Rainwater Harvesting

Lesson 5: How much water can we collect?

INTRODUCTION

In this lesson, students will learn how to calculate how much rainwater can be collected by their rainwater harvesting system. They will use variables such as the area of the collection surface and rainfall amounts for their city as well as the runoff coefficient (the percentage of precipitation that runs off a particular surface) to determine the amount of water in gallons per year that their system can collect. Computational thinking using dimensional analysis, also known as the unit factor method, will be employed to convert area in square feet and rainfall in inches to a volume in gallons. Note: *these are standard units of measure in the rainwater harvesting field.*

Teaching Strategies

To design a successful rainwater harvesting system, students need to understand the concepts of supply versus demand. In an ideal system, supply should be equal to demand. In this lesson, students begin to understand the supply side of rainwater harvesting which includes how much water they can collect from a building roof or other surfaces. In future lessons, they will work with the demand side, putting that water to work.

OBJECTIVES

- **BUILD THE SYSTEM:** Identify the types of data needed to mathematically determine how much water can be collected in a year.
- **RELATE** the amount of water collected monthly to the design of a potential storage system.

MATERIALS AND EQUIPMENT

- Excel Spreadsheet: Supply Worksheet with Formulas.xlsx - see details below*
- Worksheet: Supply worksheet.pdf
- Handout: Runoff Coefficients for Different Surfaces.pdf
- Tool for calculating landscape area: https://earth.google.com/web/
- Monthly rainfall data for Santa Fe can be found at: https://www.usclimatedata.com/climate/santa-fe/new-mexico/united-states/usnm0292
  Note: This link may need to be copied directly into your browser.

*Depending on your students' abilities and your learning priorities for this lesson, you may choose to use either the Excel spreadsheet, "Supply Worksheet with Formulas," which will calculate monthly rain collection totals automatically, or to use the "Supply Worksheet" handout that students will complete manually.

LESSON SUMMARY

In this lesson, students will use observations about their collection area and average monthly rainfall data to calculate how much water can be harvested from their study area (e.g., a portion of the school roof, a parking lot, or other paved/non-porous area) over the course of a year. Students will learn about the relationships between how much water falls on a roof surface or other collection area and how much runs off—also known as the runoff coefficient (R_c). They will identify trends in rainfall availability by month and draw relationships between rainfall and the amount of rain they may be able to collect. They will use computational thinking to build an equation to help them calculate the volume of water they can collect.

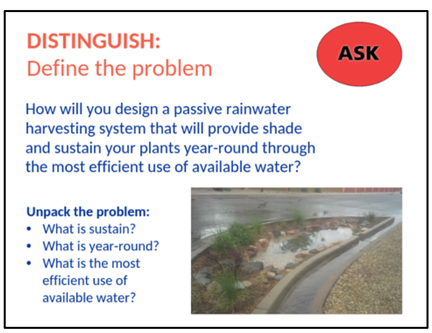
PRESENTATION GUIDE

Connect to the Unit

In the Lesson 4, students constructed explanations for stormwater management and used this information to creatively design solutions to problems they discovered. They determined the best locations of their school grounds to collect and/or direct water to a raingarden where it will infiltrate into the soil and irrigate plants.

Launch the lesson

This lesson will show students what runoff coefficients are, how to use them in determining the design of rainwater harvesting basins, and how to determine the amount of rainfall (supply) that can be collected over the course of a year for their chosen rainwater harvesting collection area.



DISTINGUISH

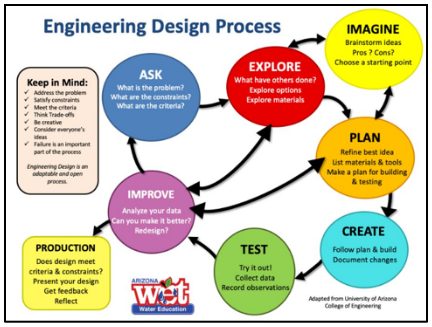
• What is the problem?

