Tray representing a Gravel Tree Stormwater System. Deep gravel pit with vegetation.
2. Place blocks or books underneath one side of each tray to create a consistent slope. Each tray should have the same slope. Place a collection tray beneath the low end of each tray to collect runoff and displaced soil.
3. Ask students to predict which tray will lose the most soil and explain why.
   a. Ask students to write their predictions using information they have observed. Ask students to then share their predictions with the class.

Activity Instructions

1. Erosion Test
    a. Pour a measured amount of water at the top of each tray. Keep the amount consistent.
    b. Observe and collect runoff water at the bottom.
    c. Measure soil loss using one or more of the following:
        i. Measure the distance soil traveled.
        ii. Grades 4-5: Measure the depth of channels formed.
    d. Collect runoff water and compare sediment amounts visually or by drying and weighing soil.
2. Recording and Data Collection
    a. Students record:
        i. Type of surface condition
        ii. Amount of water used
        iii. Observed soil movement
        iv. Quantitative measurements
    b. Students create a bar graph or line plot comparing erosion levels across trays.
3. Analysis
    a. Ask:
        i. "Which condition resulted in the most erosion?"
        ii. "Which reduces erosion the most?"
        iii. "What patterns do you notice in the data?"
    b. Have students write analysis and share answers. Encourage students to connect findings to real-world examples such as construction sites, farms, schoolyards, or stormwater systems.
4. Engineering Challenge
    a. Students design a modification to reduce erosion on the most vulnerable tray.
        i. Examples: Barriers, add vegetation, etc.
    b. Test the new design using the same amount of water.
    c. Compare results and discuss improvements.

Sharing and Speaking

a. Students present their findings using evidence from measurements and graphs.
b. Prompt discussion:
    i. "What evidence supports your conclusion?"
    ii. "How did your design change the results?"

Performance Indicators

- Informal observation of participation and collaboration.
- Student data tables and graphs.
- Written explanation describing how water causes erosion and how design choices reduce soil loss.
- Student ability to use vocabulary such as erosion, sediment, runoff, slope, and design solution.

Extensions & Variations

- Test different slope angles to analyze impact on erosion.
- Introduce rainfall intensity changes (slow pour versus fast pour).
- Connect results to the school's GTSS or other stormwater systems. (See Investigating our Stormwater System activity.)
- Analyze photographs of real erosion events and compare to tray results.
- Have students write an evidence-based argument for the best erosion control method tested.
- Consider how erosion affects urban spaces. How do buildings impact how water moves? How does water flow across impervious surfaces? What happens when flowing water picks up debris?

https://forms.cloud.microsoft/r/9B7qagEJ1p

QR Code for Feedback Form

Conclusion

Students have now generated real data about erosion, and that data should tell a clear story. Bare soil loses the most. Vegetation significantly reduces loss. The GTSS model, with its gravel and plant cover, often performs best of all. These results are not incidental; they are the empirical basis for why green infrastructure is recommended in urban stormwater management.

Facilitate a data comparison across groups. Where do results agree? Where do they differ, and why might that be? Variation in results is scientifically interesting, not a problem. It is an opportunity to discuss experimental control, measurement precision, and natural variability.

Connect the experiment to the real landscape: the creeks that run through East Knoxville are downstream of exactly the kinds of conditions students tested today. When soil erodes off an unprotected construction site, it enters drainage systems that flow toward waterways that students may fish in, walk beside, or simply know as part of their neighborhood.

In **Investigating Our Stormwater System**, students will return to the GTSS on campus but this time with data collection tools and a more systematic investigation protocol. The erosion work they just completed gives them a richer understanding of why a system like the GTSS matters: not just for managing water quantity, but for protecting soil and water quality in the landscape it serves.

Investigating our Stormwater System

Grades: 3-5

Time: Two 45–60 minute class periods (Field Investigation; Data Analysis & Explanation)

Lesson: Investigate how the Gravel Tree Stormwater System (GTSS) or rain garden manages stormwater by collecting rainfall data, measuring tree growth and water levels, comparing surfaces, and analyzing how the system reduces runoff and supports plants. loss.

Introductions

TEACHER INTRODUCTION

This is the field science activity at the heart of the 3–5 sequence. Students go outside with clipboards, rulers, and data sheets to investigate a real functioning system. Not a model, not a simulation, but the actual GTSS or rain garden on their campus. That distinction is enormously important for student motivation and for the authenticity of the scientific experience.

The data students collect here such as rainfall amounts, water level readings, and tree circumference measurements, are longitudinal. If earlier cohorts recorded data at the same location, this year's students can compare and begin to see trends. If this is the first year of data collection, this cohort is establishing a baseline that future students will return to. Either way, the data has real value beyond the classroom.

A few structural notes:

- Station rotation works well for this activity. Four stations (Rain Gauge, Observation Well/Water Level, Tree Growth, Surface Comparison) allow all students to engage with all data types without creating bottlenecks at any single location.
- The Surface Comparison station (where students observe pavement versus the permeable GTSS surface) is the most conceptually important. It is where the abstractions of the previous activities (infiltration, runoff, permeability) become visible as physical reality. Give this station adequate time.
- Weather conditions matter for data interpretation. Visiting the system on a dry day versus the day after heavy rainfall produces dramatically different observations. If possible, plan at least one visit after significant rain.
- For Grade 5 students, this is an opportunity to begin evaluating system performance, not just observing it. Prompt them to ask: is the system working? How would you know? What data would tell you?

The East Knoxville context is worth discussing: this system was designed and installed as part of a community-focused research partnership. The data students collect is not just for their science class; it contributes to a longer-term understanding of how the GTSS or rain garden performs across seasons and years. There is something seriously motivating about telling students that their data matters!

GRADE 3 INTRODUCTION

You have investigated the water cycle, observed erosion, and begun to understand why stormwater management matters. Today, you are going to investigate the actual stormwater system on your campus.

Scientists who study environmental systems do not just read about them, they go to the places where the systems exist and collect data. That is what you are doing today.

You will rotate through four stations: checking the rain gauge, reading the water level in the observation well, measuring the tree, and comparing surfaces. At each station, you will record data on your investigation sheet.

As you collect data, look for connections. Does the water level in the well relate to recent rainfall? Does the tree seem to be growing well? Is the soil inside the system different from the pavement nearby?

You are collecting real data about a real system. The students who come after you will compare their data to yours.

GRADE 4 INTRODUCTION

Field investigation is one of the most fundamental practices in environmental science. Today you will conduct one: collecting data at multiple stations, recording your observations systematically, and then bringing the data back to the classroom to analyze.

The system you are investigating, the Gravel Tree Stormwater System or the rain garden, was designed to solve a specific problem: too much stormwater running off pavement too fast, not enough infiltrating into the soil where trees can use it. As you collect data today, hold that design purpose in mind.

At each station, ask yourself: does this data tell me whether the system is working? The rain gauge tells you how much water entered the environment. The observation well tells you how much the system is currently holding. The tree measurements tell you whether the system is supporting plant growth over time. The surface comparison shows you whether the system behaves differently from untreated pavement.

Together, those four data points begin to tell a story. Your job today is to collect the data. In the classroom, you will analyze it and decide what the story says.

GRADE 5 INTRODUCTION

Environmental engineers do not just build systems, they monitor them. They collect data over time to determine whether a system is performing as designed, and they use that data to propose improvements. That is what you are doing today.

The GTSS or the rain garden was designed to infiltrate stormwater, reduce runoff, and support tree growth in an urban environment. To evaluate whether it is meeting those goals, you need data: rainfall inputs, water storage measurements, tree growth over time, and comparisons to unmanaged surfaces.

As you work through the investigation stations today, think like an evaluator, not just an observer. What does each measurement tell you? What would a well-performing system look like in this data? What would a failing system look like? Where does the system you are investigating fall on that spectrum?

After the field investigation, you will write an evidence-based evaluation of the system's performance. Your evaluation must be grounded in the data you collect today. Not impressions, not guesses, but specific measurements with specific implications.

Crosscutting Concepts & Connections

- Systems and system models
- Cause and effect
- Energy and matter
- Patterns
- Stability and change
- Engineering design

TN Academic Standards

GRADE 3	GRADE 4	GRADE 5
3.ESS2	4.ESS2	5.ETS1
3.MD.B.3	4.ESS3	5.MD.A.1
3.W.TTP.2	4.MD.A.1	5.W.TTP.1
	4.MD.A.2	5.W.TTP.2
	4.W.TTP.1	
	4.W.TTP.2	

Disciplinary Core Idea Progression

- Grade 3: Water cycles through Earth's systems driven by solar energy. Students describe how the geosphere, biosphere, hydrosphere, and atmosphere interact, and evaluate existing solutions that reduce the impact of natural hazards such as flooding.
- Grade 4: Organisms affect the physical characteristics of their regions: plants hold soil, beaver shelters alter water flow, and paved surfaces increase runoff. Students collect and analyze data to explain these cause-and-effect relationships. Human activity can affect land and water in both positive and negative ways.
- Grade 5: Design solutions can be tested and refined using controlled variables and performance data. Students evaluate how well the GTSS or rain garden manages stormwater, using field measurements as evidence to support their explanations. Data helps evaluate how well a system works.

Learning Objectives

Students will be able to:

- Collect and organize rainfall and water level data.
- Measure tree growth and analyze change over time.
- Compare infiltration in planted versus paved areas.
- Explain how the system reduces runoff.
- Connect system performance to Earth system interactions.

Materials

1. Rain gauge
2. Measuring tape
3. Observation well access or soil moisture probe
4. Clipboards
5. Student investigation sheets
6. Pencils
7. Graph paper
8. Optional stopwatch

Vocabulary

GRADE 3	GRADE 4	GRADE 5
circumference	*circumference*	*hydrosphere*
water level	*infiltration rate*	*biosphere*
longitudinal data	*system performance*	*baseline measurement*
observation well	*geosphere*	*evapotranspiration*

Activity Introduction

1. Ask students:
   a. "How does rain move across our campus?"
   b. "Where does water go after it rains?"
   c. "What does the water carry with it when it flows?"
   d. "What problems can too much runoff cause?"
   e. "How might this system solve those problems?"
   f. "Why was this system installed where it is?"
2. Explain that students will act as field scientists collecting real data to evaluate how well the system works.

Activity Instructions

1. Station 1: Rainfall Measurement
   a. Students read the rain gauge.
   b. Record rainfall amount.
   c. Compare to rainfall earlier in the week if data is available.
   d. Discuss whether rainfall seems typical for the season (Grade 3 focus on patterns).
2. Station 2: Water Level Observation
   a. Students measure the water level in the observation well or assess soil saturation in the rain garden.
   b. Record measurement.
   c. Compare water level to rainfall amount.
   d. Discuss relationship between precipitation and stored water.
3. Station 3: Tree Growth Measurement
   a. Measure tree circumference at a consistent height (foresters traditionally use 4.5 feet above ground).
   b. Record measurement.
   c. Compare to previous data if available.
   d. Discuss how stored water supports plant growth.
4. Station 4: Surface Comparison
   a. Observe a nearby paved surface.
   b. Look for visible runoff pathways or puddles.
   c. Compare how water behaves on pavement versus in the rain garden.
   d. Discuss differences in infiltration.

5. Data Analysis
  a. Grade 3
    i. Create a table and bar graph of rainfall and water level.
    ii. Describe patterns in simple cause-and-effect language.
  b. Grade 4
    i. Analyze relationships between rainfall, water level, and surface type.
    ii. Use measurement comparisons.
    iii. Write a clear explanation using data.
  c. Grade 5
    i. Develop a systems explanation connecting hydrosphere (rain), geosphere (soil), bio-sphere (trees), and atmosphere (evaporation).
    ii. Propose one improvement to increase effectiveness.
    iii. Justify proposal using collected data.
    iv. Note: The data sheet asks students to directly compare the observation well and the rain gauge. This is a great opportunity to talk about why the units aren't directly compatible - they don't measure the same area. The observation well collects water from a large soil area, but the rain gauge only catches the rain that falls directly on top of it. However, that estimation can still be useful to scientists, as long as they understand what the units mean in each case.

Sharing and Speaking

  a. Writing and Discussion Prompts
    i. What happens to rain when it hits pavement?
    ii. How does gravel and soil change water movement?
    iii. How does stored water help trees?
    iv. How does this system reduce flooding?
    v. How are different Earth systems interacting here?

Performance Indicators

- Students accurately record measurements.
- Students create appropriate graphs.
- Students explain cause-and-effect relationships.
- Grade 5 students connect explanation to interacting Earth systems and human impact.

Extensions & Variations

- Track rainfall and water level over a month and analyze patterns.
- Compare system performance after light rain versus heavy rain.
- Design a proposal to expand green infrastructure on campus.

Conclusion

Students have now collected field data about a functioning stormwater system. The next step is to make sense of it.

In the classroom, bring all station data together. For Grade 3: organize the data by station and look for patterns. Does the system seem to be holding water? Is the tree growing? For Grade 4: begin comparing across stations. Does the water level data support or contradict what the rainfall gauge shows? For Grade 5: initiate a structured written evaluation. Using data as evidence, does this system appear to be performing as designed?

One conversation to have across all grades: what would we need to see this system do to call it a success? Defining success criteria before evaluating evidence is a scientific habit of mind with wide applicability.

In **Shape the Land, Watch the Water**, students will step back from the specific GTSS and think about the larger landscape it sits within, including the slope of the land, the placement of impervious surfaces, and the path water takes from sky to creek. Understanding the watershed context of the system they just investigated will deepen their appreciation of why it was placed where it was.

https://forms.cloud.microsoft/r/9B7qagEJ1p

QR Code for Feedback Form

Shape the Land, Watch the Water

Grades: 3-5

Time: 60 minutes; optional follow-up observation after real rainfall

Lesson: Use natural materials to build and test a model watershed outdoors, observing how land shape, soil, and vegetation influence runoff and erosion.

Introductions

TEACHER INTRODUCTION

Watersheds are one of the most important and most underappreciated concepts in environmental science. Every point on the Earth's surface is part of a watershed, or a geographic area where all water drains to a common outlet. Knox County sits within the Tennessee River watershed; East Knoxville is drained primarily through First Creek and Second Creek toward the Tennessee River near downtown. Every drop of rain that falls on your school campus is, eventually, part of that larger story.

This activity makes watershed thinking tangible by having students build and test miniature watersheds outdoors. The construction process itself (shaping hills, valleys, and collection points from soil and natural materials) engages spatial reasoning in a way that maps and diagrams cannot. When students pour water on a model they built and watch it flow exactly where gravity dictates, the concept clicks in a way that is difficult to achieve through any other means.

A few facilitation notes:

- Build time is learning time. Resist the impulse to rush through model construction. The conversations students have while deciding where to place a ridge, how steep to make a slope, and where to designate a "lake" or "river" point are geomorphologically substantive.

