



EARTHECHO WATER BY DESIGN

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THE ANATOMY OF AN AQUIFER



PRESENTED in PARTNERSHIP with **NORTHROP GRUMMAN**
Foundation



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This activity has been adapted from: *Hands-on Activity: Do as the Romans: Construct an Aqueduct!* © 2013 by Regents of the University of Colorado; original © 2004 Worcester Polytechnic Institute. Contributed by the Center for Engineering Educational Outreach, Tufts University. Accessed 2017, https://www.teachengineering.org/activities/view/construct_an_aqueduct

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EARTHECHO WATER BY DESIGN THE ANATOMY OF AN AQUIFER

INTRODUCTION

This design challenge is in support of launching your students from passive to active learners through a cross-curricular, hands-on team challenge in direct correlation to real world issues of water conservation. This lesson will allow students to understand the structure of aquifers and how they impact our freshwater supply. Your students will also understand groundwater in regards to the water cycle. The hands-on design challenge will have your students creating a model of an aquifer.

SUMMARY

1. Subject(s): Science, Technology, Engineering, and Math
2. Topic or Unit of Study: Water, Conservation, Engineering, Earth Science
3. Grade/Level: 6-8
4. Objective: As a result of these activities, students will be able to:
 - a) Understand the role of aquifers on our drinking water supply.
 - b) Explore and analyze how aquifers work in different areas.
 - c) Comprehend the effects of excessive pumping in the US and in other countries.
 - d) Identify the different types of rocks found in aquifers (sandstone, clay, shale, granite, etc.), recognize their water-bearing capacity and apply this knowledge to the creation of an aquifer model with an infrastructure design that promotes a more efficient recharging system.
 - e) Build a model of an aquifer that must demonstrate the following:
 - i. Confined, unconfined, and perched aquifers
 - ii. Recharge and discharge areas
 - iii. Interaction between groundwater, runoff, and streamflow, subsidence
 - f) Demonstrate permeability.
 - g) Explain the water cycle in groundwater discharge and recharge.



TEACHER BACKGROUND

Groundwater accounts for from about 30% of California's drinking water sources during regular periods to about 60% during a drought period. It is the largest source of usable water in the entire United States. While its importance is huge, groundwater is less appreciated as it is found beneath the earth and "invisible" to the public eye. Groundwater is stored in aquifers. Many people are not aware that water needs to be restored or recharged into the aquifers to keep it from getting polluted.

What is an aquifer?

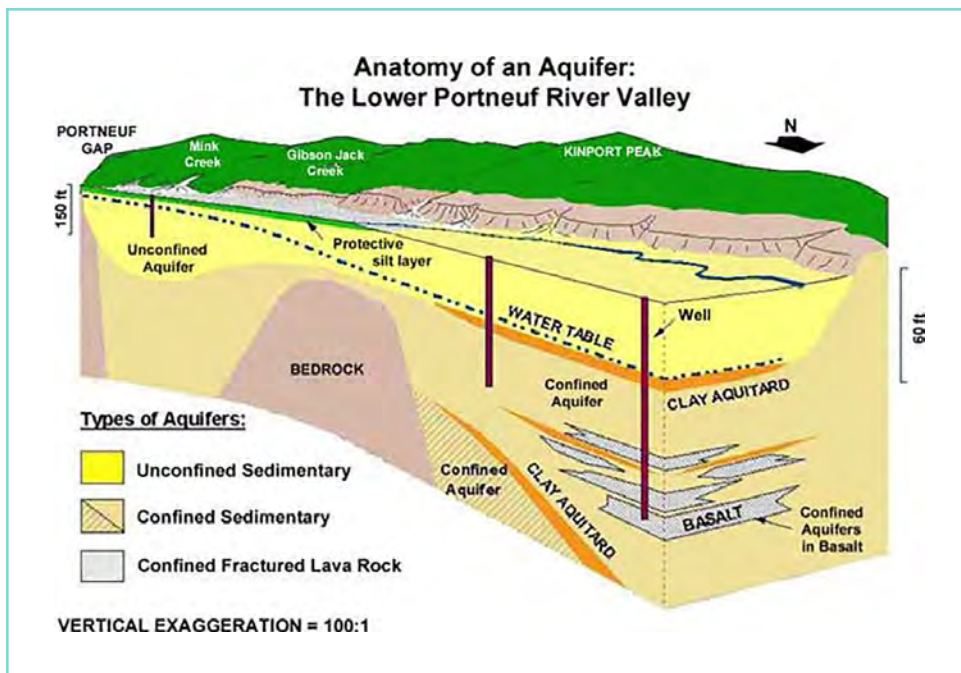
An aquifer is formed when spaces develop within rock fragments and soil particles that can become filled with water (storage) and through which water can easily move (transmission). Aquifers are both permeable and porous because they are made mostly of sandstone, conglomerate, fractured limestone, and unconsolidated sand and gravel. Fractured volcanic rocks such as columnar basalts also make good aquifers. The rubble zones between volcanic flows are generally both porous and permeable and make excellent aquifers. Rocks such as granite and schist are generally poor aquifers because they have a very low porosity.