Remind students of the problem they are trying to solve:

Design a rainwater harvesting system that will allow water to infiltrate into the groundwater system, provide shade at your school, and meet all the plants' watering requirements.

Remember to create an integrated design using the ***Principles of Rainwater Harvesting.***

- Which plants provide shade?
- What are their watering requirements?
    - Are their watering requirements constant or do they change with the seasons?
- What is meant by *integrated design*?
- How does it affect plants that are chosen?
- What are the functions of each part of my design?



Where are we in the engineering design process?

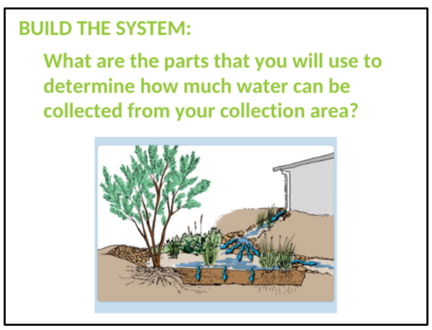
We are still Asking, Exploring and Imagining.

DISTINGUISH

• What do you need to know to size your system appropriately?

Ask the students what information they need to design and build a rainwater harvesting system that will meet their selected criteria and constraints.

One of the first things they need to know is how much water they can collect from their chosen collection area. They will also need to know how much water their plants need. In this lesson, students will focus on determining how much water can be collected and made available for their raingarden.



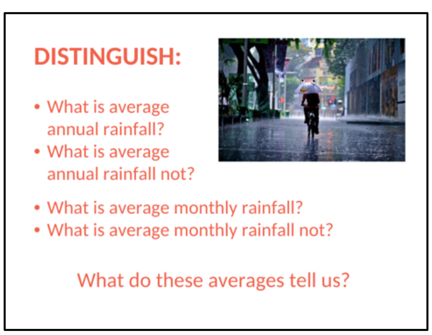
BUILD THE SYSTEM

• What are the parts that you will use to determine how much water can be collected from your collection area?

Give students time in small groups to discuss this.

Students should understand that they need to know how to calculate the surface area (in square feet) of their collection area. They will also need to know the amount of rain (in inches) that falls on that surface in an average month. If they don't come up with these at this point, don't tell them. This is an opportunity to find out what they already know.

In this lesson, students will learn that the volume of rainwater they can collect is dependent on the intensity of a precipitation event and will vary throughout the year. They will learn that the runoff coefficient also plays a role in how much rain they can collect.



DISTINGUISH

• What is average annual rainfall?

The amount of rain that we usually get each year.

• What is average annual rainfall not?

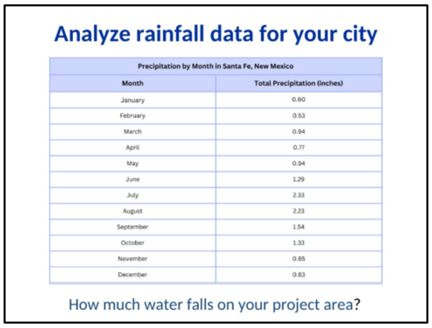
It is not monthly, weekly or daily data.

Ask students whether they think it would better to use daily, monthly, or annual rainfall values to determine the size of their system. What are the advantages and disadvantages of each?

- **What is average monthly rainfall?**

The typical amount of rain that we get in each month of the year.

- **What is average monthly rainfall not?**



Precipitation by Month in Santa Fe, New Mexico	
Month	Total Precipitation (inches)
January	0.60
February	0.53
March	0.94
April	0.77
May	0.94
June	1.29
July	2.33
August	2.23
September	1.54
October	1.33
November	0.85
December	0.83

It's still not daily. Would daily data be better to use than monthly? Why or why not?