- The outdoor setting is intentional. Students should be looking at real slopes, real vegetation patterns, and real drainage features as they build. Periodically direct their attention to the actual landscape around them: "what direction is this part of the campus draining?"

- For Grade 5, add a design constraint after the initial observation: now modify your watershed to reduce erosion and slow runoff reaching the outlet point. The modification phase (adding vegetation, barriers, or permeable materials) turns observation into engineering.

East Knoxville has experienced significant flood events, particularly in low-lying areas near First Creek. The watershed concept helps students understand why flooding in one area is connected to land management decisions far upstream. That connection between local decisions and downstream consequences is a core principle of environmental stewardship.

GRADE 3 INTRODUCTION

You live in a watershed. So does your school. So does everyone on Earth.

A watershed is an area of land where all the rainwater drains toward the same place, like a creek, a river, or a lake. The shape of the land determines where water goes. Gravity pulls it downhill, into valleys and streams.

Today you will build a miniature watershed using soil, sticks, stones, and leaves. You will shape hills and valleys, choose where water collects, and then test it by adding water at the highest point.

As you build, ask yourself: where will the water go? What will it carry with it? Where will it end up? Then watch and see whether the water does what you predicted.

GRADE 4 INTRODUCTION


Adobe Stock | #257292428

A watershed is a system. Every slope, every patch of vegetation, every stretch of pavement within it influences how water moves toward the outlet.

Think about East Knoxville. First Creek runs through the neighborhood before joining the Tennessee River near downtown. Every surface in the First Creek watershed, whether it's parking lots, lawns, schoolyards, or construction sites, contributes water and whatever it carries to that creek. The decisions people make about how to cover the land affect what arrives at the outlet.

Today you will build and test a model watershed, then analyze how different features affect runoff and erosion. You will measure and record what you observe, and you will look for cause-and-effect relationships: what specific features of your watershed produced the outcomes you measured?

After testing your initial design, you will have the chance to modify it to improve its performance to help reduce erosion and slow runoff at the outlet point.

GRADE 5 INTRODUCTION

Watershed science is the foundation of modern stormwater management, flood control, and water quality protection. Understanding how land shape, surface cover, and precipitation interact to produce runoff is essential for anyone who works on environmental systems (which, increasingly, means almost everyone who works on cities).

Today's activity asks you to do three things. First, build a model watershed that accurately represents the physical features that influence water flow. Second, test it with controlled inputs and measure the outputs. Third, evaluate your design: does it perform the way you predicted? What would you change?

As you work, think at two scales: the model in front of you, and the real landscape outside. How does the watershed you built compare to the actual drainage patterns on your campus? Where does your school fit within the First Creek watershed? What decisions made about the land near your school, such as the amount of pavement, the placement of vegetation, or the design of the stormwater system, affect what arrives at First Creek after a storm?

Your analysis should connect your experimental data to real-world implications.

Crosscutting Concepts & Connections

- Systems (land, water, gravity, and vegetation interacting)
- Cause and effect (rainfall leads to runoff and erosion)
- Scale and proportion (models represent real landscapes)
- Engineering design (modifying land to reduce flooding)
- Math (measurement, comparison, data analysis)
- Communication (evidence-based explanation)

TN Academic Standards

GRADE 3	GRADE 4	GRADE 5
3.ESS2	4.ESS2	5.ETS1
3.MD.B.3	4.ESS3	5.MD.B.2
3.W.TTP.2	4.W.TTP.1	5.W.TTP.1
	4.W.TTP.2	5.W.TTP.2

Disciplinary Core Idea Progression

- Grade 3: Water cycles through Earth's systems and moves across land, collecting in rivers, lakes, and oceans. Students develop models of how the geosphere, hydrosphere, and biosphere interact, and evaluate solutions that reduce the impact of flooding.
- Grade 4: Patterns in landforms and waterways can be observed and modeled. Human activities and vegetation affect how water moves — paved surfaces increase runoff, and plant roots hold soil in place. Students use maps and data to identify and explain these patterns.
- Grade 5: Engineering design solutions can be built, tested, and improved based on measured outcomes. Students model watershed behavior, test the effects of land-feature modifications, and use runoff data to evaluate how well their interventions reduce flooding or erosion.

Learning Objectives

Students will be able to:

- Define a watershed and explain how water moves through it.
- Construct a small-scale watershed model using natural materials.
- Observe and measure runoff patterns.
- Modify land features to reduce erosion or flooding.
- Support conclusions with data and observations.

Materials

1. Outdoor space with soil access
    a. Indoor modification: Aluminum trays, soil
2. Sticks, leaves, grass clippings, small stones
3. Hand shovels or scoops
4. Buckets or watering cans
5. Measuring cups or graduated containers
6. Rulers
7. Clipboards, paper, pencils

Vocabulary

GRADE 3	GRADE 4	GRADE 5
watershed	*watershed*	*watershed*
landforms	*landforms*	*channel*
vegetation	*vegetation*	*gradient*
drainage	*drainage*	*impervious*

Activity Introduction

1. Gather students in an outdoor space with soil.
2. Ask:
    a. “Where does rainwater go after it falls here?”
    b. “How does water know where to travel?”
3. Explain:
    a. “A watershed is an area of land where all rainwater drains to the same place. Gravity pulls water downhill.”
    b. Have students look around and identify high and low areas.

Adobe Stock | #1678811844

Observation & Discussion

1. Ask students to point out:
    a. Slopes
    b. Low spots where water collects
    c. Areas with more vegetation
    d. Areas of bare soil
2. Discuss how these features might influence water movement.

Activity Instructions

1. Model Construction
    a. In small groups, students build a mini watershed directly on the ground using soil, sticks, leaves, and stones. (Indoor modification: students build a mini watershed in their aluminum tray.) They should include:
        i. Hills or higher areas
        ii. Valleys or low collection areas
        iii. A designated “river” or “lake” point
2. Testing Rainfall
    a. Using watering cans, pour a consistent amount of water over the highest point.
    b. Observe how water flows downhill.
    c. Notice where:
        i. Water moves quickly

        ii. Soil erodes
        iii. Water collects
3. Data Collection
    a. Measure one or more of the following:
        i. Distance water traveled
        ii. Amount of runoff collected in a container
        iii. Depth of channels formed
    b. Record observations and measurements.
4. Experimentation
    a. Students change one variable:
        i. Add vegetation or leaf cover
        ii. Add a gravel layer
        iii. Adjust slope
    b. Repeat the rainfall test.
    c. Compare runoff amount and erosion before and after modifications.
    d. Record observations and measurements.


Adobe Stock | #401433225

Sharing and Speaking

a. Log the data from each group in a class-wide bar graph or line plot.
b. Ask:
    i. "How did water move through your watershed?"
    ii. "What changes reduced erosion?"
    iii. "What evidence supports your conclusion?"
c. Encourage students to refer to data and observations.

Performance Indicators

- Student model demonstrates downhill flow.
- Student collects and records measurable data.
- Student explains how slope and vegetation influence runoff.
- Student provides an evidence-based explanation of design improvements.

Extensions & Variations

- Visit the school's GTSS and compare it to student-built watersheds.
- Map the school grounds to identify real watershed features.
- Observe the same area after a natural rain event.
- Introduce a pollution simulation using soil color differences to show contamination movement.
- Introduce items seen in urban landscapes to the watershed models. How do buildings, playgrounds, roads, impact the way water moves?
- Write an argument explaining the best design for reducing flooding on campus.

Conclusion

Students have now done something geographers and hydrologists do professionally: they have thought carefully about the shape of land and what it means for water. That is the foundation of good stormwater system design!

Debrief with a focus on the modification phase (especially for Grades 4 and 5): what interventions reduced erosion and slowed runoff? Students should be able to connect specific design choices such as adding vegetation to a slope, or placing a barrier in a channel, to specific observed outcomes.

Pull the lens back: the watershed model students built today is a simplified version of the real watershed their school occupies. Every design choice in that real watershed (where to put a parking lot, where to plant trees, where to install a stormwater system) has downstream consequences.

In **Biofiltration Engineering Lab**, students will bring their engineering thinking to bear on a specific component of stormwater management: cleaning water as it moves through the system. They will design, build, and test filtration systems, learning that managing stormwater is not just about controlling where water goes, but about what condition it is in when it arrives.

https://forms.cloud.microsoft/r/9B7qagEJ1p

QR Code for Feedback Form

Biofiltration Engineering Lab

Grades: 3-5

Time: 60 minutes; optional redesign/ testing day

Lesson: Design, build, test, and improve a biofiltration system that reduces sediment in stormwater while maintaining water flow.

Introductions

TEACHER INTRODUCTION

Biofiltration is the process by which natural materials (soil, gravel, sand, organic matter, and the microorganisms living within them) remove pollutants from water as it passes through. It is not a new technology; it is what healthy soil has always done. What is new is the deliberate engineering of biofiltration systems in urban environments where natural soil has been paved over, compacted, or contaminated.

Rain gardens, bioswales, and gravel tree systems like the GTSS all rely on biofiltration. When stormwater enters the GTSS on campus, it is not just being stored, it is being cleaned. Sediment settles out. Fine particles are filtered by the gravel and soil matrix. Pollutants are adsorbed to soil particles or broken down by soil microorganisms. The water that reaches the tree roots and, eventually, the groundwater below is measurably different from the stormwater that entered.

This activity asks students to design that filtration process themselves, which is a significant cognitive demand. They must think in three dimensions (layer order matters), in time (flow rate is a design variable), and in tradeoffs (cleaner output often means slower flow). That kind of multi-variable reasoning is developmentally appropriate for Grades 3–5 and excellent preparation for the more formal engineering design process in Grades 6–8.

A few notes:

- Emphasize that the design phase is not guessing; it should draw on what students know about material properties from earlier activities. Gravel drains fast. Clay-heavy soil holds water longer. Soil filters fine particles. Students who connect their design choices to evidence from earlier investigations are doing science.

- Flow rate measurement requires consistent technique. Either time how long it takes for a defined volume to pass through, or measure the volume collected in a fixed time. Whichever method you use, be consistent across groups so that results are comparable.

- Turbidity comparison is often more compelling when students hold collection cups up to a light source. The visual difference between filtered and unfiltered water is striking and reinforces the abstract concept of filtration with immediate sensory evidence.

The engineering design cycle (design, build, test, analyze, improve) is the structural spine of this activity. Keep students in that cycle. A group that tests their first design and immediately redesigns based on what they observed is doing exactly the right thing.

GRADE 3 INTRODUCTION

Rainwater picks up pollutants as it runs across pavement, soil, and rooftops. By the time it reaches a creek or a drain, it is carrying sediment, oils, and other particles from the surfaces it crossed.

One of the ways we manage that is through biofiltration: passing water through layers of natural materials that trap particles and clean the water as it moves through.

Today you will design your own biofiltration system. You will choose the materials, decide the order of the layers, and then test whether your design produces cleaner water.

As you design, think about what you already know about these materials. Which ones let water through quickly? Which ones hold it longer? Which ones are the finest, or the most likely to catch small particles?

After your first test, you will have the chance to redesign. This is how engineers work: test, learn, improve.

GRADE 4 INTRODUCTION

Designing a biofiltration system requires thinking about two competing goals at once: how clean is the output water, and how quickly does it flow?

These goals often push in opposite directions. A very fine-grained filter might produce very clear water, but slowly. A coarse filter lets water through quickly, but may not remove fine particles. The best designs find a workable balance that is both clean enough and fast enough.


Adobe Stock | #403270496

Today you will design, build, and test a layered filtration system. Before you build, write a clear hypothesis: which layer order will produce the best balance of water clarity and flow rate, and why? Your hypothesis should reference the specific properties of the materials you are choosing.

After the first test, analyze your data. Did your filter perform as predicted? What was the most important variable? Then redesign: what would you change to improve performance?

Your design decisions should be based on evidence from this activity and from earlier investigations. Ground cover reduces erosion because it intercepts particles before they enter runoff. That same logic applies here: layer order and material choice determine what gets caught and what passes through.

GRADE 5 INTRODUCTION

Biofiltration is applied environmental engineering. The materials are natural, but the design is deliberate, and the difference between a good design and a poor one is measurable.

Today you will approach this as a full engineering design challenge. You will define your own success criteria (what counts as "clean enough" and "fast enough"?), select and arrange materials to meet those criteria, test your design against a control, and produce a data-backed evaluation of your system's performance.

This challenge is genuinely difficult. You are optimizing across multiple variables simultaneously: particle removal efficiency, flow rate, system lifetime before clogging, and material cost and availability. Real biofilter engineers face the same optimization problem.

After testing, you will write an analysis that: (1) describes your design and the reasoning behind it, (2) presents your results with specific data, (3) evaluates whether your design met your success criteria, and (4) proposes specific, evidence-based improvements.

Think about the GTSS on your campus as you work. That system is also a biofilter, built at a larger scale, designed to last for years, and installed in a real East Knoxville context. Your design today is a prototype of something like it.

Crosscutting Concepts & Connections

TN Academic Standards

GRADE 3	GRADE 4	GRADE 5
3.ESS2	4.ESS2-3	5.ETS1
3.ESS3	4.ETS1	5.NBT.B.7
3.MD.B.3	4.W.TTP.1	5.W.TTP.1
3.W.TTP.2	4.W.TTP.2	5.W.TTP.2

- Cause and effect (material choice affects filtration and flow rate)
- Systems (water interacting with soil, gravel, sand, and organic matter)
- Structure and function (layered materials serving different roles)
- Engineering design (iterative testing and improvement)
- Math (measurement, graphing, comparison)
- Communication (evidence-based argument)

Disciplinary Core Idea Progression

- Grade 3: Water moves through Earth's systems and can carry sediment that changes landforms. Existing solutions can reduce the impact of natural hazards such as flooding. Students evaluate these solutions and apply basic engineering criteria to design problems.
- Grade 4: Organisms affect the physical characteristics of their environment — plants filter and slow water movement. Human activity can affect land and water positively or negatively, and design solutions can be tested and compared against specified criteria.
- Grade 5: Design solutions are tested with controlled variables; results are used to identify failure points and drive redesign. Students apply this process to a layered filtration system, measuring flow rate and output clarity as performance indicators and justifying improvements with evidence.

Learning Objectives

Students will be able to:

- Explain how sediment travels in stormwater.
- Design and construct a layered filtration system.
- Measure filtration effectiveness and flow rate.
- Analyze data and refine their design.
- Communicate conclusions supported by evidence.