Groundwater percolates or flows rapidly over large distances in aquifers whose pore spaces are large or where porosity arises from interconnected fractures. It would take more effort to force water through tiny pores, so larger pore spaces tend to have higher permeability, produce less energy loss, and allow water to move more rapidly. However, a downside of this is that the rate of the spread of contaminants can be difficult or impossible to prevent. On average, the porosity and permeability of rocks decreases as their depth below land surface increases; the pores and cracks in rocks at great depths are closed or greatly reduced in size because of the weight of overlying rocks.

What does an aquifer look like?

Confined aquifers are formed when porous rock layers become tilted in the earth. A confining layer of less porous rock both above and below the porous layer is formed. Wells drilled into this type of aquifer are pushed up to the surface without the aid of a pump as pressure gets confined in the porous rock and its water. This type of well is called artesian.





The diagram above represents a cut-away perspective view of a system of multiple aquifers and is greatly exaggerated in its vertical scale to show some of the details. Several different aquifers occur in this valley. In the northern valley, multiple confined aquifers are stacked on top of one another and separated by aquitards made of clay. In the southern valley, the upper surface of the unconfined aquifer is the water table.

How does an aquifer work?

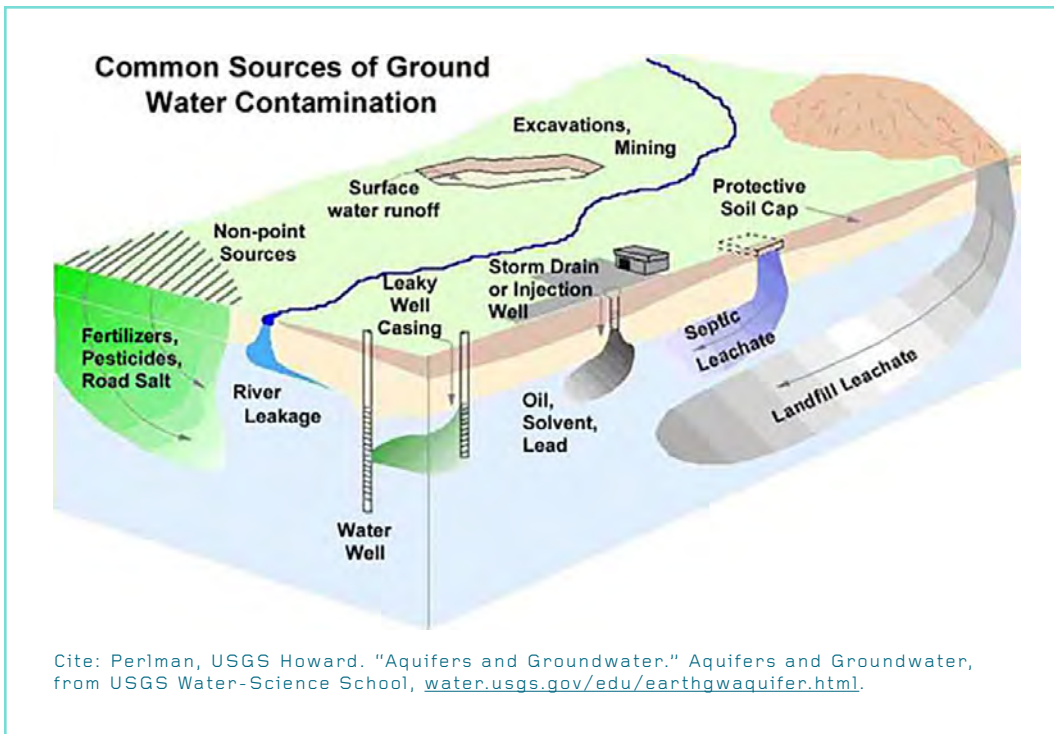
An aquifer is filled with moving water, and the amount of water stored in the aquifer can vary from season to season and year to year. Groundwater may flow through an aquifer at a rate as large as 50 feet per year or as small as 50 inches per century, depending on the permeability. But no matter how fast or slow, water will eventually discharge or leave an aquifer, and must be replaced by new water to replenish or recharge the aquifer. Thus, every aquifer has a recharge zone or zones and a discharge zone or zones.