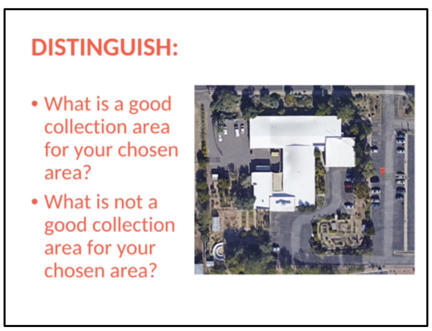
Discuss the frequency of precipitation in our area. Students will likely know about times of year when we get more rain, like the monsoon season. They may know that there are long periods with no rain, too. Ask them: "Will annual or monthly data tell you about one big storm?" No, neither one will. "Would it be helpful to have more data on rainfall or less?" More, yet when is it too much and too time-consuming?

For most rainwater professionals using daily data is overkill. A constraint that we all have in designing and building a rainwater harvesting system is time. So, we are going to analyze monthly rainfall.

DISTINGUISH

- **What else do you need to know to determine how much water could be harvested from your collection surface?**

We need to know the surface area of the collection surface that we will be harvesting from.



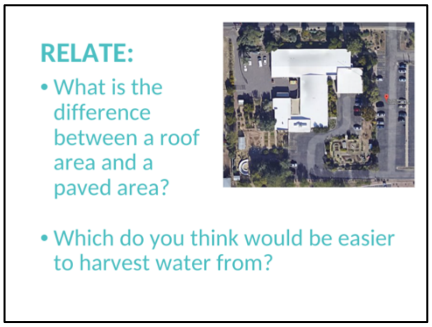
DISTINGUISH

- **What is a good collection area for your chosen area?**

The collection area for their system should have been determined in Question 8 on their Schoolyard Inspection Datasheet in Lesson 4. Ask students, "What constraints or criteria does a collection area need to meet?" (It must be close to the location to be watered, the rain garden basin. It must be an impermeable surface to collect water off, e.g., a roof or paved playground area.) Remember, where do we need shade?

- **What is not a good collection area for your chosen area?**

It is not any area off the school grounds. It's not a low point.



RELATE

• What is the difference between a roof area and a paved area?

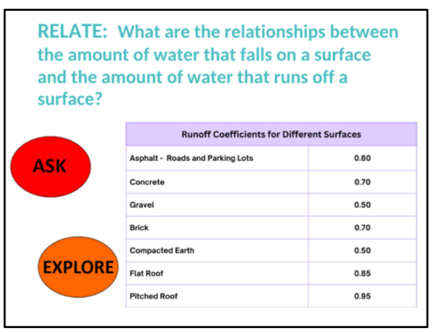
Engage students in a discussion: would a roof area or paved/non-porous area on the ground be easier to collect water from? Why?

• Which do you think would be easier to harvest water from?

Higher areas, like rooftops, are often easier to collect water from because gravity helps move the water, and existing structures—like gutters and downspouts—can be used for harvesting. Lower, paved areas (such as parking lots) may require more effort to direct water to where it's needed. For example, capturing runoff from a parking lot might involve making curb cuts to divert water from a larger surface area than a roof.

How to calculate the surface area of the collection area:

Use Google Earth (https://earth.google.com/web/) to help your students find the area that they are planning to work on. Students may be working only with a portion of the roof or surface area for their projects. Circle the room to ensure that students are using the correct formulas for various shapes to calculate their collection area. Note: *they may need to use different shapes and add the areas together.*



RELATE

• What is the relationship between the amount of water that falls on a surface and the amount of water that runs off a surface?

Give student groups time to discuss. Ideally, they'll understand that the more impermeable a surface, the more water can be collected.

Why might different surfaces have different amounts of runoff?

Have students recall Lesson 2 when they experimented with permeable and impermeable surfaces. Permeable surfaces allow rainwater to soak in, while impermeable surfaces shed water. Remind students that not all impermeable surfaces behave the same—some shed more water than others depending on their material and slope.

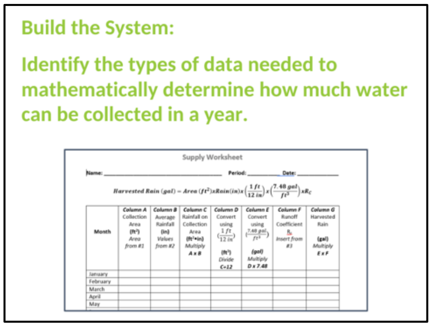
Would an asphalt parking lot shed more or less water than a gravel parking lot?