Materials

1. Clear 2-liter bottles (cut in half) or clear containers with drainage holes
2. Coffee filters or mesh liners
3. Gravel
4. Sand
5. Soil
6. Activated charcoal (optional)
7. Food coloring (optional)
8. Leaves, grass clippings, or other organic material
9. Graduated cylinders or measuring cups
10. Stopwatch or timer
11. Water mixed with measured quantity of soil (simulated stormwater)
12. Collection cups
13. Rulers
14. Graph paper
15. Student data sheets

Vocabulary

GRADE 3	GRADE 4	GRADE 5
filtration	*layering*	*biofiltration*
biofiltration	*filtration*	*permeability*
turbidity	*porosity*	*organic matter*
flow rate	*flow rate*	*flow rate*

Activity Introduction

1. Present a sample of "stormwater" (water mixed with soil).
2. Ask:
   a. How does water get muddy? Why is some water muddier than others?
   b. "What problems can happen when muddy water enters rivers or lakes?"
   c. "How might we reduce sediment in stormwater?"
3. Explain:
   a. "Today you will act as engineers designing a biofiltration system to clean stormwater."

Activity Instructions

1. Design Phase
   a. Students sketch a layered filter design using available materials.
   b. They must decide:
      i. Order of materials
      ii. Thickness of layers
   c. Goal: balance cleaner water and reasonable flow speed
2. Testing Phase
   a. Pour a measured amount of simulated stormwater into each filter.
   b. Measure:
      i. Time required for water to pass through (flow rate).
      ii. Volume of water collected (Grade 3: cups, Grades 4-5: mL).
      iii. Visual clarity of filtered water.
      iv. Optional: Allow sediment to settle and compare turbidity visually or with a simple clarity scale.
3. Data Collection
   a. Students record:
      i. Design description
      ii. Layer order and depth

    iii. Flow time
    iv. Water clarity observations
  b. Students create:
    i. Bar graph comparing flow rates.
    ii. Bar graph or rating scale comparing clarity.

4. Redesign Phase
  a. Students identify one variable to change (layer order, thickness, material).
  b. Repeat test with same volume of water.
  c. Compare results and determine whether performance improved.

5. Analysis and Discussion
  a. Ask:
    i. “Which design filtered sediment most effectively?”
    ii. “Which design had the fastest flow rate?”
    iii. “What changes did you make during the redesign? Did they help with filtration?”
    iv. “Was there a tradeoff between speed and cleanliness?”
    v. “What evidence supports your conclusion?”
  b. Encourage students to support claims with specific data.

Sharing and Speaking

  a. Students write (in groups or individually) and present:
    i. Initial design
    ii. Data collected
    iii. Modifications made
    iv. Final conclusions

Performance Indicators

- Completed data table and graphs.
- Evidence-based written explanation describing how their design worked.
- Ability to explain how material structure affects filtration.
- Use of key vocabulary accurately in discussion or writing.

Extensions & Variations

- Introduce a cost constraint for materials and evaluate efficiency.
- Test different rainfall intensities (slow pour versus fast pour).
- Connect findings to the school’s GTSS and discuss similarities in layered design. (See GTSS Investigations activity)
- Collect materials as a class from the school’s campus to connect students to local soil makeup and materials (i.e. East TN generally has clay soils, garden beds generally have loamy soil)
- Introduce pollution beyond sediment (food coloring) to discuss limits of filtration.
- Have students write a proposal recommending the best design for a school stormwater system.

Conclusion

Students have designed, tested, and evaluated a real filtration system. That is applied science in the fullest sense, and it is worth pausing to name what they accomplished!

Share data across groups. Which designs produced the clearest water? The fastest flow? Were there tradeoffs, as expected? A group whose filter produced very clear water but nearly zero flow has discovered something genuine: over-engineering a filter creates a different kind of failure than under-engineering it.

Connect explicitly to the GTSS: the gravel-and-soil system on campus is performing biofiltration at scale, continuously, across every rainfall event. Students who have now designed their own filtration system have a meaningful conceptual basis for understanding how it works, and why the material selection and layering in the real system is not arbitrary.

In **Flood Prevention Engineering (Intermediate/Advanced)**, students will draw on everything they have learned in the 3–5 sequence to design, build, and test a comprehensive stormwater management system. They will work within real constraints, face genuine tradeoffs, and produce evidence-based evaluations of their designs. The biofiltration thinking they developed today is one of the tools they will bring to that challenge.

https://forms.cloud.microsoft/r/9B7qagEJ1p

QR Code for Feedback Form

Flood Prevention Engineering (Intermediate/Advanced)

Grades: 3-5

Time: 2–3 class periods (Design Day; Build/Test Day; Analyze/Improve Day)

Lesson: Design, test, and improve a model stormwater system that reduces runoff speed, increases infiltration, and protects plant areas using defined criteria and constraints.

Introductions

TEACHER INTRODUCTION

This activity is the capstone of the 3–5 stormwater sequence, and it should feel like one. Students are not doing a new investigation; they are integrating everything they have done up to this point.

They understand the water cycle and how land surfaces affect it. They have measured erosion under different conditions. They have investigated the GTSS as a functioning system. They have modeled watershed behavior and watershed intervention. They have designed and tested biofiltration systems. Now they bring all of that to a design challenge with defined criteria, real constraints, and performance data to evaluate.

The engineering design process to define problem, define criteria and constraints, brainstorm solutions, build, test, analyze, and improve, is not new to students at this point. What is new here is the complexity of the problem and the rigor of the evaluation. The criteria are measurable (50% infiltration, runoff leaving more slowly than bare soil). The constraints are real (material budget, build space, two test trials). The stakes, in the context of the classroom, are genuine.

A few notes for the teacher:

- The "bare soil control" test at the start of Observation and Discussion is essential. It gives students a baseline to compare their design against — without it, they cannot evaluate whether their intervention made a measurable difference.
- Intermediate and advanced modifications are both included. Use them based on your knowledge of your students. The intermediate version scaffolds the problem statement; the advanced version presents more abstract design criteria. Both involve the same engineering process.
- The written evaluation at the end is as important as the physical design. Students who can explain, in evidence-based writing, what their system did well and what they would change next time are developing a scientific communication skill that matters far beyond this classroom.

East Knoxville has a real flooding history. Portions of the neighborhood near First Creek have experienced significant flood damage. The problem students are solving today, protecting buildings from water that would otherwise pool or rush toward them, is not hypothetical. It is one of the central challenges of urban stormwater management in their own community. The more students understand that their work is connected to a real local problem, the more invested they will be in solving it well.

GRADE 3 INTRODUCTION

Over the past several stormwater activities, you have learned a lot about water and how it moves. You modeled the water cycle. You watched soil erode. You investigated the stormwater system at our school. You built a watershed. You designed a filtration system.

Today, you are going to use all of that knowledge to solve a real engineering challenge.
The problem: when it rains at our school, water rushes toward buildings instead of soaking into the ground where plants can use it. Your team must design a system that guides water away from the building and toward a plant zone where it can infiltrate.

You have a budget of materials. You have a specific space to work within. And you only get two test trials.

Design carefully, test honestly, and improve based on what you learn.

GRADE 4 INTRODUCTION

You have investigated, measured, and analyzed stormwater systems from multiple angles. Now you will design one.

Your challenge is an engineering problem with defined success criteria: water must reach the plant zone, and at least 50% of the water must infiltrate before leaving the system. Your design must also slow runoff compared to the bare soil control you will test before building.

Engineering problems have constraints. You have a material budget. You have limited build space. You have two test trials to demonstrate that your design works.


Adobe Stock | #225446436

Before you build, sketch your design and explain the reasoning behind each element. What does each component do? Why did you choose those materials? Where did your earlier investigations inform your choices?

After testing, write an evaluation: what did your system do well? What did not work as expected? What would you change if you had another trial?

GRADE 5 INTRODUCTION

This is the capstone of three years of stormwater investigation. You have the knowledge, the data, and the vocabulary to do this well. The question is whether you can apply it under real constraints.

Your engineering challenge today mirrors challenges that environmental engineers face in cities across Tennessee and across the country. A site produces too much runoff. Buildings and infrastructure are at risk. Soil is eroding. The engineer must design a system that redirects and slows water, increases infiltration, and protects the site, all within a defined budget and footprint.

Your system will be evaluated against measurable criteria. The data you collect during testing is your evidence. Your written evaluation must make a clear, evidence-based argument about whether your design succeeded and where it fell short.

Think about the GTSS. It was designed by engineers who faced exactly this kind of problem in East Knoxville. They chose gravel for its permeability. They selected trees for their root systems and canopy. They positioned the system to intercept runoff from surrounding pavement. Every element of the design was a decision, made for a reason, that can be evaluated against data.

Design with that same intentionality. Then let your data tell you whether it worked.

Crosscutting Concepts & Connections

- Systems and system models
- Cause and effect
- Energy and flow
- Structure and function
- Stability and change
- Tradeoffs and optimization

TN Academic Standards

GRADE 3	GRADE 4	GRADE 5
3.ETS1	4.ETS1	5.ETS1
3.MD.A.2	4.ESS2	5.NBT.A.4
3.MD.B.3	4.MD.A.1	5.NBT.B.7
3.W.TTP.2	4.MD.A.2	5.W.TTP.1
	4.W.TTP.1	5.W.TTP.2
	4.W.TTP.2	

Disciplinary Core Idea Progression

- Grade 3: Design solutions to real-world problems must meet specified criteria and constraints. Students apply evidence to support their design choices, connecting the problem of flooding to what they know about how water moves through Earth's systems.
- Grade 4: The effectiveness of design solutions can be tested and compared against specified criteria. Human activity can affect land and water positively or negatively; students consider these tradeoffs when evaluating competing designs.
- Grade 5: Prototypes are tested with controlled variables; failure points are identified and used to drive redesign. Students measure runoff volume and flow rate, compare solutions quantitatively, and justify improvements using evidence. Human-designed systems can reduce flooding and protect ecosystems.

Learning Objectives

Students will be able to:

- Define criteria and constraints for a stormwater design problem.
- Design and test a multi-component system.
- Measure runoff volume and flow rate.
- Compare multiple solutions using quantitative data.
- Justify design improvements using evidence.

Materials

1. Large trays with sloped soil landscape
2. Model "building"
3. Marked "plant protection zone"
4. Collection cup to measure runoff leaving system
5. Graduated cylinders
6. Stopwatch
7. Materials such as gravel, sand, mulch, sponges, small plants, craft sticks
8. Budget cards assigning cost values to materials
9. Structured student lab sheets

Vocabulary

GRADE 3	GRADE 4	GRADE 5
criteria	*criteria*	*criteria*
constraint	*constraint*	*constraint*
infiltration	*retention*	*infrastructure*
retention	*control*	*tradeoff*

Activity Introduction

1. Present the problem:
   a. "Our school wants to redesign part of the campus to better manage stormwater. During heavy rain, water runs off near buildings instead of soaking into plant areas. Your team must design a system that protects the building, increases infiltration, and reduces runoff leaving the system."
   b. Intermediate modification: "Our school is experiencing minor flooding when it rains. When it rains a lot, water runs near the building instead of soaking into the ground where plants grow. Your team needs to come up with a plan to keep the building and playground dry and help water soak into the ground."
2. Define criteria:
   a. Water must reach the plant zone.
   b. At least 50 percent of water must infiltrate before reaching runoff cup.
      i. Grade 3: Mark the collection cups at 50% of the measured volume of water used to test the trays.
   c. Runoff must leave system more slowly than bare soil control.
3. Define constraints:
   a. Limited material budget.
   b. Limited build space.
   c. Two test trials only.

Observation & Discussion

1. Test a "bare soil" control.
2. Measure:
   a. Time for water to exit system.
   b. Volume collected in runoff cup.
3. Discuss what happened and why.

TRAY DIAGRAMS
Showing tray setups with
book underneath tray to
create slope, different
materials, measuring up
setup

Activity Instructions

1. Design Phase
   a. Teams sketch system including labeled components.
   b. Teams select materials within budget.
2. Build Phase
   a. Construct system in tray.
3. Test Phase
   a. Pour measured volume of water.
   b. Measure and record:
      i. Time to first runoff.
      ii. Total runoff volume.
      iii. Amount infiltrated (calculated).
4. Graph
   a. Create bar graph comparing runoff volume between control and design.
   b. Optional: calculate percent reduction in runoff.
5. Improve Phase
   a. Writing prompt (in groups or individually): What worked in the test phase? Why did it work? What can be improved?
   b. Modify one variable and retest.
   c. Compare results quantitatively.

Sharing and Speaking

a. Each group presents:
   i. Their design.
   ii. Data results.
   iii. Whether criteria were met.
   iv. Tradeoffs observed (cost vs effectiveness, speed vs infiltration).

Performance Indicators

- Student defines and applies criteria and constraints.
- Student collects accurate quantitative data.
- Student represents data using graph.
- Student compares multiple solutions using evidence.
- Student writes short evidence-based recommendation.

Extensions & Variations

- Compare permeable vs impermeable surface percentages.
- Incorporate local rainfall intensity data.
- Model extreme rainfall scenario.
- Connect explicitly to on-campus GTSS and evaluate how the model reflects real infrastructure. (See Investigating Our Stormwater System activity)

Conclusion

With the completion of this activity, students have completed the Grades 3–5 stormwater sequence. Honor this moment with something a little more formal than previous activities.

Conduct a design gallery and evaluation share-out. Each team presents their system, their data, and their written evaluation. Celebrate rigor: the team that failed their first trial and rebuilt based on data is doing better, more defensible science than the team that got lucky on the first try.

Then step back and name what students have done across the full 3–5 arc. They have modeled a global system. They have measured local erosion. They have investigated a real stormwater system in their own neighborhood. They have built and tested watershed models. They have designed two different types of filtration and management systems. They have collected data, analyzed it, and communicated findings in writing.

They have, in other words, practiced being environmental scientists and engineers!

In East Knoxville, stormwater management is not a solved problem. It is an ongoing challenge in a neighborhood with aging infrastructure, active development, and real flooding risk in low-lying areas near First Creek. The GTSS on their campus is one response to that challenge as a real, local, small-scale demonstration of what green infrastructure can do.

