Rainwater Harvesting

Lesson 8: Basin Sizing

INTRODUCTION

In this lesson, students are reminded of the four major parts of a passive rainwater harvesting system: collection, conveyance, infiltration, and storage. In working through the unit, students have learned how much water they can collect from their collection area, and they know what plants they can grow with that water in order to meet the engineering design problem. Now they will have to figure out other parts of the puzzle. They will need a way for their plants to access the water and they will need to plan and size their infiltration basins.

Students will be sizing their basins based on the 100-year storm or flood event for their region. They will use data on the percolation or infiltration rate to figure out the depths of their basins. They will have to iterate back and forth between depths and surface areas in order to store the amount of water needed for their plants. Iteration is a major part of the engineering design process.

Teaching Strategies

This lesson utilizes research to analyze and interpret data about 100-year storm events and percolation rates. Students use mathematics and computational thinking to size infiltration basins to most optimally meet the engineering design challenge.

Students develop drawings of their basins using infiltration data and iterate back and forth using their data to optimize their storage capacity.

The NOAA website link enables students to find flood event data for their geographic area.

OBJECTIVES

- **BUILD THE SYSTEM:** Identify all of data needed to size basins to sustain plants year-round through the most efficient use of available water and meet city ordinances pertaining to standing water.
- **BUILD THE SYSTEM:** Use **mathematics and computational thinking** to size infiltration basins to optimally meet the engineering design challenge for the chosen site.
- **RELATE:** **Plan and carry out investigations** that relate water storage needs to water supply and demand.

MATERIALS AND EQUIPMENT

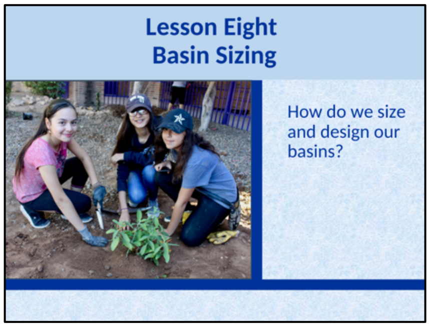
- NOAA - https://hdsc.nws.noaa.gov/pfds/
- Brad Lancaster website: https://www.harvestingrainwater.com/resources/rain-garden-planting-zones/
- Water Budget Calculation Worksheet (filled out in Lesson 7)
- Santa Fe Basin Sizing Worksheet

LESSON SUMMARY

Students will learn to use data, mathematics and computational thinking to size infiltration basins to optimally meet the engineering design challenge. They will see that infiltration basins are a key part of their rainwater harvesting system, essential to meeting their plants' water requirements.

PRESENTATION GUIDE

Connect to the Unit

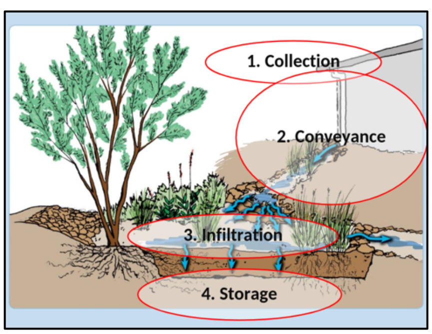


In lessons 5 through 7, students learned to view rainwater harvesting from the perspective of supply and demand. They calculated the amount of rain that could be stored or used every month from their collection area and calculated the water demand needs of the plants for their project site. Now they will add another essential component to their system.

Launch the lesson

Students will be reminded of the four major parts of a passive rainwater harvesting system: collection, conveyance, infiltration and storage. They know how much water they can collect from their collection area and will now find a way for their plants to access the water. They will also need to plan and size their infiltration basins. Students will be sizing their basins based on the 100-year storm or flood event for their region. They will use data on the percolation or infiltration rate to figure out the depths of their basins. They will have to iterate back and forth between depths and surface areas in order to store the amount of water needed for their plants.

Remind students of the driving question to be solved.



BUILD THE SYSTEM:

- **What are the parts of a rainwater harvesting system?**

Ask students if they remember the 4 major parts or roles of a rainwater harvesting system that were discussed earlier in the unit. They should recall collection, conveyance, infiltration and storage.

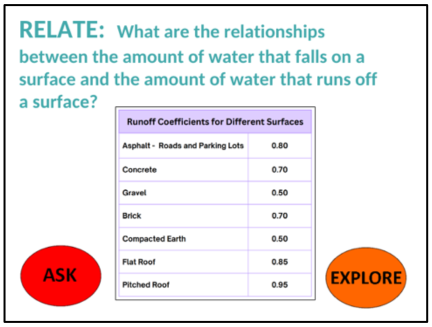
RELATE:

- **How are the parts related?**

The following slides will assist in facilitating a discussion about how each of the components are connected to each other. Though covered previously, students should now have a deeper understanding of the relationships.