Aquifers that allow water to move relatively freely through them can move groundwater significant distances in a number of days. They also allow groundwater to sink so deeply that it can take thousands of years to move back to the surface, or even go into deep storage where it might stay for much longer periods.

How is an aquifer contaminated?

As shown in the diagram below, an aquifer can become contaminated by many things we do at and near the surface of the earth. Contaminants reach the water table by any natural or manmade pathway along which water can flow from the surface to the aquifer.





To deal with the issue of contaminants, [Change the Course](#), a first-of-its-kind national water initiative, has started projects to help reduce groundwater pumping rates or replenish groundwater tables by facilitating natural recharge. The Change the Course movement is creating partnerships with farmers and irrigators to install new technology to more precisely manage water applications or to provide infrastructure that allows natural flows to refill depleted groundwater tables.

VOCABULARY:

Aquifer - Underground layer of water-bearing permeable rock

Aquitard - Zone that restricts groundwater flow from one aquifer to another

Water table - Zone of saturation - area in which soil or sand are permanently saturated with water

Bedrock - Solid, unweathered rock deep below the ground surface

Unconfined aquifer - Water from the ground surface seeps directly into this type of aquifer

Confined aquifer - Deeper in the ground than unconfined aquifer; has a layer of rock that blocks ground surface water from seeping in

Perched aquifer - A small water body above the water table which lies in an unsaturated zone

Recharge zones - Area around an aquifer which is replenished by precipitation or surface water

Discharge zones - Area where groundwater flows to the land surface

Runoff - Flow of water from excess stormwater or meltwater

Streamflow - Volume of water that moves through a specific point in a given timeframe



5E LESSON PLAN

Task:

In this design challenge, students will work with specified materials to create a model of an aquifer. Then, the students will engage in a design project that will challenge them to engineer the most efficient and practical way to recharge groundwater.

Estimated Timeline:

1. Multiple sessions (5 days)
2. 250 minutes (50 minutes/session)

Before the Activity

- Prepare materials
- Make copies of the challenge write-up and rubric.
- Prepare the videos

Engage

1. Ask students if they have ever dug a hole in the sand at the beach. What happens as they dig deeper into the sand? Does the sand get wetter as they dig deeper? Does the hole start to fill up with water?
2. Have students do a Think-Pair-Share for the following prompt: Last year California had a wet winter, yet this winter the state is rapidly approaching drought status again. Where did all the water go?
3. Watch the video [Recharging Aquifers](#). Students should take guided notes. Use the following questions to begin a discussion to assess student understanding:
 1. What is an aquifer? What are they composed of, and why are they important to us?
 2. How does the amount of water in aquifers compare to the amount of water in lakes and other surface reservoirs?
 3. How long can it take for water to seep down into aquifers ('recharge')? Why is this a concern?
 4. How can we measure groundwater levels using technology?
 5. What impacts could overpumping groundwater have on people, ecosystems, and the environment?
 6. What are some potential solutions to the issue of groundwater depletion?
4. Point out that, luckily, aquifers store a large amount of water that we may not see, but definitely drink during drought years. All the snow and rain from last year drained into the ground. As snow melts, water moves downward, through the top layers of an aquifer, which is a natural storage tank for groundwater. What if we could access this water when there is not a lot of rainfall?



5. Remind students how digging a hole at the beach is a great way of illustrating the concept of how at a certain depth, the ground is saturated with water. The upper surface of this zone of saturation is called the water table and the zone beneath it is the aquifer. At the beach, the level of the water table is always at the same level as the ocean, which is just below the surface of the beach, while everywhere else we have to dig deeper.
6. Introduce the idea of drilling wells. “Wells drilled into aquifers provide water for drinking, agriculture, and industrial uses. However, aquifers can dry up when people drain them faster than nature can refill them.” (<https://www.nationalgeographic.org/encyclopedia/aquifer/>)
7. Student activity: Visualizing artesian pressure
 1. Fill a plastic sandwich bag with water
 2. Place a straw through the opening,
 3. Tape the opening around the straw closed, DO NOT point the straw toward anyone
 4. Squeeze the baggie. Artesian water is pushed out through the straw.
8. Distribute one blank poster board to each group. Students will use this paper to create an engineering storyboard. An engineering storyboard is a record of how an engineering design team researches, explores, tests, and improves designs they make to solve problems. The theme for this storyboard is How to Conserve Clean Water in an Aquifer System. Have groups develop a team name and write it at the top of their storyboard. Explain that each time students learn a new concept, do an experiment, create a design, or test a design, it should be recorded on the storyboard for teachers and students to see and comment on. Students should take a few minutes to record any notes or other information about aquifers that they think is important.
9. Introduce the idea that if we can pull water out of the ground, other things can get into the drinking supply by showing the video clip: [Groundwater Aquifer Contamination](#)