When these students reach Grades 6–8, they will return to these same systems, but they will return as more sophisticated thinkers: able to calculate infiltration rates, evaluate system performance against quantitative benchmarks, define design criteria with precision, and propose evidence-based improvements. The understanding they built in 3–5 is the foundation that will make that work possible.

https://forms.cloud.microsoft/r/9B7qagEJ1p

QR Code for Feedback Form

3-5 Student Data Sheets and Printables

Table of Contents

Water Cycle Relay

Data Sheets & Reading Exercises

Soil on the Move Data Sheets & Reading Exercises

Investigating Our Stormwater System Data Sheets & Reading Exercises

Shape the Land, Watch the Water Data Sheets & Reading Exercises

Biofiltration Engineering Lab Data Sheets & Reading Exercises

Flood Prevention Engineering Data Sheets & Reading Exercises

REPRINTING LICENSE

WATER CYCLE RELAY

Game Instructions

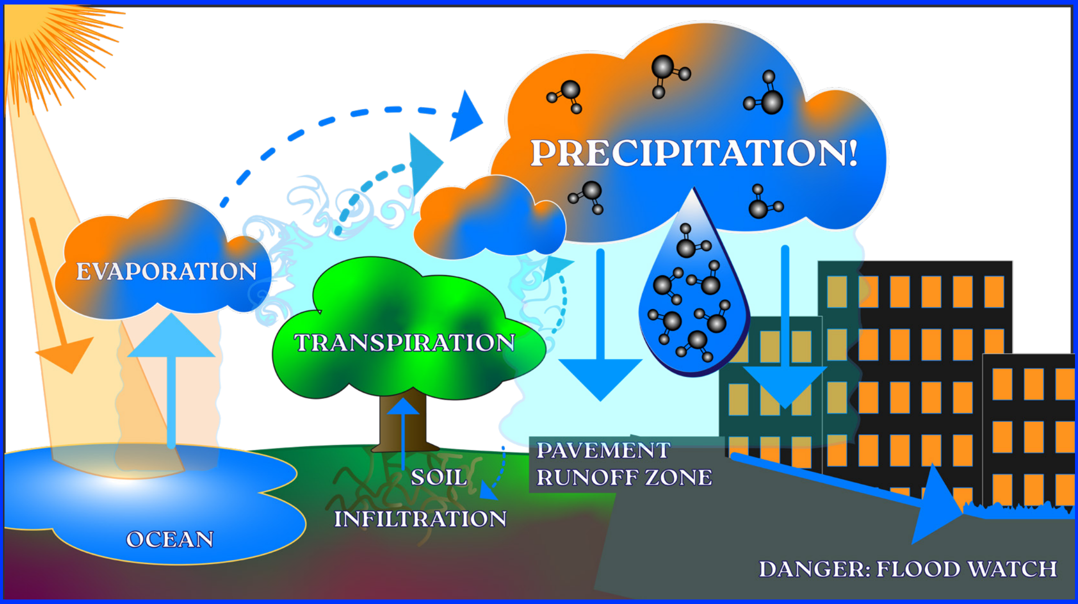
Grades 3–5 | All-Grades Set

HOW TO USE THESE CARDS

Print on cardstock. Cut along the dashed lines. Each sheet contains two role cards.

There are 6 role cards: Sun, Cloud, Land, Plant, Runoff Zone, and Water Molecules. Give each team their card at the start of the simulation.

Laminating the cards is recommended for multi-year use.



A diagram showing the water cycle, as students will experience it in the Water Cycle Relay. The sun warms water in the ocean, which evaporates into a cloud. The cloud then rains precipitation down on the land. Some rainwater infiltrates into the soil, is taken up by plants and trees, and through transpiration, heads back to the cloud. Some rainwater becomes runoff on the pavement, leading to a flood in the city.

SUN TEAM

You are the Sun. You give water the energy it needs to evaporate.

The sun warms the ocean, causing evaporation.

WHAT YOU DO

1. Water molecules start in the Ocean zone.
2. Choose one water molecule at a time.
3. Hand that student one energy token.
4. The water molecule goes to the Cloud and returns the token immediately.
5. Tokens always stay at Sun station.

ROUND RULES

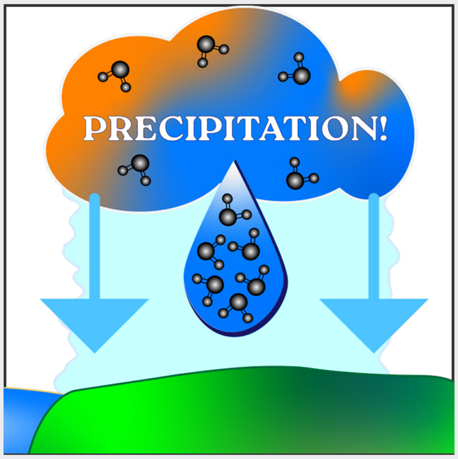
NORMAL: Give tokens at a slow, steady pace.
HOT: Give tokens faster! More energy means more evaporation.
URBAN: Return to normal pace.

YOUR POWER: More energy from you means more rain later.

cut here

RAIN TEAM

You are the Cloud. You collect evaporated water, then let it rain.



When the cloud is full of water molecules, it rains.

WHAT YOU DO

1. Count water molecules and collect their tokens as they arrive from the Sun.
2. When you reach the teacher's number (e.g., 5), it rains.
3. Say 'PRECIPITATION!' loudly.
4. Send ALL water molecules to the Land Team at once.
5. Do not release water early. Wait for the full count.
6. Return collected tokens to the Sun Team when it rains.

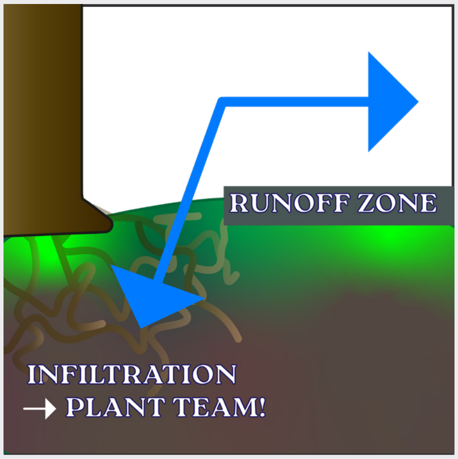
ROUND RULES

NORMAL: Standard threshold - release at the teacher's number.
HOT: More water arrives faster. Precipitation happens more often.
URBAN: Threshold stays the same - but watch what happens on the ground.

YOUR POWER: You decide when it rains.

LAND TEAM

You are the Land. Where rain goes depends on the surface it hits.



Water that falls on land either infiltrates or becomes runoff.

WHAT YOU DO

1. When the Cloud releases precipitation, water molecules come to you.
2. Direct each water molecule to either Soil or Pavement.
3. Soil → send to the Plant Team.
4. Pavement → send to the Runoff Zone.

ROUND RULES

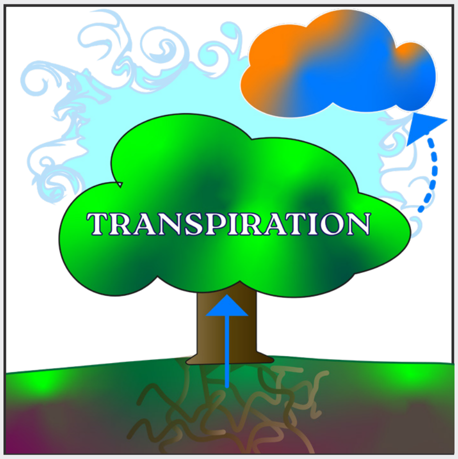
NORMAL: Send most water to Soil.
HOT: Keep the same split as Normal.
URBAN: Send most water to Pavement.

YOUR POWER: Land surface type changes everything downstream.

cut here

PLANT TEAM

You are the Plants. You absorb water from the soil — and send some back up.



Plants pull water out of the ground and release it into the air.

WHAT YOU DO

1. Water molecules arrive from the Soil area.
2. Hold them here and count slowly to 5 (or the teacher's number).
3. After counting, send some water molecules back to the Cloud.
4. This is transpiration. You don't have to send all of them back, keep some.

ROUND RULES

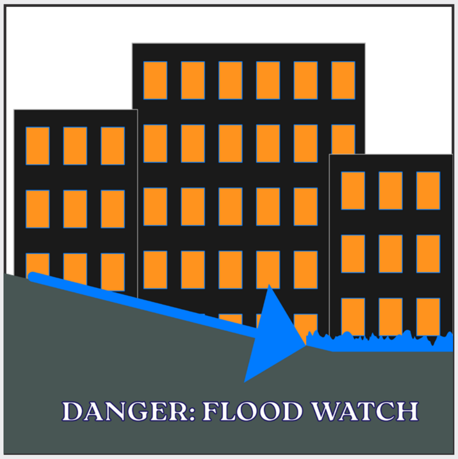
NORMAL: Send a portion of water back to Cloud.
HOT: Send more water back — heat increases transpiration.
URBAN: Fewer water molecules may arrive if Land sends most to Pavement.

YOUR POWER: Plants help keep the water cycle moving.

GRAVITY TEAM

You are pulling the water toward low places, places where the ground can't absorb it.

Runoff can create a flood in the city.



WHAT YOU DO

1. When Water Molecules arrive at the Pavement, send them down the hill to the Runoff Zone.
2. When over half of the Water Molecules are in the Runoff Zone, start whispering "Flood! Flood! Flood!" in as loud a whisper as you can. (Not yelling - still whispering!)

ROUND RULES

NORMAL: Few students should end up here.
HOT: Similar to Normal.
URBAN: The Runoff Zone fills up fast - what does that mean for the streets and buildings?

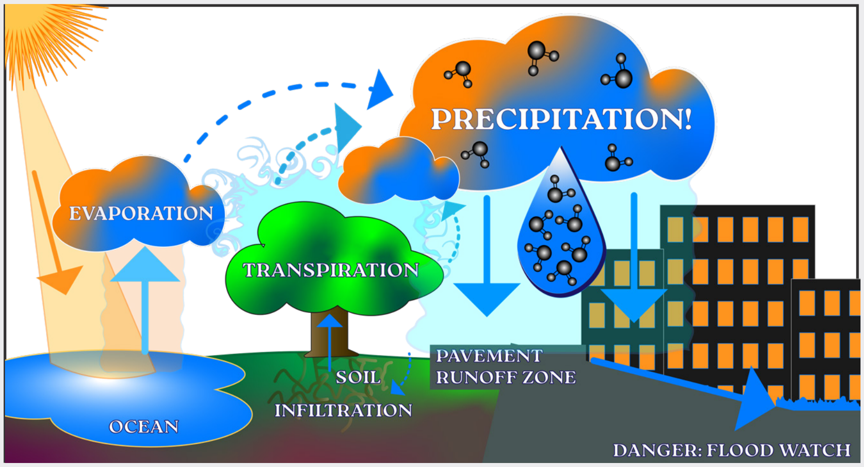
YOUR POWER: When this zone is full, it shows why stormwater management matters.

cut here

WATER MOLECULES

You are water. You move through the cycle — and record your journey.

A diagram showing the water cycle.



WHAT YOU DO

1. Start in the Ocean zone.
2. Only move when a Team student tells you to.
3. Sun gives you a token → go to Cloud and return the token.
4. Cloud says 'Precipitation!' → go to the Land Team.
5. If Land sends you to Soil → Plants will send you back to Cloud.
6. If Land sends you to Pavement → Gravity sends you to Runoff Zone. Stay in the Runoff Zone until the end of the round. Watch out for floods!
7. Record every station on your Journey Sheet.

ROUND RULES

NORMAL: Track your path through a healthy landscape.
HOT: More energy means you may cycle through faster.
URBAN: Watch where you end up. Runoff is likely!

YOUR POWER: No two water molecules take the same journey.

Water Cycle Relay – Teacher Support Sheet

PURPOSE

A live-action simulation. Students physically move through the water cycle and experience how land surfaces, temperature, and plants change stormwater outcomes.

CORE SCIENTIFIC IDEAS

Energy from the sun drives evaporation.
Clouds release precipitation when water accumulates to a threshold.
Soil and plants allow infiltration; pavement forces runoff.
Plants return water to the atmosphere through transpiration.

ENERGY TOKEN CLARIFICATION

Tokens represent solar energy for evaporation only.
Water molecule receives token → moves immediately to Cloud → Rain Team student returns token.
Tokens stay at Sun station. Water molecules never carry tokens beyond evaporation.

SPACE SETUP

Mark zones: Ocean · Sun · Cloud · Land (Soil + Pavement areas) · Runoff
Use cones or tape. Keep pathways open for safe movement. Walking only.

PRECIPITATION THRESHOLD

Choose a number before the simulation (5–7 students works well for most classes).
Cloud holds water until the threshold, then releases all at once: say 'Precipitation!'
Adjust threshold between rounds if the system feels too slow or too fast.

ROUNDS

Round 1 — Normal: Sun steady pace. Land sends most water to Soil.**
Round 2 — Hot: Sun distributes tokens faster. More evaporation.**
Round 3 — Urban: Land sends most water to Pavement. Watch Runoff Zone fill.**
Optional Round 4 — Extreme Storm: Lower cloud threshold temporarily.**

DISCUSSION PROMPTS

What changed between the Normal and Urban rounds?
Why did the Runoff Zone fill up? What does that represent in East Knoxville?
What would adding more Plant team members do to the system?
How does the GTSS on our campus change where water goes?

MANAGEMENT TIPS

Set start and freeze signals. Walking only, no running.
Rotate roles between rounds. Every student should experience movement and control.
Run simulation before data sheets. Embodied experience first, analysis second.

Water Cycle Relay

Grade 3 Printables

Water Cycle Relay | Grade 3 | Data Observation Sheet

Name: ______________________________ Date: __________________

Directions

You are a water molecule. Today you will move through the water cycle three times: Normal Round, Hot Round, and Urban Round. Record where you go each round, then compare.

Word Bank: Ocean · Cloud · Land · Soil · Pavement · Plant · Runoff

My Journey – Normal Round

Write each station you visit in order. Start with Ocean.

Count your visits:	Cloud	Soil	Pavement/Runoff

My Journey – Hot Round

Count your visits:	Cloud	Soil	Pavement/Runoff

My Journey – Urban Round

Count your visits:	Cloud	Soil	Pavement/Runoff

Name: ______________________________ Date: __________________

Class Round Totals

Your teacher will give the class totals. Write them in.

Station	Normal	Hot	Urban
Cloud			
Soil			
Pavement/Runoff			

Bar Graph – Runoff Across Rounds

Use the Runoff row above. Draw a bar for Normal, Hot, and Urban.

Reflection

Which round had you in the Cloud the most?

Which round sent you to Runoff the most?

How did the land change your journey?

Name: ______________________________ Date: ____________

BEFORE YOU READ

Think about what you saw in the Urban Round. Where did most of the water end up? Write one word to describe it.

VOCABULARY

evaporation *condensation* *precipitation* *runoff*

READING PASSAGE

How Water Moves

Water never really disappears.

When a puddle dries up after a sunny day, the water has not gone. It has **evaporated**, turned from liquid into water vapor and risen into the air. Energy from the sun is what makes this happen. Without solar energy, water would stay liquid and never rise.

As water vapor rises, it cools. When it cools enough, it **condenses**, water vapor turns back into tiny water droplets. Those droplets collect together into clouds.

When enough water collects in a cloud, it falls back to Earth as **precipitation**. In East Tennessee, that almost always means rain.

Now the water is back on the ground. Where it goes next depends on the surface it lands on. If it lands on grass or soil, it can infiltrate, soak down through the ground. Plant roots absorb some of it. Some of it moves deeper into the soil.

If it lands on pavement or a rooftop, it cannot soak in. It becomes **runoff**, flowing across the surface toward the lowest point it can find.