Collection: What are the Parts of Collection?

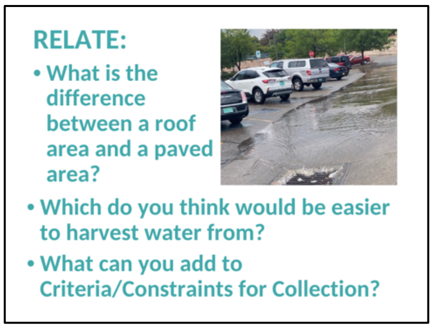
Collection includes type of surface, size of surface, and amount of rain.



RELATE: What are the relationships between the amount of water that falls on a surface and the amount of water that runs off a surface?

It's the question of how much of the water actually runs off of your roof. The amount of water that will run off a particular surface differs depending on the surface. Permeable surfaces allow rainwater to sink in. Impermeable surfaces shed rainwater. To take this effect into consideration when calculating runoff volumes, a runoff coefficient (R_c) is used.

Remind students, 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.



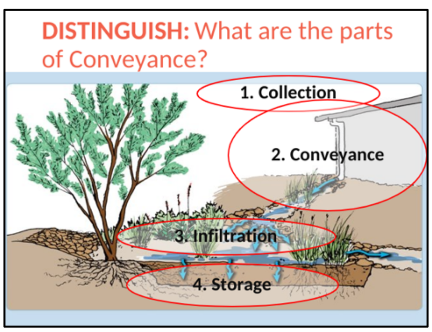
RELATE:

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

One is higher and one is lower.

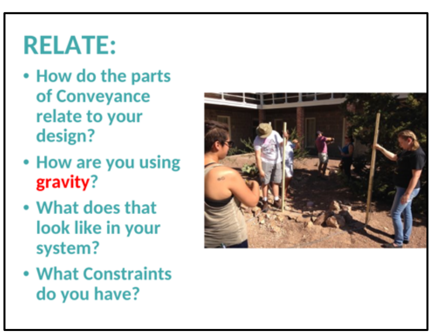
Which do you think would be easier to harvest water from? In most cases the higher one because you can use gravity to help you move it into your system.

This ties into our Rainwater Harvesting Principles: Start at the top of the watershed and leads us into Conveyance.



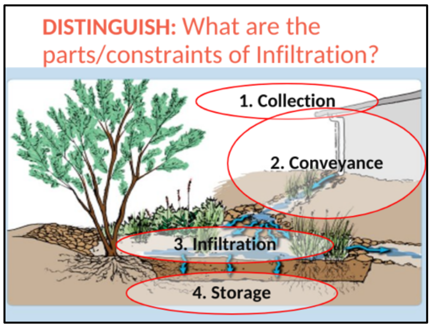
Collection: What are the Parts of Conveyance?

Elevation differences, gravity, infrastructure like rain gutters and downspouts.



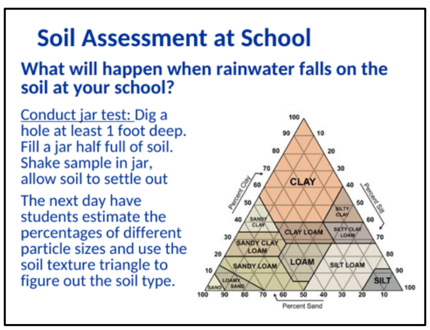
RELATE:

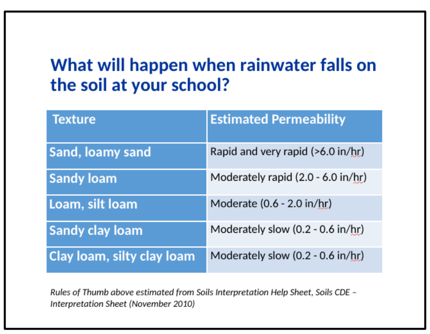
- How do the parts of Conveyance relate to your design?
- How are you using **gravity**?
- What does that look like in your system?
- What Constraints do you have?



DISTINGUISH: What are the parts/constraints of Infiltration?

Types of soil, percolation rate, mulch, and time: we need to sink the water in a basin within 96 hours. These are all Constraints for our design. We cannot change them.




What will happen when rainwater falls on the soil at your school?

Texture	Estimated Permeability
Sand, loamy sand	Rapid and very rapid (>6.0 in/hr)
Sandy loam	Moderately rapid (2.0 - 6.0 in/hr)
Loam, silt loam	Moderate (0.6 - 2.0 in/hr)
Sandy clay loam	Moderately slow (0.2 - 0.6 in/hr)
Clay loam, silty clay loam	Moderately slow (0.2 - 0.6 in/hr)

Rules of Thumb above estimated from Soils Interpretation Help Sheet, Soils CDE – Interpretation Sheet (November 2010)

Soil – Infiltration

Ask, "Do you remember doing the Jar Test in Lesson 4?"