That’s where organizations like the West Basin Water District come in. The West Basin Water District saw the problem with diminishing fresh water sources and is working to create a solution. The Hydro Engineers and Environmentalists with West Basin Water District are not waiting around for the next rainfall or snowstorm to refill the aquifers, they are exploring desalination as a source of drinkable water which can recharge the aquifers. Desalination plants such as West Basin Water District are actively looking for ways to convert current sources of salt water, which is the largest source of all water on our planet, to fresh water by removing salt. These innovative ideas will help us conserve our freshwater supply.



Explore

1. Assign 3-4 students to each team and give them Student Handout.
2. Describe the challenge to the class and show them the materials they will use.
3. Clarify the project requirements and expectations.

Materials:

I. Aquifer Model (building supplies should be upcycled materials whenever possible)

- Fish tank (25 gallons, 24" x 12" x 20")
- Soil
- Rocks, gravel, sand, pebbles
- Clay
- Liquid soap pumps/spray bottle
- Straws, rubber tubing, glass tubing
- Food coloring
- Water in measuring cups or cylinders
- 30cc syringes

Explain

- Have student teams prepare a short presentation explaining how they approached their aquifer model and their recharging system design.

Elaborate

- After completion of the challenge, modify the course to make it a little harder. Ask students to suggest some of the problems a community might face if the re-charging system is not efficient and the system has numerous artesian wells. Also, think about how aquifers may become contaminated and identify different sources of contamination.
- Have students draw a 3D picture of their model - sketch on graph paper or create in software such as SketchUp.
- Have students write an essay on adjustments they would make to their model if money was not limited. What kind of high quality materials would they use and why? What would be the benefit?

Differentiation

- Partner struggling students with higher scoring students.
- For EL - partner lower-level English Speaking students with students who only speak English, to encourage conversation in English.
- Provide models of what a successfully completed project looks like.
- Provide an altered lesson with sentence stems, thinking maps, etc.