This is the water cycle: **evaporation**, **condensation**, **precipitation**, and back to the land. It runs continuously, all around us.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. What energy source drives the water cycle?

2. What is the difference between infiltration and runoff?

3. Describe what happens when rain lands on soil versus pavement.

4. How does what you observed in the simulation match what this passage describes?

Water Cycle Relay

Grade 4 Printables

Water Cycle Relay | Grade 4 | Data Observation Sheet

Name: ______________________________ Date: __________________

Directions

You will move through three rounds of the water cycle. After each round, record your data, then analyze patterns across all three.

Word Bank: Ocean · Cloud · Land · Soil · Pavement · Plant · Runoff · Transpiration · Infiltration

Round 1: Normal Conditions

Journey path (list every station in order, starting at Ocean):

Total stops	Cloud	Soil (infiltration)	Pavement/Runoff

Round 2: Hot Conditions

Total stops	Cloud	Soil (infiltration)	Pavement/Runoff

Round 3: Urban Conditions

Total stops	Cloud	Soil (infiltration)	Pavement/Runoff

Name: ______________________ Date: ______________

Pattern Analysis

What changed between Normal and Hot rounds?

What changed between Normal and Urban rounds?

Which round felt the fastest? Why?

Class Round Totals

Station	Normal	Hot	Urban
Cloud			
Soil			
Pavement/Runoff			

Bar Graph – Compare All Three Rounds

Draw a grouped bar graph showing all four stations across the three rounds. Use a key to label Normal, Hot, and Urban.

Name: ______________________________ Date: ____________

BEFORE YOU READ

In the relay, what was one thing the Plant team did that no other team could do? Why does that matter for the water cycle?

VOCABULARY

transpiration *runoff* *system* *energy*

READING PASSAGE

The System Behind the Storm

The water cycle is not a straight line. It is a system, a set of parts that interact, where each part's behavior affects the others.

Consider what plants do. Through transpiration, plants absorb water through their roots and release water vapor from their leaves into the atmosphere. This is not a small contribution: in a healthy forest, transpiration can return enormous amounts of water to the atmosphere, cycling it back into cloud formation. When you played the Plant team role and sent water molecules back to the Cloud, you were modeling that process.

Now consider what pavement does. Because pavement is impermeable, water that lands on it cannot infiltrate. As a result, it has only one destination: runoff. In the Urban Round, when the Land team directed most water to Pavement, the Runoff Zone filled up quickly. That outcome represents what actually happens in neighborhoods like East Knoxville during heavy rain, parking lots, streets, and rooftops shed water all at once because none of it can soak in.

The consequences are real. Fast-moving runoff picks up sediment and pollutants from surfaces. It rushes into First Creek faster than the creek can handle, raising water levels and, during heavy storms, causing flooding downstream.

Stormwater systems like the GTSS are a response to this problem. They restore some of the infiltration and transpiration functions that pavement removed. The gravel bed allows water to infiltrate near the tree. The tree returns some of that water to the atmosphere through transpiration. One system at one school is a small intervention, but it represents a way of thinking about land as something that should work with the water cycle, not against it.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. Why is the water cycle described as a system rather than a straight line?

2. What does transpiration contribute to the water cycle?

3. Because of pavement's properties, what happens to water that lands on it?

4. How does the GTSS restore functions that pavement removed?

Water Cycle Relay

Grade 5 Printables

Water Cycle Relay | Grade 5 | Data Observation Sheet

Name: ______________________________ Date: __________________

Directions

You will move through three rounds. For each round, track your full pathway and calculate percentages. Then compare the rounds as interacting Earth systems.

Word Bank: Ocean · Cloud · Land · Soil · Pavement · Plant · Runoff · Transpiration · Infiltration · Evaporation

Round 1: Normal Conditions

Journey path:

Total	Cloud	Soil	Pavement/Runoff

Percent in Cloud (Cloud ÷ Total × 100): ______%

Percent infiltrated (Soil ÷ Total × 100): ______%

Percent runoff (Runoff ÷ Total × 100): ______%

Round 2: Hot Conditions

Journey path:

Total	Cloud	Soil	Pavement/Runoff

Percent Cloud: ______%

Percent infiltrated: ______%

Percent runoff: ______%

Round 3: Urban Conditions

Journey path:

Total	Cloud	Soil	Pavement/Runoff

Percent Cloud: ______%

Percent infiltrated: ______%

Percent runoff: ______%

Name: ______________________________ Date: __________________

Systems Analysis

Which Earth system (atmosphere, hydrosphere, geosphere, biosphere) was most active in each round?

Round	Most Active Earth System	Evidence from your data
Normal		
Hot		
Urban		

Class Round Totals

Station	Normal	Hot	Urban	Totals
Cloud				
Soil				
Pavement/Runoff				
TOTALS				

Percent runoff per round (Runoff total ÷ round total × 100):
Normal: ______% Hot: ______% Urban: ______%

Graph – Percent Runoff by Round

Create a bar graph or pie chart comparing percent runoff across the three rounds.

Design Question

If you were redesigning the land surface to reduce runoff, what would you change? Support your answer with data from your journey.

Name: ______________________________ Date: ____________

BEFORE YOU READ

The simulation left some things out of the real water cycle. Name one thing you noticed was missing or simplified.

VOCABULARY

model *variable* *relationship* *watershed*

READING PASSAGE

What the Model Shows and What It Doesn't

Every **model** is a simplification. That is not a flaw, it is the point.

The Water Cycle Relay was a **model** of something real: energy drives evaporation, clouds release precipitation when they reach a threshold, and land surface type determines whether water infiltrates or runs off. In the Urban Round, the Runoff Zone filled up. That is the model working, it shows, in physical form, why surface permeability matters.

But a model is also defined by what it leaves out. The real water cycle involves solar radiation intensity varying by season and latitude. It involves soil chemistry affecting infiltration rates. It involves groundwater systems, storm intensity distributions, and the effect of plant canopy on how rain reaches the ground. None of that appeared in the simulation.

This is not a limitation to apologize for. It is a description of what **models** do: they isolate **variables** to make specific **relationships** visible. The simulation made one **relationship** clear, more pavement means more runoff, without being distracted by the dozens of other factors that also matter in real **watersheds**.

Environmental scientists and engineers work with **models** like this continuously. They build a simplified version of a **watershed**, run it under different conditions, and observe what changes. Then they compare the **model**'s predictions to real field data. When the **model** and the data disagree, that disagreement is informative, it reveals something the model is missing, which points toward what needs to be studied next.

The Gravel Tree Stormwater System on your campus was designed through this kind of iterative process. Engineers at the University of Tennessee built models to understand where runoff was going, designed interventions, observed the results in the field, and refined the system. The GTSS is not a guess. It is the outcome of a modeling and testing cycle, the same cycle you practiced in the simulation today.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. What did the simulation represent accurately?

2. What did it leave out, and why is that acceptable in a model?

3. How do scientists use disagreement between a model and real data?

4. What would you add to the simulation to better represent stormwater movement at your school?

Soil on the Move

Grade 3 Printables

Name: ______________________________ Date: __________________

Prediction

Which tray do you predict will have the MOST erosion?

Why?

Which tray do you predict will have the LEAST erosion?

Why?

Data Table

Surface condition	Distance soil traveled (cm)	Turbidity (circle: 1 · 2 · 3)	Erosion amount (circle)
Bare soil		1 · 2 · 3	A lot / Some / A little / None
Grass/vegetation		1 · 2 · 3	A lot / Some / A little / None
Gravel		1 · 2 · 3	A lot / Some / A little / None
Barrier added		1 · 2 · 3	A lot / Some / A little / None
GTSS model		1 · 2 · 3	A lot / Some / A little / None

Turbidity scale: 1 = clear   2 = a little cloudy   3 = very cloudy

Name: ______________________ Date: ______________

Bar Graph – Turbidity by Surface

Y-axis: turbidity rating (1–3). X-axis: five tray conditions. Draw a bar for each.

Which tray had the most erosion?

Which tray had the least erosion?

What pattern do you notice?

Written Response

In our experiment, bare soil had ____________ erosion. The surface that reduced erosion the most was:

I think this worked because:

In East Knoxville, this matters because:

Name: ______________________________ Date: ____________

BEFORE YOU READ

Look back at your runoff water sample from the bare soil tray. What did it look like? What do you think made it look that way?

VOCABULARY

erosion *sediment* *particles* *ground cover*

READING PASSAGE

When Water Carries the Land

After a heavy rain in East Tennessee, something happens to the creeks and rivers. They turn brown.

That brown color is not just muddy water. It is soil, real soil, carried from hillsides, construction sites, and bare patches of ground by the force of flowing water. The process is called **erosion**.

Erosion is not always a bad thing. Over thousands and millions of years, it is how rivers carve valleys and how landscapes take their shape. The hills around Knoxville exist because water has been moving rock and soil here for a very long time.

But **erosion** can become a problem when it happens too fast. When land is cleared for a new building or road, the plants and roots that held soil in place are removed. Bare soil has no protection. When rain hits it, water picks up **particles** of soil and carries them downhill.

The **particles** that water carries are called **sediment**. **Sediment** travels with the water until the water slows down. When water slows, it deposits the **sediment**, drops it, and it collects in creeks, drains, and low spots on the landscape.

What protects soil from erosion? **Ground cover** does. Grass, plants, mulch, and gravel all slow water down before it can pick up soil and carry it away. That is exactly what you tested today.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. What causes the brown color in creeks after a storm?

2. What is sediment and what happens to it when water slows down?

3. How does ground cover protect soil?

4. Which surface in your experiment had the most erosion, and why does this passage explain that result?

Soil on the Move

Grade 4 Printables

Name: ______________________________ Date: __________________

Hypothesis and Experimental Design

Write a hypothesis predicting which surface will have the most erosion and why:

Write a hypothesis predicting which surface will have the least erosion and why:

The variable we will keep the same:

The variable we are testing:

Data Table

Surface condition	Water (mL)	Distance (cm) [Measure to the nearest 1/2 cm]	Channel depth (mm)	Turbidity (1–4)	Notes
Bare soil					
Grass/veg					
Gravel					
Barrier					
GTSS model					

Turbidity rating scale: 1 = very clear, 2 = mostly clear, 3 = mostly cloudy, 4 = very cloudy

Line Plot

Draw a number line for Distance sediment traveled (cm), 0.0–30.0.
Mark an X for each tray condition. Use a different color for each tray condition.

Name: ______________________________ Date: __________________

Analysis

The condition with the most erosion was _______________. Evidence:

Because the surface was _______________, the water:

The condition with the least erosion was _______________. This worked because:

Human activity can increase erosion by:

Human activity can also reduce erosion by:

For example, in East Knoxville:

Engineering Challenge

The tray I chose to improve:

My design change:

My prediction for the improved design:

Name: ________________________________ Date: ____________

BEFORE YOU READ

On the bare soil tray, water picked up soil particles. What do you think happened to those particles when the water slowed down or stopped?

VOCABULARY

erosion *sediment* *deposition* *turbidity*

READING PASSAGE

How Water Shapes the Land

Erosion and **deposition** are two halves of the same process.

When water flows across a surface, it picks up **sediment** like soil particles, rock fragments, and organic material. How much it can carry depends on how fast it is moving. Fast-moving water transports large particles. Slow-moving water carries less. Water that stops moving **deposits** everything it was carrying.

The clearest example is what happens where rivers meet the ocean. A river carries **sediment** along its entire length. When it reaches the ocean and slows dramatically, it deposits that sediment. Over time, the deposits build up into a delta, a fan-shaped landform made entirely of material the river carried from upstream. This is **deposition** at a large scale.

In your experiment, the same relationship played out at tray scale. On bare soil, water accelerated downslope with nothing to slow it. Because velocity stayed high, the water maintained carrying capacity for sediment all the way to the bottom of the tray. The **turbid** runoff water you collected was evidence of that transport.

Where vegetation or gravel was present, the picture changed. Plant roots hold soil particles in place, reducing how easily they are dislodged. Stems and leaves intercept raindrops before they hit the soil, reducing the impact force that starts erosion in the first place. Gravel slows flow velocity and creates small zones where **deposition** occurs before water reaches the bottom.

Human activity often removes these protections. In Knox County, construction sites often strip vegetation from hillsides. First Creek and Lick Creek, which flow through East Knoxville toward the Tennessee River, receive the sediment that erodes from those sites. High **turbidity** in those creeks affects aquatic habitat, smothers stream beds, and signals that **erosion** is occurring upstream. Human activity can also reduce **erosion** through replanting, gravel cover, and engineered systems like the GTSS, which is exactly what your experiment demonstrated.

Name: ______________________ Date: __________

THINK IT THROUGH

1. What is the relationship between water velocity and how much sediment water can carry?

2. What is deposition, and what conditions cause it?

3. What two things does vegetation do to reduce erosion?

4. How does erosion from development in Knox County affect First Creek?

Soil on the Move

Grade 5 Printables

Name: ______________________ Date: ______________

Experimental Design

Research question:

Hypothesis:

Independent variable:

Controlled variables:

Measurement methods (circle all that apply): distance traveled / channel depth / turbidity rating / sediment mass after drying / other:

Data Table

Surface	Water (mL)	Flow time (s)	Distance (cm) [Measure to the nearest 1/2 cm]	Flow velocity (cm/s) = Distance (cm)/ Flow time (s)	Channel Depth (mm)	Turbidity (1–5)	Sediment load (light, medium, or heavy)
Bare soil							
Grass/veg							
Gravel							
Barrier							
GTSS model							

Turbidity rating scale: 1 = completely clear, 2 = mostly clear, 3 = mostly cloudy, 4 = very cloudy, 5 = completely cloudy

Name: ______________________ Date: _____________

Mechanistic Analysis

The surface with the highest erosion was ____________. In this condition, water velocity was likely (circle): FASTER / SLOWER, because:

Higher velocity increases carrying capacity, which means:

The surface with the lowest erosion was ____________. The physical mechanism that reduced erosion was:

Specifically, the ____________ reduced flow velocity by ____________, which reduced sediment transport because:

Engineering Challenge

Tray selected for redesign:

Current erosion rating:

Proposed modification:

Predicted mechanism of improvement:

Name: ______________________ Date: ______________

Data Collection

Run the experiment one more time using your modified design. Record your data here:

Data Table - Trial 2

Surface	Water (mL)	Flow time (s)	Distance (cm) [Measure to the nearest 1/2 cm]	Flow velocity (cm/s) = Distance (cm)/ Flow time (s)	Channel Depth (mm)	Turbidity (1–5)	Sediment load (light, medium, or heavy)
Modified Tray [list materials]:							

Did your modifications work like you expected? Explain what worked and what didn't.

Evidence-Based Argument

Using data from this experiment, construct an argument for the most effective erosion control method you tested. Your argument must: state a clear claim, include at least two measurements or observations as evidence, explain the physical mechanism (why it works at the particle or velocity level), and connect to a real-world application in East Knoxville.