Show students a video explaining a runoff coefficient, the amount of water that will run off a particular surface.

What is the runoff coefficient and what does it mean?

The runoff coefficient is the proportion of water that runs off a particular surface. It accounts for the loss of some water that is captured and stays on the surface rather than running off.

Have students study the chart of different runoff coefficients on different surfaces. Runoff coefficients for different surfaces can fall into a range of upper and lower bounds. For the purposes of this lesson, one number is given for each surface type.



BUILD THE SYSTEM

• Identify the types of data needed to calculate how much rainwater can be collected over a year.

Introduce the *Supply Worksheet*, which guides students through the key factors that influence rainwater collection at their selected site. You may choose to pre-fill the worksheet with local rainfall data (see Materials section for links), or have students find and enter the data themselves. The *Supply Worksheet* is also available as an Excel spreadsheet with built-in formulas, if you prefer that students complete the activity digitally. (Refer to the worksheet options at the start of this lesson.)

Supply Spreadsheet

To facilitate understanding, walk students through an explanation of each column on the spreadsheet. It may be helpful to use a document viewer to review the worksheet with students.

Column A – *Collection Area in ft^2*. This is calculated as below:

Area of Collection Surface: Length (ft) x Width (ft) = Area (ft^2)

Column B – *Average Monthly Rainfall in inches* – you may opt to have students find the information themselves using the website links provided or prefill the data on the worksheet before handing it out.

Column C – *Rainfall on Collection Area*. This is the amount of rain that falls onto the collection area. Students calculate this by multiplying Columns A x B.

Notice the units: ft^2 x in. Is this a volume? Yes, but it is not a standard unit for measuring volume. What units do we use to measure volume? (ft^3, gal, L). How do we get there? (We need to convert our units).

Column D is a *conversion factor* to get us to ft^3. How many inches in a foot? (12 inches)

If we multiply our value by $({}^{1\text{ft}}/_{12\text{in}})$ we can cancel out inches and Column D is the Rainfall on the Collection Area in ft^3. This process of converting values to a common unit is called dimensional analysis or the unit factor method.

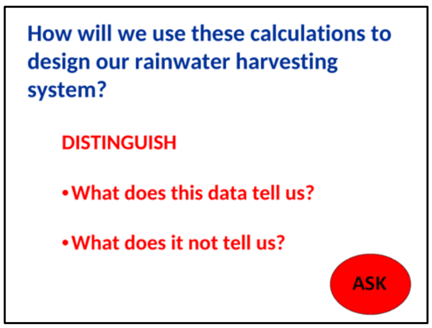
Column E is another *conversion factor* to get us from cubic feet to gallons. How many gallons in a ft^3? $({}^{7.48\text{gal}}/_{\text{ft}^3})$ So, if we multiply by this conversion factor, it gives us Rainfall on Collection Area in gallons.

Column F of the *Supply Worksheet* is where students add the appropriate runoff coefficient for their collection surface. The runoff coefficient will not change for one type of collection area, so students should enter the same in every row. (These are listed on the Runoff Coefficient chart)

Note: *if they are using two different collection areas with a different runoff coefficient it would be better for them to use a second supply worksheet for the second type of collection area.*

Column G lists how much water can be harvested from the collection area in gallons. In other words, it is the amount of water they can collect each month and over the course of the year.

Give students time to fill in the spreadsheet with the information they have. Circulate the room to make sure they are on task.



DISTINGUISH

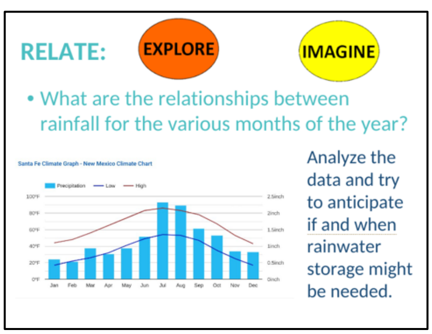
• What does this data tell us?