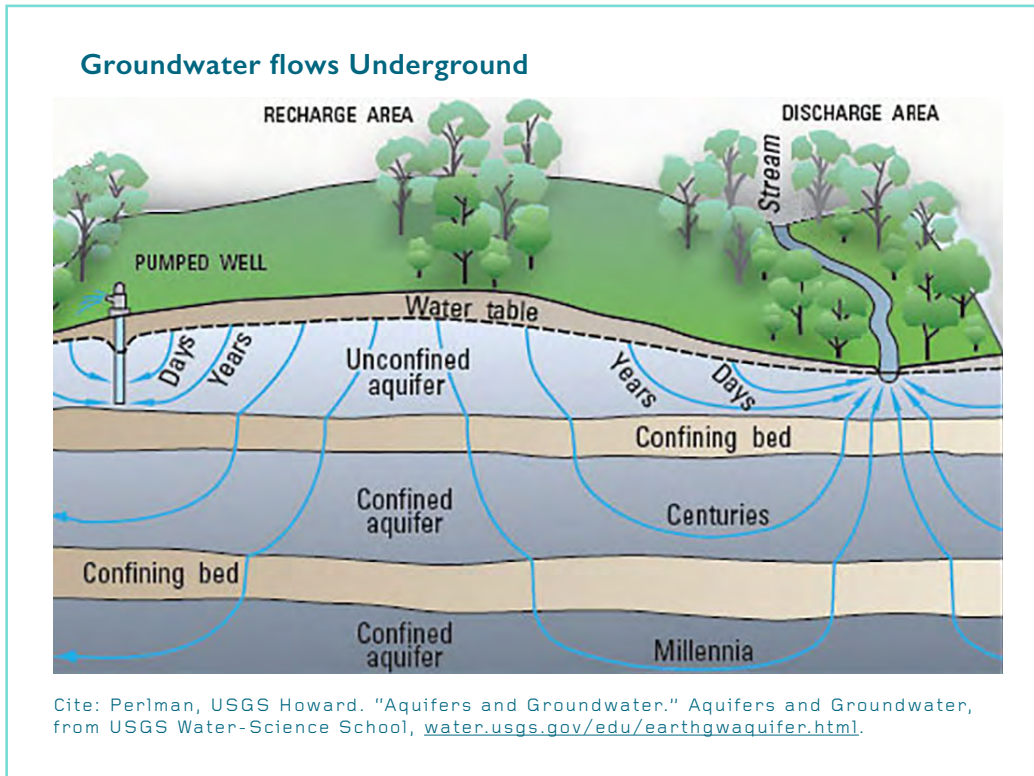
Evaluate

- Have students reflect on what they learned while completing this project. They should consider the engineering process and how this idea could be applied in the real world.
- Use the Aquifer Model Design Assessment Rubric to assess student work on the engineering project. Criteria include testing of knowledge and concepts, design and construction of the re-charging system, and operation of the system



THE ANATOMY OF AQUIFERS

Name _____ Period _____ Date _____

**Challenge Task:**

Using the provided materials, build a model of an aquifer that must demonstrate the following:

- Confined, unconfined, and perched aquifers
- Recharge and discharge areas
- Interaction between groundwater; runoff, and streamflow, subsidence



Materials:

These materials have corresponding cost. Use the materials that you need for your aquifer model, but keep in mind that you have an initial budget of “\$100” to spend. You can earn additional money with every written summary about a recommended resource you turn in. Each summary is worth \$20.

- Fish tank (25 gallons, 24" x 12" x 20") - \$20
- Soil, \$2/kg
- Rocks, gravel, sand, pebbles, \$2/kg
- Clay \$2/kg
- Liquid soap pumps/spray bottle \$1 each
- Straws, rubber tubing, glass tubing \$1 each
- Food coloring \$1 each
- Water in measuring cups or cylinders (\$5/liter)
- 30cc syringes \$1 each

Procedures:

1. After thoroughly studying the anatomy of an aquifer, decide on different materials you can use to create a model of an aquifer. Show the different aquifer types and the recharge and discharge systems. Your team should be able to demonstrate the many elements of aquifers that exist in nature.
2. The aquifer model must demonstrate two main functions of aquifers: storage and transmission of water. Not only must your model show evidence of water storage, but it also must show water percolating through the system you are designing and building.
3. During the demonstration your team must recharge water into a pre-identified recharge area in two minutes. You may add as much water as you can without causing a runoff. You must demonstrate the most efficient way of recharging an aquifer, including collecting precipitation or recycled water (infiltration), introducing it into the system (recharging), preventing runoff and contamination.
4. Measure both the amount of water you poured, or recharged, into your aquifer, as well as the distance the water percolated, or flowed along, as evident in the presence of water in your interconnected aquifer.



Review and Reflection Questions

1. Where does the water in an aquifer come from?
2. How does an aquifer work?
3. Why are aquifers important to us?
4. Explain the human impact on aquifers - both negative and positive.
5. Determine three or more factors which would cause one aquifer to dry out quicker than another.
6. What additional suggestions would you give an agency, such as West Basin Water District, to aid in recharging aquifers?



ASSESSMENTS

AQUIFER MODEL DESIGN ASSESSMENT RUBRIC

The Anatomy of Aquifers

Points

<p>Identifying the problem(s) and brainstorming solutions</p>	<p>30 Showed a clear understanding of the problem(s) to solve. Independently brainstormed solutions.</p>	<p>20 Needed some teacher direction to define the problem(s) and brainstorm possible solutions.</p>	<p>10 Needed lots of teacher direction to define the problem(s). Little if any independent brainstorming.</p>	
<p>Working as a team member</p>	<p>25 Worked well together. All team members participated and stayed on task. Most of the members wrote a summary to get more spending money.</p>	<p>15 Some team members were occasionally off task. Only a couple of the members wrote a summary to get more spending money.</p>	<p>10 Most team members were often off task and not cooperating or participating fully. Only one or none wrote a summary to get more spending money.</p>	
<p>Using the design process</p>	<p>25 Team brainstormed main design ideas, tested and improved the design. Final design is a complete or nearly complete aquifer system and shows creative problem solving.</p>	<p>15 Team brainstormed design ideas and tested the design. Final design showed only some elements of an aquifer system and/or did not include improvements.</p>	<p>10 Team brainstormed few design ideas and did little testing or redesigning. Final design lacks clear design idea(s).</p>	
<p>Processing the science and engineering</p>	<p>20 Team gave a strong presentation of the solution to the challenge and showed clear understanding of the science concepts and design process. Team gave a thoughtful response to the Elaborate section on potential community problems.</p>	<p>10 Team gave a basic presentation of the solution to the challenge and showed basic understanding of the science concepts and design process. Team gave some response to the Elaborate section on potential community problems.</p>	<p>5 Team gave a weak presentation of the solution to the challenge and showed little understanding of the science concepts and design process. Team gave a short or even no response to the Elaborate section.</p>	

total



RESOURCES

Recommended Teacher and Student Resources:

1. [EarthEcho Expeditions](#)
2. Aquifer (confined/unconfined)
<http://changethecourse.us/>
<https://water.usgs.gov/edu/watercyclegwdischarge.html>
<http://imnh.isu.edu/digitalatlas/hydr/concepts/gwater/aquifer.htm>
<http://www.watereducation.org/all-california-water-sources>
<https://water.usgs.gov/edu/earthgwaquifer.html>
<https://www.calacademy.org/educators/recharging-aquifers>
<https://www.e-education.psu.edu/earth111/node/911>
<https://www.nationalgeographic.org/encyclopedia/aquifer/>
3. Groundwater, runoff, and streamflow interaction (surface water) model- showing how human activities affect these interactions
<https://water.usgs.gov/edu/rivers-contain-groundwater.html>
<https://pubs.usgs.gov/circ/circ1139/>
4. Problems, Issues, and Concerns
<https://www.revealnews.org/article/9-sobering-facts-about-californias-groundwater-problem/>
<http://ktla.com/2017/03/30/californias-snowpack-one-of-deepest-recorded-in-state-history-poses-flooding-risk/>
5. Groundwater Association - resources on groundwater and background information
<http://www.ngwa.org/Fundamentals/teachers/Pages/Lesson-Plans.aspx>
6. Groundwater: A Hidden Resource
<http://www.esi.utexas.edu/files/080-Lesson-Plan-Groundwater.pdf>
7. USGS Aquifers and Groundwater Information
<https://water.usgs.gov/edu/earthgwaquifer.html>
8. Proposal for L.A. River Revitalization Action Plan Aquifer Replenishment
https://www.parks.ca.gov/pages/795/files/ca_rec_trails_comte_april_18_2012_small.pdf



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- Society, National Geographic. "Aquifer." National Geographic Society, 9 Oct. 2012, www.nationalgeographic.org/encyclopedia/aquifer/
- "Recharging Aquifers." California Academy of Sciences, www.calacademy.org/educators/recharging-aquifers
- *What is an Aquifer?*, imnh.isu.edu/digitalatlas/hydr/concepts/gwater/aquifer.htm

EDUCATIONAL STANDARDS

NGSS STANDARDS

Performance Expectations:

MS-ESTI-1. - Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

SEP – Constructing explanations and designing solutions

DCI - ETSI.C: Optimizing the Design Solution

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of test results leads to greater refinement and ultimately a better solution.

DCI – ETSI.B: Developing Possible Solutions

A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETSI-4)



Performance Expectations

MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

DCI – ETS1.B: Developing Possible Solutions

Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3)

CCC – Cause and Effect

The uses of technologies and limitations on their use are driven by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1)

Performance Expectations

MS-ESS 2-4: Develop a model to describe the cycling of water through Earth’s systems driven by energy from the sun and the force of gravity.

Performance Expectations

MS-ESS 3-1: Construct an explanation based on evidence for how the uneven distributions of Earth’s mineral, energy, and groundwater resources are the result of past and current geoscience processes.

Performance Expectations

MS-ESS3-3. - Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

SEP – Constructing explanations and designing solutions

DCI – ESS3.C: Human Impacts on Earth Systems

- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth’s environments can have different impacts (negative and positive) for different living things.
- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise.

CCC – Cause and Effect

- Relationships can be classified as causal or correlational, and correlational does not necessarily imply causation

Science and Engineering Practice

Constructing Explanations and Designing Solutions - Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.



Common Core State Standards - Math

- 6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-ESS3-3), (MS-ESS3-4)
- 7.RP.A.2 Recognize and represent proportional relationships between quantities. (MS-ESS3-3), (MS-ESS3-4)
- 6.EE.B.6 Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. (MS-ESS3-2), (MS-ESS3-3), (MS-ESS3-4)
- 7.EE.B.4 Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

Common Core State Standards - English Language Arts

- RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