Claim:

Evidence 1 (measurement or observation):

Evidence 2 (measurement or observation):

Mechanism:

Real-world connection:

Name: ______________________________ Date: ____________

BEFORE YOU READ

In the bare soil tray, did the channel that formed stay the same width and depth, or did it change as more water flowed through? What does that pattern suggest?

VOCABULARY

flow velocity *sediment transport* *carrying capacity* *erosion*

READING PASSAGE

Velocity, Sediment, and the Physics of Erosion

Erosion is a physics problem.

When water flows across a surface, it exerts a force on the soil particles beneath it. Whether a particle moves depends on a balance between the force the water applies and the resistance of the particle, its weight, shape, and how tightly it is held in place by surrounding particles, roots, or other material.

Flow velocity is the central variable. The relationship between velocity and **sediment transport** is not linear: small increases in velocity produce large increases in how much sediment water can carry. This is why a creek that runs clear most of the year can turn brown after a single heavy storm. The storm increases **flow velocity**, and that increase dramatically raises the stream's **carrying capacity** for sediment.

In your experiment, the bare soil tray represented the worst case: no root structure holding particles in place, no ground cover to slow water, no gravel to absorb energy. Water accelerated down the slope with nothing to interrupt it. Channel formation, the grooves you measured, is the visible signature of that process. Water found the path of least resistance and concentrated there, which increased local velocity, which deepened the channel further. This feedback loop is one reason erosion accelerates once it starts.

The vegetated tray broke that loop at several points. Roots physically anchored particles. Above-ground biomass intercepted incoming water, distributing its impact energy across leaf and stem surfaces before it reached the soil. This is known as canopy interception, and it is one of the primary mechanisms by which forests reduce **erosion** rates on hillslopes.

The GTSS model tray likely produced the lowest turbidity in your results. Gravel dissipates flow energy through friction and creates small zones where velocity drops and sediment deposits before it can be transported further. This is the same mechanism operating in the actual GTSS on your campus, not just infiltration management, but active energy dissipation that reduces the **erosive** force of incoming stormwater. Understanding that distinction matters: the GTSS is not just moving water, it is slowing it, and slowing water is what protects soil.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. Why does a small increase in flow velocity produce a large increase in sediment transport?

2. What is the feedback loop in channel formation and why does it cause erosion to accelerate?

3. What is canopy interception and how does it reduce erosion?

4. How does gravel in the GTSS reduce sediment transport, and why is that different from just allowing infiltration?

Investigating Our Stormwater System

Grade 3 Printables

Name: ______________________________ Date: __________________

Station 1 – Rainfall

Today's rainfall reading: _______________ inches

Circle: MORE / LESS / ABOUT THE SAME than last visit

Is this a rainy or dry season for East Tennessee? How might today's rainfall affect what we see at the other stations?

Station 2 – Water Level

Water level in the observation well today:

Circle: HIGH / MEDIUM / LOW

Does this match what the rain gauge showed? Circle: YES / NOT SURE / NO. What do you think this means?

Station 3 – Tree Growth

Tree circumference today: _______________ (inches or cm)

Previous measurement (if available):

The tree: circle: GREW / STAYED THE SAME / FIRST TIME MEASURING

One observation about the tree:

Name: ______________________ Date: _____________

Station 4 – Surface Comparison

Describe the GTSS surface:

Describe the nearby pavement:

Where did you see puddles or runoff?

Which surface absorbs more water? Circle: GTSS / PAVEMENT. Why?

Data Comparison and Bar Graph

Create two bar graphs, one showing today's rain gauge reading and one showing the observation well reading, side by side. Label each bar with its name and units. Give your graphs a title.

Measurement	Rain gauge reading	Observation well reading
Value		
Units		

Which bar is taller? Does that surprise you? Circle: YES / NO. Why or why not?

Name: ______________________________ Date: ____________

BEFORE YOU READ

At the GTSS, which surface (the gravel or the nearby pavement) had puddles on it after rain? What does that tell you about where the water went?

VOCABULARY

circumference *water level* *longitudinal data* *observation well*

READING PASSAGE

Reading a Living System

The stormwater system at your school is not a model. It is a real, working piece of infrastructure, and the data you collect from it is real data.

Every time you visit the GTSS, you are doing what scientists call **longitudinal data** collection: measuring the same things in the same place over time. That kind of data is powerful because it shows change. A single rain gauge reading tells you how much rain fell today. A year of rain gauge readings tells you what is normal, what is unusual, and whether patterns are shifting.

The **observation well** works the same way. The **water level** inside it rises after rain and drops between storms as water either evaporates, gets absorbed by the tree's roots, or moves deeper into the soil. When you measure it each visit, you are building a record of how the system responds to rainfall over time.

Tree **circumference** grows slowly. A single measurement around the trunk is just a starting point. If your class returns to measure it each semester for several years, you will have evidence of how much the tree has grown with the help of the stormwater system's water storage compared to trees planted in ordinary pavement cuts with no water source.

The comparison between the GTSS surface and nearby pavement is visible every time it rains. Pavement sheds water because it cannot absorb it. The gravel around the GTSS tree allows water to soak in rather than running off. That difference, seen clearly enough after a storm, is the point of the whole system.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. What is longitudinal data and why is it more useful than a single measurement?

2. What does a rising water level in the observation well tell you?

3. Why does tree circumference take a long time to show meaningful change?

4. In your own words, describe the difference between what happens to rain at the GTSS versus on nearby pavement.

Investigating Our Stormwater System

Grade 4 Printables

Name: ______________________________ Date: __________________

Station 1 – Rainfall

Today's rainfall: _______________ inches Previous reading: _______________ Difference: _______________

Is rainfall above or below typical for this season? Circle: ABOVE / BELOW / TYPICAL

How does today's rainfall amount affect what you expect to find at the water level station?

Station 2 – Water Level

Observation well water level today: _______________ Previous measurement: _______________
Change: _______________

Is this change consistent with the rainfall data? Explain:

If the water level is lower than expected given the rainfall, what might explain the difference?

Word Bank: evaporation · transpiration · deeper infiltration · overflow · dry soil absorbing quickly

Station 3 – Tree Growth

Tree circumference today: _______________ Previous: _______________ Growth since last visit: _______________

Name: ______________________________ Date: __________________

Station 4 – Surface Comparison

	GTSS surface	Nearby pavement
Surface material		
Visible water?	YES / NO	YES / NO
Puddles present?	YES / NO	YES / NO
Estimated infiltration	High / Med / Low	High / Med / Low
Notes		

The key difference between these two surfaces is:

Because of this difference, the GTSS:

Data Analysis and Writing

Using data from all four stations, explain how the GTSS manages stormwater. Use measurements from at least two stations as evidence and describe at least one cause-and-effect relationship.

Rainfall data showed:

Water level data showed:

These are connected because:

Name: ________________________________ Date: ____________

BEFORE YOU READ

If the observation well reading was lower than you expected given the rainfall, where else could that water have gone?

VOCABULARY

circumference   *infiltration rate*   *system performance*   *geosphere*

READING PASSAGE

What the Data Actually Shows

Measuring a system tells you what it is doing. Interpreting that data tells you whether it is doing what it is supposed to do.

When you compare today's rainfall reading to today's observation well reading, you are asking: how much of the rain that fell ended up stored in the system? If the well level rose significantly after a heavy rain, that is evidence the system is capturing and holding water. If it did not rise much, that water went somewhere else, deeper into the geosphere through natural infiltration, back into the atmosphere through evapotranspiration, or off as surface runoff the system did not capture.

System performance is not just one number. The GTSS was designed to do several things: reduce runoff from surrounding pavement, store water near the tree's root zone, and support tree growth over time. Evaluating whether it is working means looking at all three, not just the one that is easiest to measure.

The tree **circumference** data connects the water data to biology. The tree's growth depends on how much water is available in the soil around its roots. If the stormwater system is functioning, the tree should have more consistent access to water than a tree planted in ordinary compacted soil. Growth rate, measured over multiple visits, is the evidence for that.

The surface comparison at Station 4 adds a visual layer. Where do puddles form? Where does water soak in quickly? The answers tell you something about relative **infiltration rates**, even without precise measurement equipment. The **geosphere**, specifically the gravel and soil layers of the GTSS, is doing the work of separating what happens at these two surfaces.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. What does it mean to evaluate system performance rather than just measure it?

2. If the observation well level did not rise much after significant rainfall, what might explain that?

3. How does the tree's circumference data connect to the water level data?

4. What does the surface comparison at Station 4 tell you that the water level measurement alone cannot?

Investigating Our Stormwater System

Grade 5 Printables

Name: ______________________________ Date: __________________

Station 1 – Rainfall

Today's rainfall: _______________ Convert to metric: _______________ Previous visit: _______________

Difference: _______________

Total rainfall over last three visits (if available):

How does this compare to the average for this time of year in East Tennessee?

Station 2 – Water Level

Observation well reading today: _______________ Previous visit: _______________

Change: _______________

Estimate what percentage of this visit's rainfall the system appears to have retained:

(water level change ÷ rainfall amount) × 100 = _______%

This is an estimate, not an exact calculation, because the well and the rain gauge do not measure the same area.

Explain one reason the real percentage might differ:

What happened to the water not retained? (Consider: deeper infiltration, evapotranspiration, overflow.)

Station 3 – Tree Growth

Circumference today: _______________ Previous: _______________ Change: _______________

Name: ______________________ Date: ______________

Station 4 – Surface Comparison

Surface	**Material**	**Moisture level (1–5)**	**Water movement**	**Runoff risk**
GTSS			None / Slow / Fast	Low / Med / High
Pavement			None / Slow / Fast	Low / Med / High

The difference in infiltration between the two surfaces is evidence that:

Earth Systems Analysis

Using your data from all four stations, explain how at least three of the four Earth systems interact at the GTSS.

Earth system	**What specifically happens here**
Hydrosphere (water inputs and movement)	
Geosphere (soil, gravel, and their role)	
Biosphere (tree and root interactions)	
Atmosphere (evaporation and transpiration)	
Connection between systems	

System Evaluation and Improvement Proposal

Based on today's data, evaluate performance against the three design criteria: (1) reduce runoff, (2) support tree growth, (3) store water after rainfall.

Proposed improvement:

Name: ______________________________ Date: ____________

BEFORE YOU READ

A system can receive water and either store it, move it deeper, release it to the air, or shed it as runoff. Which of those pathways do you think the GTSS uses most, and how would you know?

VOCABULARY

hydrosphere *biosphere* *baseline measurement* *evapotranspiration*

READING PASSAGE

Earth Systems at Work in One Place

The GTSS is small enough to walk around in thirty seconds. It is also a place where four of Earth's major systems interact in ways you can measure.

The **hydrosphere** is the most visible: rainfall enters the system, water moves through the gravel into the soil, the observation well records what is stored, and transpiration from the tree releases water vapor back to the atmosphere. Each of those is a different phase of the same water moving through the same system.

The **geosphere**, the gravel and soil layers, determines how fast that water moves and where it ends up. Coarse gravel has high permeability: water moves through it quickly and little is retained near the surface. Finer soil below holds more water against gravity, keeping it available to roots. The layered structure of the GTSS is not accidental; it reflects deliberate decisions about how to slow water without stopping it.

The **biosphere** enters through the tree. Roots absorb water from the soil and release it through transpiration from leaves. This process, **evapotranspiration**, is one of the primary ways water leaves the system between rain events. A large, actively growing tree can move considerable amounts of water through this pathway. When you compare water level readings across visits, the drops between rain events are partly the tree doing its work.

The atmosphere connects all of this to larger cycles. Water that evaporates or transpires from the GTSS joins the atmosphere, eventually returning as precipitation somewhere else. The system is a small but real contributor to those larger flows.

Your **baseline measurement**, the first data point you recorded for any of these variables, is the reference against which everything else is compared. Without it, change is invisible. With it, you can begin to describe how this system behaves over time, which is the beginning of being able to evaluate whether it is doing what it was designed to do.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. Name the four Earth systems that interact at the GTSS and describe how each one is involved.

2. What is evapotranspiration and how does it affect the observation well reading between rain events?

3. Why does the layered structure of the GTSS matter for how water moves through it?

4. What makes a baseline measurement necessary, and what can you learn from it that a single current measurement cannot tell you?

Shape the Land, Watch the Water

Grade 3 Printables

Name: ______________________________ Date: __________________

My Watershed Map

Draw your group's watershed model. Label the high areas and low areas. Draw an arrow showing the direction you think water will travel.

Where do you predict water will collect?

First Rainfall Test

Where did water go first?

Where did water collect?

Did any soil move? Circle: YES / A LITTLE / NO

How far did water travel? _______________ cm

Class Bar Graph – Distance Water Traveled

Draw a bar for your group in the class graph. X-axis: groups A–F. Y-axis: distance (cm, scale set by teacher).

Name: ______________________________ Date: __________________

Change and Retest

Your group will change one thing about your model. Circle what you changed: added leaves / added gravel / changed the slope / added a barrier

Draw your model again. Circle or label the part you changed.

After our change, water traveled: _______________ cm

Compared to before, this was: Circle: MORE / LESS / ABOUT THE SAME

Writing Response

Water moved differently after we changed _______________ because:

Name: ____ Date: ________________

BEFORE YOU READ

In your watershed model, trace where a raindrop landing on the highest point would travel. What would stop it, or where would it end up?

VOCABULARY

watershed *landforms* *vegetation* *drainage*

READING PASSAGE

Where Does the Rain Go?

Water always moves downhill. It follows the land's shape, finds the lowest path available, and keeps going until something stops it or it soaks in.

A **watershed** is a piece of land where all the rain drains toward the same place. The hills and ridges around the edges act like the walls of a bowl, everything that falls inside those edges flows toward the middle and eventually toward a creek, river, or lake at the bottom.

East Knoxville has several **watersheds**. First Creek collects rain from the hills around it and carries that water south toward the Tennessee River. When it rains on Magnolia Avenue, in parking lots, or on the grassy hillside behind school, much of that water drains toward the creek. Most of the time it gets there without anyone noticing.

The **landforms**, or the hills, valleys, and flat stretches, tell water where to go. A steep hill sends water rushing fast. A flat valley slows it down and gives it a chance to soak in. **Vegetation**, the grasses and trees covering the land, slows water further and holds soil in place. Bare soil with no plants lets water move quickly and carry soil particles with it.

The **drainage** patterns you observed today follow the same rules that move water through First Creek's entire watershed every time it rains.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. What does the shape of the land have to do with where water goes?

2. What is a watershed, and what forms its edges?

3. How do steep hills and flat valleys affect water differently?

4. How does what you saw in your model connect to the way water moves through First Creek's watershed?

Shape the Land, Watch the Water

Grade 4 Printables

Name: ______________________________ Date: __________________

Pre-Investigation Observation and Prediction

Identify and describe:

Feature	**Description**
One high area	
One low area	
Area with more vegetation	
Area of bare soil	

Where do you predict water will move fastest, and why?