Once students have completed their spreadsheets, have them analyze the data by comparing monthly and annual water collection totals. Ask: How much water can be harvested each month? How does that compare across the year? What does this data tell us about when water is most available—and when it's scarce?

Encourage students to consider how these patterns influence design decisions, such as tank size, plant selection, and water storage strategies.

• What does it not tell us?

It doesn't tell us about individual storm sizes. The data only tells us the amount of water available for use. It does not tell us if we have enough water to meet plants' watering requirements.



RELATE

• What are the relationships between rainfall for the various months of the year?

• Which month will supply the most water? Which month will supply the least water?

Have students refer to their Supply Worksheet to guide their thinking. Prompt them to consider how seasonal rainfall patterns impact the design of a rainwater harvesting system that can support plants year-round. They should observe that most precipitation falls between June and October, which may affect storage needs, plant selection, and irrigation planning.

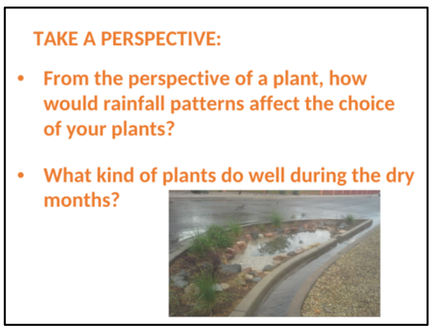
• How might we need to accommodate months with low rainfall?

Months with little or no rainfall will affect the types of trees and shrubs they can successfully support. Drought tolerance and water storage become important factors in plant selection.

Students should also think about the effects of extreme weather. In the Southwest, stronger and more frequent storms are expected due to climate change.

Introduce the concept of a *100-year storm*—a major event that can drop several inches of rain in a matter of hours. In the Santa Fe area, that means a storm dropping 2 inches or more of rain in 60 minutes. This is an important design consideration for sizing water storage systems and planning overflow strategies.

Add the 100-year storm to the students' list of design criteria.
Students will revisit how to integrate this into their systems in Lesson 8.



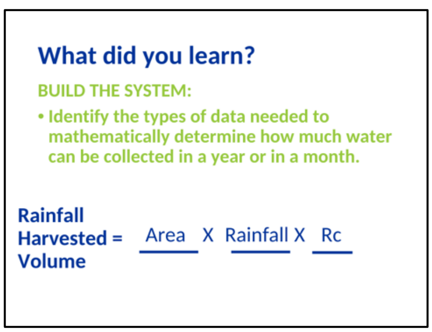
TAKE A PERSPECTIVE

• From the perspective of a plant, how would rainfall patterns affect the choice of your plants?

Remember that the watering requirements for your plants need to be met by your system.

• What kind of plants do well during the dry months?

They should start to realize that native and or arid adapted plants should do through the dry months. Note: *This is just a preliminary discussion.*



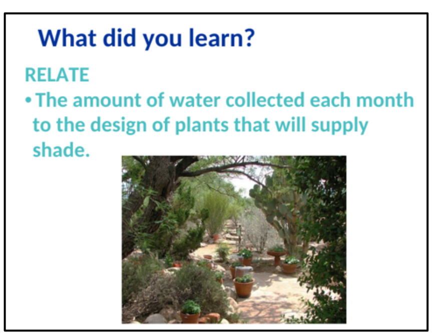
CONCLUSION

BUILD THE SYSTEM

• Identify the types of data needed to mathematically determine how much water can be collected in a year or in a month.

Rainfall Harvested Volume = Area x Rainfall x R_c

(R_c is the Runoff Coefficient)



RELATE

• The amount of water collected each month to the plants supported by that water to supply shade.

Once students have completed the *Supply Worksheet* and applied DSRP thinking to analyze the data, return to your criteria and constraints lists. Which of the criteria and constraints questions does this exploration answer? Which criteria and constraints have been specified, clarified, or quantified by this exploration? What new criteria and constraints should be added to each list based on this exploration?