Baseline Test – Data Collection

Measurement	**Value - Trial 1**	**Units**
Amount of water poured		mL
Distance water traveled		cm
Amount of runoff collected		mL
Did soil visibly move?	YES / NO	

Describe where water moved fastest:

Describe where water slowed or soaked in:

Name: ______________________________ Date: __________________

Modification and Retest

Our group changed:

Why did we predict this change would affect runoff or water movement?

Measurement	Value - Trial 2	Units
Amount of water poured		mL
Distance water traveled		cm
Amount of runoff collected		mL
Did soil visibly move?	YES / NO	

Was there more or less runoff after the change? Circle: MORE / LESS / ABOUT THE SAME

Line Plot – Class Data

Work together as a class to create a line plot showing the distance water traveled for each group. Mark each value on the line plot with an X. Use one color/symbol for the first test and a different color/symbol for the second test. Include a legend.

What do you notice?

What does the spread of data tell you about how different watershed designs affected movement?

Was there any difference between most groups' first test and their retest? What does that tell you about the engineering "design-test-redesign" process?

Name: ______________________________ Date: __________________

Evidence-Based Argument

Write a claim about what your data showed. Then give one piece of evidence that supports your claim.

Claim:

Evidence:

Pick one place near school — the parking lot, the field, the sidewalk on Magnolia Avenue — and describe how rain would behave there differently than in your model. Use at least one vocabulary word.

Word Bank: watershed · landform · vegetation · drainage

Name: ______________________________ Date: ____________

BEFORE YOU READ

When you removed vegetation from your model watershed, what changed about the way water moved? Name one specific difference you observed.

VOCABULARY

watershed *landforms* *vegetation* *drainage*

READING PASSAGE

How Land Shape Determines Water's Path

Every watershed has a boundary, even if you cannot see it.

The boundary is defined by the highest surrounding ground, ridges and hilltops that separate one drainage basin from another. Rain that falls on one side of a ridge drains into one creek system. Rain that falls on the other side drains into a completely different one. The same raindrop could end up in First Creek or in Loves Creek depending on exactly where it lands.

Within a watershed, landforms sort water into predictable patterns. Steep slopes accelerate flow. Flat areas allow water to pool and infiltrate. Valleys concentrate water into channels. In East Knoxville, the terrain moves water toward the creek systems that thread through the neighborhood before all of it reaches the Tennessee River.

Vegetation changes those patterns significantly. Plant roots hold soil particles in place, reducing how easily they are dislodged when rain hits. Stems and leaves intercept water before it reaches the ground, absorbing some of the impact force that starts erosion. Where vegetation has been removed, construction sites, unpaved lots, bare hillsides, water accelerates, picks up soil, and carries it downstream.

Human activity reshapes watersheds. When a neighborhood is developed, roads and parking lots replace vegetation and open soil. Water moves faster. Runoff increases. The watershed boundary does not move, but how water behaves inside it changes considerably.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. What determines the boundary of a watershed?

2. How do steep slopes and flat areas affect water differently within the same watershed?

3. What does vegetation do to change water movement, and what happens when it is removed?

4. How does adding roads and parking lots change the way a watershed behaves during rainfall?

Shape the Land, Watch the Water

Grade 5 Printables

Name: ______________________ Date: ______________

Pre-Investigation Analysis and Sketch

Describe the slope:

Describe the vegetation cover:

Predict the path water will take.

In the sketch box, draw the watershed boundary, label the collection point, and mark at least two features you think will affect flow.

Baseline Test – Full Data Collection

Measurement	Value	Units / Notes
Amount of water used		mL
Distance water traveled		cm (to nearest 1/2 cm)
Depth of any channel formed		cm
Amount of runoff collected		mL
Time until flow visibly slows		seconds

Note any conditions that may have affected your reading:

Name: ______________________________ Date: __________________

Class Line Plot – Runoff Amounts

Number line: Runoff Collected (mL), 0–200 mL in increments of 10. Plot each group's runoff amount. Use 1/2 if a measurement falls between two values.

What is the range of the class data? _______________ to _______________ mL

What does the range tell you about how different watershed designs performed?

Modification and Retest

Our group changed:

Why did we predict this change would affect runoff?

After modification	Distance (cm)	Runoff (mL)	Change from baseline
Results			

Evidence-Based Argument

Claim:

Word Bank: watershed · landform · vegetation · drainage

Name: ______________________________ Date: ____________

BEFORE YOU READ

In an urban watershed with lots of pavement, what happens to water that would have infiltrated if the surface were soil or gravel? Where does it go instead, and how fast?

VOCABULARY

watershed   *channel*   *gradient*   *impervious*

READING PASSAGE

Watersheds, Gradients, and the Physics of Flow

A watershed is a system with inputs, pathways, and outputs, and the behavior of that system is governed by the physical properties of the land it drains.

The primary driver is gradient, the steepness of the slope. Water accelerates on steep terrain and slows on gentle terrain. Gradient determines flow velocity, and flow velocity determines almost everything downstream: how much sediment water can carry, how quickly it reaches streams, how much time it has to infiltrate before running off. A watershed with predominantly steep, impervious surfaces produces rapid, high-volume runoff after a storm. A watershed with gentle slopes and permeable soil moves the same rainfall much more slowly, with substantially more infiltration and less erosion.

Channels form where flow concentrates. In a natural watershed, channels are the result of water following paths of least resistance over time, gradually deepening them through erosion. In an urban watershed, channels also include engineered infrastructure (storm drains, culverts, curb cuts) that redirect water quickly toward an outlet. Efficient drainage reduces the time water spends on the landscape, which reduces infiltration and increases the volume delivered to streams during storm events. Speed, in this context, is not an advantage.

Impervious surfaces fundamentally alter watershed hydrology. When rain falls on concrete or asphalt, none of it infiltrates, all of it becomes runoff within seconds. The more impervious cover a watershed contains, the higher its runoff volume and the faster its storm response. East Knoxville's creek systems (First Creek, Loves Creek) respond quickly to rainfall and carry high sediment loads during storms, reflecting the substantial impervious cover in their drainage areas.

The GTSS introduces a permeable surface with high infiltration capacity into an otherwise impervious environment. By doing so, it locally reduces runoff volume, slows water, and recharges soil moisture. One parcel within the watershed begins to behave differently than the pavement surrounding it, and that difference is measurable.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. How does gradient affect flow velocity, and why does flow velocity matter for erosion and infiltration?

2. What is the difference between a natural channel and an engineered drainage channel, and what tradeoff does engineered drainage create?

3. How do impervious surfaces change how a watershed responds to rainfall?

4. How does the GTSS change the behavior of the land it occupies, and why does the passage say that difference is measurable?

Biofiltration Engineering Lab

Grade 3 Printables

Name: ______________________________ Date: __________________

My Filter Design

What do you think will happen to the water as it moves through the layers?

Draw your filter below. Label each layer with its material. Start at the top (where water goes in) and end at the bottom (where water comes out). Arrow on left edge indicates water flow direction downward.

I put _______________ at the top because:

Trial 1 – Observations and Timing

We poured _______________ cups of simulated stormwater into our filter.

How long did it take for water to start dripping out? _______________ seconds

Clarity of water coming out (circle): VERY MUDDY / A LITTLE MUDDY / PRETTY CLEAR

One thing I noticed:

Name: ________________________________ Date: ___________________

Class Bar Graph – Flow Times, Trial 1

X-axis: groups A–F. Y-axis: Time for Water to Exit (seconds) — scale set by teacher. Draw a bar for your group, then fill in other groups as teacher reads results.

Redesign – Trial 2

Our group changed:

We changed it because we thought it would make the water: Circle: CLEARER / COME THROUGH FASTER / BOTH

Trial 2 - Results

Time to exit (sec)	Clarity
	VERY MUDDY / A LITTLE MUDDY / PRETTY CLEAR

Was the water clearer than before? Circle: YES / ABOUT THE SAME / NO

Was the water faster or slower? Circle: FASTER / SLOWER / ABOUT THE SAME

Writing Response

The layer that helped clean the water most was ________________ because:

If we built the filter a third time, we would change ________________ because:

Name: ______________________________ Date: ____________

BEFORE YOU READ

In your filter, did the water come out cleaner at the bottom than it went in at the top? What do you think stopped the particles from passing through?

VOCABULARY

filtration *biofiltration* *turbidity* *flow rate*

READING PASSAGE

How Layers Clean Water

When rain runs off a parking lot or sidewalk, it picks up whatever is sitting on that surface, soil, bits of leaves, oil residue, grit. By the time it reaches a storm drain or a creek, it is carrying all of that with it.

One way to clean that water is to send it through layers of natural materials. Coarse gravel catches large particles first. Sand catches smaller ones. Soil and organic material, decomposed leaves and other plant matter, trap the finest particles and let helpful bacteria do some of the cleaning work too. This layered approach is called **biofiltration**, and it is the same idea behind the gravel and soil in the GTSS on our school campus.

The **turbidity** of water, how cloudy or murky it looks, goes down as it passes through each layer. Water that enters the top of a filter dark and muddy often comes out the bottom much clearer because the layers have trapped most of the particles along the way.

Dense, tightly packed layers do a better job of removing particles, but they also slow water down. Thin layers with larger pieces let water pass through at a higher **flow rate**, but miss some of the smaller particles. Every filter design involves that tradeoff between how clean the water gets and how fast it moves.

In East Tennessee, the soil is often red clay, which is very fine-grained and does not let water pass through easily. That is one reason engineers working on stormwater systems here use gravel rather than packed soil as the main **filtration** layer: it cleans water while still allowing it to move at a useful speed.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. What kinds of materials does stormwater pick up as it flows across hard surfaces?

2. How does each layer in a biofiltration filter help clean the water?

3. What is turbidity, and what happens to it as water moves through a filter?

4. What is the tradeoff every filter design involves?

Biofiltration Engineering Lab

Grade 4 Printables

Name: ________________________ Date: _______________

Design Sketch and Prediction

Sketch your filter design. Label each layer with its material and approximate depth in centimeters. Start from the top. Arrow indicates water flow downward.

Which layer do you predict will do the most to remove sediment, and why?

Trial 1 – Data Collection

Measurement - Trial 1	Value - Trial 1
Amount of simulated stormwater poured	___ mL
Time for first drops to exit filter	___ seconds
Volume of water collected	___ mL
Clarity rating (circle: 1–2–3–4–5)	1 very muddy · 2 · 3 · 4 · 5 clear

One observation about what happened inside the filter:

Line Plot – Class Flow Times, Trial 1

Number line: Time for First Drops to Exit Filter (seconds), 0–120 in increments of 10. Mark your group's flow time with an X.

Name: ______________________________ Date: __________________

Redesign and Trial 2 – Tradeoff Analysis

Variable our group changed:

Why we predicted this would improve our filter:

Measurement - Trial 2	**Value - Trial 2**
Amount of simulated stormwater poured	___ mL
Time for first drops to exit filter	___ seconds
Volume of water collected	___ mL
Clarity rating (circle: 1–2–3–4–5)	1 very muddy · 2 · 3 · 4 · 5 clear

In Trial 2, compared to Trial 1: flow was (circle) FASTER / SLOWER / ABOUT THE SAME, and water clarity was (circle) BETTER / WORSE / ABOUT THE SAME

Did changing one thing improve both measures, or did improving one make the other worse? Describe what your data shows:

Evidence-Based Argument

Claim:

Evidence (at least one measurement):

Name: ______________________________ Date: ____________

BEFORE YOU READ

Your filter had a tradeoff between cleaner water and faster flow. In your own design, which did you end up prioritizing?

VOCABULARY

layering *filtration* *porosity* *flow rate*

READING PASSAGE

The Engineering Problem in a Bottle

When engineers design a stormwater filtration system, they are solving two problems at the same time. The solutions to those problems pull in opposite directions.

The first problem is quality: the water leaving the system should be as free of sediment and pollutants as possible. The second problem is **flow rate**: the system needs to process water quickly enough to handle real storm volumes. A filter that produces clear water but takes an hour to process a small cup is not a workable design for managing runoff from a school parking lot during a rainstorm.

The physical reason for the tradeoff is **porosity**. Materials with small pore spaces, fine sand, packed soil, clay, trap particles effectively because there are many surfaces for particles to catch on and the spaces are too small for larger particles to pass through. But small pore spaces also slow water down significantly. Materials with large pore spaces, coarse gravel, wood chips, allow water to move quickly but let smaller particles pass through without being captured.

Layering is the engineering solution. By stacking materials from coarse to fine, a filter captures a wide range of particle sizes across multiple stages. Coarse gravel near the top intercepts large debris and prevents it from clogging finer layers below. Sand in the middle traps medium particles. Organic material at the bottom provides surface area for fine particles to bind to and supports microbial activity that breaks down some dissolved pollutants.

The GTSS on our campus uses this same principle. Its primary medium is gravel, which maintains a high **flow rate** even during heavy rain. It does not filter as finely as a layered sand-and-soil column would, but it manages stormwater volume effectively while still providing meaningful **filtration**. Engineers chose that design based on the specific conditions of a Knoxville schoolyard, where handling high runoff volume during storms matters more than achieving maximum clarity.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. What two problems does a stormwater filter need to solve, and why do the solutions create a tradeoff?

2. What physical property of a material determines how well it traps particles and how fast water moves through it?

3. How does layering materials from coarse to fine address the tradeoff problem?

4. What design decision did engineers make for the GTSS, and what does that tell you about its intended purpose?

Biofiltration Engineering Lab

Grade 5 Printables

Name: ________________________________ Date: ____________________

Design Documentation

List each layer of your filter from top to bottom. For each layer, record the material, depth, and what you expect it to physically do — not just 'clean it,' but specifically what particles it should trap and why its position makes sense.

Layer	Material	Depth (cm)	What this layer does physically and why it is placed here
1			
2			
3			
4			
5			

Sketch the design to scale with labeled dimensions.

Define Your Success Criteria

What counts as 'clean enough' for your design?

What counts as 'fast enough' for your design?

Name: ______________________________ Date: __________________

Trial 1 & 2 – Full Data Collection

Measurement	Trial 1	Trial 2 (after redesign)
Amount of stormwater poured (mL)		
Time for first drops to exit (sec)		
Volume of water collected (mL)		
Recovery % (collected ÷ poured × 100)		
Turbidity rating (1–5)		
Clarity: meets criteria? YES / PARTLY / NO		
Speed: meets criteria? YES / PARTLY / NO		

Redesign and Trial 2

Variable changed for Trial 2:

Reasoning:

Did the change improve overall performance or create a new tradeoff? Use specific numbers:

Name: ______________________________ Date: __________________

Written Analysis

Using data from both trials, evaluate your filter design. Address whether it met the goal of producing cleaner water, whether the flow rate was reasonable, what your data specifically shows about the tradeoff between filtration quality and flow speed, and what you would change in a third trial.

Based on the results of the gravel material test and what you already know about gravel from previous activities, what does gravel do well as a filtration material, and what does it allow through that a finer material might catch? Use specific measurements, not general claims.

Name: ______________________________ Date: ____________

BEFORE YOU READ

Your gravel layer let water through quickly. What is one type of particle or pollutant you think it probably did not catch, and why?

VOCABULARY

biofiltration *permeability* *organic matter* *flow rate*

READING PASSAGE

Filtration, Permeability, and the Limits of Natural Systems

A **biofiltration** system is not a perfect filter. It is a set of engineered tradeoffs, and understanding what it removes, what it misses, and why requires knowing something about the materials it uses.

The key variable is **permeability**, which describes how easily a fluid moves through a material. **Permeability** depends on pore size, pore shape, and whether the pores are connected well enough to form continuous pathways for water. A highly permeable material like coarse gravel moves water quickly but provides limited contact time between the water and the filter medium. Contact time matters because most filtration mechanisms, particle interception, adsorption, microbial degradation, require the water to spend time close to the filtering material. High **permeability** trades away that contact time in exchange for a higher **flow rate**.

Organic matter shifts this calculation in useful ways. Decomposed plant material has irregular surfaces that dramatically increase the total area available for particles to attach to. It also hosts microbial communities that metabolize some dissolved pollutants that purely physical filtration cannot remove. Adding organic matter to a filter typically improves clarity at the cost of some permeability, the same fundamental tradeoff expressed in different materials.

The limits of biofiltration are worth understanding clearly. Natural filtration systems remove suspended sediment effectively and handle some dissolved pollutants through adsorption and microbial activity. They do not reliably remove dissolved heavy metals above certain concentrations, synthetic chemicals that microbes cannot break down, or very fine colloidal particles that stay suspended indefinitely. For stormwater from a school campus, those gaps matter less, because sediment and nutrient runoff are the primary concerns, and biofiltration handles both reasonably well.

The GTSS is designed for that context. Its gravel layer manages high **flow rates** during storm events, reduces sediment load, and routes water to tree root zones rather than sending it to a storm drain. Whether its gravel layer is sufficient to meet the school's stormwater goals, or whether additional filtration materials would improve performance, is exactly the kind of question your experimental data can begin to answer.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. What is permeability, and how does it affect the tradeoff between filtration quality and flow rate?

2. What does organic matter contribute to a biofiltration system that gravel alone cannot provide?

3. What types of pollutants does biofiltration handle well, and where are its limits?

4. Based on your experimental data and this passage, what would you add to the GTSS design to improve its filtration performance, and what tradeoff would that change introduce?

Flood Prevention Engineering

Grade 3 Printables

Name: ______________________________ Date: __________________

Our Design Challenge

When it rains hard at school, water runs off the land near the building instead of soaking into the ground where plants grow. Your job is to design a system that helps water soak in and protects the plant area.

Our design needs to do these three things: reach the plant zone, hold/retain water, and slow the flow of runoff.
Circle YES when your design does each one:

Criterion	After Trial 1	After Trial 2
Water reaches the plant zone	YES / NOT YET	YES / NOT YET
Runoff cup stays below the marked line	YES / NOT YET	YES / NOT YET
Water leaves more slowly than bare soil	YES / NOT YET	YES / NOT YET

Control Test – Bare Soil

Time for water to first reach the runoff cup: _______________ seconds

Did the water go above the marked line? Circle: YES / NO

Draw the plant zone and the building. Trace the path the water took with an arrow. Circle the plant zone and write YES if water reached it or NO if it did not.

Name: ______________________________ Date: __________________

Design Sketch

Draw your system in the tray below. Label each material and where you will put it.

I chose to put _______________ near the building because:

Trial 1 – Test Results

Time for water to first reach the halfway mark on the runoff cup: _______________ seconds

Circle: Did the water go above the marked line? YES / NO

Did water reach the plant zone? YES / NO

Compared to bare soil, water moved: Circle: FASTER / SLOWER / ABOUT THE SAME

Bar graph – draw a bar for Control and a bar for Our Design. Y-axis: Time for Water to Reach Runoff Cup (seconds). Scale set by teacher.

Name: ________________________________ Date: ___________________

Improve and Retest

Our group decided to change:

We changed it because:

Trial 2 – Test Results

Time for water to first reach the halfway mark on the runoff cup: _______________ seconds

Circle: Did the water go above the marked line? YES / NO Did water reach the plant zone? YES / NO

Did our design meet all three criteria after the change? YES / NOT YET

Compared to the first trial, water moved: Circle: FASTER / SLOWER / ABOUT THE SAME

What would we try next if we had more time?

Name: ______________________________ Date: ____________

BEFORE YOU READ

In your control test (before you added anything), where did the water go first? Did it reach the plant zone?

VOCABULARY

criteria *constraint* *infiltration* *retention*

READING PASSAGE

Designing for Rain

Engineers who work on stormwater problems usually start the same way: they figure out what the solution needs to do before they build anything.

That list of things the solution must do is called the criteria. For a school stormwater system, the criteria might include: water must reach the plants, the ground near the building must stay dry, and runoff must leave more slowly than it does now. Until a design meets all of those conditions, it is not finished.

Engineers also have to work within constraints. A constraint is a limit on money, space, or materials. A design that works perfectly but costs ten times the budget is not actually a solution. Finding something that meets the criteria and fits within the constraints is the real challenge.

Before building anything, engineers test what happens with nothing in place, bare soil, no design at all. That test is called the control. It gives them something to compare to. If their design reduces runoff compared to bare soil, that comparison is their evidence that it worked.

The stormwater system at our school went through this same kind of process. Engineers decided what it needed to do, figured out what materials and space were available, and built something they could test and measure. The gravel, the tree, the placement near the parking lot, each of those reflects a decision made against specific criteria and within specific constraints.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. What is the difference between criteria and constraints?

2. Why do engineers test bare soil before testing their design?

3. What makes a design a real solution rather than just a good idea?

4. What do you think one criterion for the GTSS might have been when engineers first designed it?

Flood Prevention Engineering

Grade 4 Printables

Name: ______________________________ Date: __________________

Design Criteria and Constraints

Criteria	Constraints
(1) Water must reach the plant zone. (2) Runoff volume reduced by at least half vs. bare soil. (3) Water must exit more slowly than bare soil.	Limited material budget. Limited build space. Two test trials only.

Which criterion do you think will be hardest to meet, and why?

What material will do the most work in your design, and what will it do physically?

Control Test – Bare Soil Baseline

Measurement	Value
Amount of water poured	___ mL
Time for water to first reach runoff cup	___ seconds
Volume collected in runoff cup at end	___ mL
Did water reach the plant zone?	YES / NO

This is your baseline. All three criteria will be compared against these numbers.

Design Sketch and Material Budget

Did your design stay within the budget? Circle: YES / NO

Name: ______________________________ Date: __________________

Trial 1 Results and Criteria Check

Measurement	Value
Amount of water poured	___ mL
Time to first runoff	___ seconds
Volume in runoff cup	___ mL
Water reached plant zone?	YES / NO

Criterion	Status
(1) Water reached plant zone	MET / NOT MET
(2) Runoff volume at or below marked line	MET / NOT MET
(3) Water exited more slowly than bare soil	MET / NOT MET

Criteria met: _____ out of 3. Which criterion was hardest to meet, and what do you think caused that?

Line Plot — Class Runoff Volumes

Number line: Runoff Volume Collected — Trial 1 (mL), 0–250 mL in increments of 25. Mark your group's value with an X. Mark the bare soil control with a triangle.

Range of class data: _______________ to _______________ mL

Name: ______________________ Date: ______________

Improve and Compare – Trial 2

Variable your group changed for Trial 2: __________

Why you predicted this would improve performance:

Measurement	Value
Amount of water poured	___ mL
Time to first runoff	___ seconds
Volume in runoff cup	___ mL
Water reached plant zone?	YES / NO

Criterion	Status
(1) Water reached plant zone	MET / NOT MET
(2) Runoff volume at or below marked line	MET / NOT MET
(3) Water exited more slowly than bare soil	MET / NOT MET

Criteria met: _____ out of 3.

Data Interpretation

Did your improvement help? Describe the difference using specific numbers from both trials:

Did improving one measure make another harder to meet? Use one of the sentence frames below to describe what you found.

- When we changed [variable], the [runoff / flow time / plant zone result] got better, but the [other measure] got __________.
- Changing [variable] improved all three criteria because ____________.
- Despite changing [variable], none of the criteria improved. We think this happened because __________.

Name: ______________________________ Date: ____________

BEFORE YOU READ

Your design had a budget and a space limit. Name one thing you would have added or changed if those constraints did not exist.

VOCABULARY

criteria *constraint* *retention* *control*

READING PASSAGE

The Control, the Criteria, and the Tradeoff

Before a stormwater engineer builds anything, they run a test with nothing in place. Bare soil, no intervention, same amount of water as the real test. That is the **control**, and its purpose is simple: it gives you a number to beat.

Without a **control**, you cannot know whether your design actually helped. Maybe the runoff was low because you poured less water. Maybe it was fast because of the slope. The **control** holds everything constant except the design itself, so that when you compare results, the difference you see is caused by the design and nothing else.

Criteria tell you how much better is good enough. A stormwater design that improves **retention** of stormwater by two percent compared to bare soil technically improved things, but if the **criterion** is a fifty percent improvement of stormwater retained, that design did not meet the standard. **Criteria** set the bar in advance so that evaluation is about data, not about whether the team worked hard or the design looked impressive.

Constraints shape what you can actually build. A limited budget restricts which materials you can combine. A size restriction means the most effective design might not fit. Real stormwater engineers face the same pressures, the GTSS on our campus was built with a specific gravel type, a specific tree species, and a specific footprint, all determined by what was available, affordable, and permitted by the school site.

When a design meets some **criteria** but not others, that is not failure, it is information. The **retention** was good but the flow to the plant zone was too slow. The runoff volume was low but the cost was over budget. Each of those outcomes tells you exactly where to focus during the next iteration.

Name: ______________________________ Date: ____________

THINK IT THROUGH

1. What is a control test and why is it necessary before testing a design?

2. What is the difference between a design that improved something and a design that met the criteria?

3. How do constraints affect what an engineer can build?

4. What does it mean when a design meets some criteria but not all?

Flood Prevention Engineering

Grade 5 Printables

Name: ______________________________ Date: __________________

Problem Analysis and Criteria Development

During heavy rain, water runs off paved surfaces near the school building and overwhelms natural drainage, causing flooding and preventing water from reaching plant zones. Design a multi-component system that reduces runoff volume, increases infiltration, and routes water to plant areas.

In your own words, what is the core engineering problem this design needs to solve?

Criterion	Why it matters — what real problem does meeting this address?
Water must reach the plant zone	
Runoff volume must be reduced	
Water must exit more slowly than bare soil	

What constraint do you think will most limit your design options, and how will you work around it?

Control Test – Baseline Data

Describe where water went that did not become runoff:

Name: ______________________________ Date: __________________

Design Documentation

Describe your system design component by component. For each, record the material, placement in the tray, and the physical mechanism it uses to reduce runoff or increase infiltration.

Component	Placement	Physical mechanism

Trial 1 and Trial 2 Results

Measurement	Trial 1	Trial 2
Time to first runoff (sec)		
Runoff volume (mL)		
Runoff % (Runoff ÷ Poured × 100)		
Water reached plant zone?	YES / NO	YES / NO
Criteria met (out of 3)		

Variable changed for Trial 2:

Name: ______________________________ Date: __________________

Line plot: Class Runoff Percentages, Trial 1

Draw a number line labeled "Runoff as Percentage of Water Poured" from 0 to 100% in increments of 10.
Plot your group's percentage for Trial 1.
Round to the nearest 1/2 where values fall in-between increments.
Mark the bare soil control percentage with a triangle.
Work together with your class to compile all groups' data into a single line plot representing the whole class.

What is the median runoff percentage for designed systems? __________%

How does the class median compare to the bare soil control?

What design features appear in the systems with the lowest runoff percentages?

After Trial 2, add each group's Trial 2 data to the line plot in a different color than Trial 1 (or using a different symbol, like X's and O's). Add a legend to the line plot explaining the meaning of each color or symbol.

Evidence-Based Evaluation and Proposal

Describe the modification made for Trial 2, including the physical reasoning:

Did any tradeoffs emerge? Did meeting one criterion more fully make another harder to meet? Describe with specific data:

Write a recommendation. Based on your two trials, what design approach best meets all three criteria within the given constraints, and what would you test next if you had a third trial?

Name: ______________________________ Date: ____________

BEFORE YOU READ

Your design met some criteria and possibly not others. Which tradeoff (if any) showed up in your data between Trial 1 and Trial 2?

VOCABULARY

criteria *constraint* *infrastructure* *tradeoff*

READING PASSAGE

Iteration, Evidence, and the Engineering Record

An engineering design process does not end when you find something that works. It ends when you have enough evidence to explain what worked, what did not, and why, so that the next person building a similar system can start from where you left off rather than from scratch.

That record begins with the control test. Every number in the control, runoff volume, time to first exit, percentage of water retained, becomes a reference point. A design that reduces runoff by forty percent is only meaningful relative to the control. Without it, forty percent means nothing.

Criteria translate the problem into measurable targets. The design problem for this activity is real: stormwater running off hard surfaces near a school building is not infiltrating. It is pooling, and in some cases eroding the soil beneath structures, and it is not reaching plant zones where trees and vegetation could use it. The three criteria, water reaches plants, runoff volume is halved, runoff exits more slowly than bare soil, each correspond to a specific failure in the current system. Meeting all three means the design addresses the actual problem, not just one symptom of it.

Constraints are not the enemy of good design. They are the conditions under which good design happens. A solution that requires unlimited budget or unlimited space is not a generalizable solution. In clay-heavy soils like those common in East Knoxville, gravel generally outperforms layered sand and soil for long-term permeability, fine-grained layers tend to clog over time as clay particles work their way in. That constraint pushed the GTSS design toward a material that could handle the specific site conditions, not just the ideal case.

Name: ______________________________ Date: ____________

READING PASSAGE (continued)

When your design produced a tradeoff, when improving retention slowed flow to the plant zone, or when reducing runoff volume pushed you over budget, that tradeoff is the most useful thing in your data. It shows that the design space has a real tension in it, and that resolving one side of the problem puts pressure on the other. That is the information the next design iteration should start from.

THINK IT THROUGH

1. Why does an engineering record matter beyond the specific project it describes?

2. What does each of the three design criteria correspond to in terms of the real problem being solved?

3. How did site-specific constraints shape the GTSS design?

4. What makes a tradeoff useful information rather than just a failure to meet criteria?