BUILD THE SYSTEM:

- **What are the parts of the ground below the basin bottom?**

Soil types, compaction levels, and spaces between soil particles that allow water to pass through.

What is the percolation rate? - *How quickly water sinks or infiltrates into the ground at the site.*

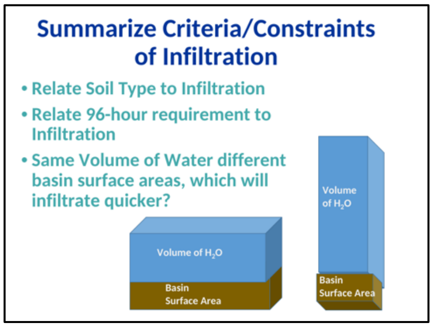
Soil Types and Permeability

As they discovered by performing the Lesson 4 jar test, sandier or more gravelly soils will allow water to infiltrate faster. Silt and clay inhibit the flow of water into the ground. Soil composition directly relates to how deep a basin should be constructed.

Basins – Potential Issue

What happens when water is left standing in a basin over time? Mosquitos breed. Mosquitos are vectors for several diseases which are currently on the rise due to climate change.

How does a city manage standing water? State water regulations tell us that all stormwater in a man-made basin must infiltrate into the ground in 96 hours – this is a criteria if it hasn't already been listed.



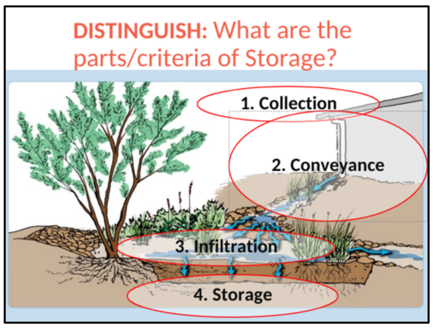
Summarize Criteria/Constraints of Infiltration

- **Relate Soil Type to Infiltration**
- **Relate 96-hour requirement to Infiltration**
- **Same Volume of Water different basin surface areas, which will infiltrate quicker?**

Soil type will determine the infiltration rate of the water.

Rainwater harvesting basins are considered retention basins. State water laws require that water infiltrates within 96 hours in a detention basin.

The time for a set volume of water to infiltrate will decrease if spread over a wider basin area.

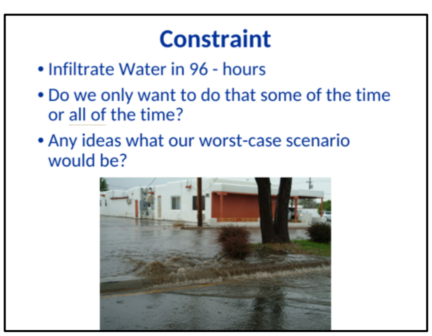


DISTINGUISH: What are the parts/criteria of Storage?

Plants store water and we determined that amount in Lessons 6-7.

The type of plants can also help with infiltration rates. This is in our Principals of Rainwater Harvesting document under Stacking Functions.

Area and Volume of Basins are also part of the storage.



Constraint

We are required to infiltrate water within 96 hours by state water law. This does not mean that we can selectively agree to obey the law. We also want to plan for our worst-case scenario of a 100-year flood event.

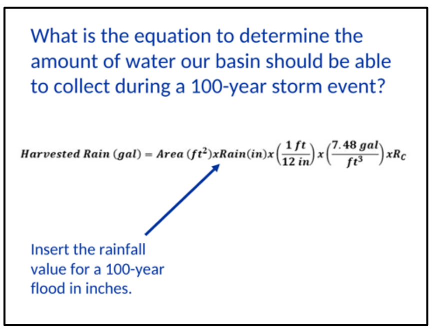
100-Year Storm Event

NOAA publishes data for the amount of rainfall that occurs in large storm events:
https://hdsc.nws.noaa.gov/pfds/

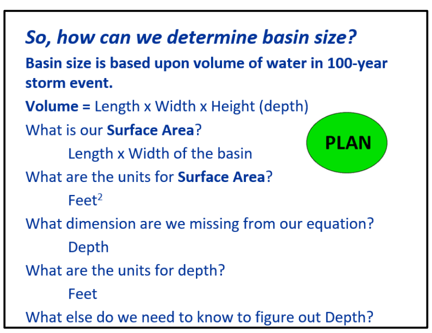
These are designated by the probability that they will occur. A 100-year storm event based upon climate records is statistically calculated to occur every 100 years. Ask students, "Does that mean that they will only occur every 100 years?" No, they can occur more often and even on consecutive days depending on weather patterns. Tell them that as the climate changes, we are experiencing more extreme storm events across the globe.

Ask again, "What volume of rain should we engineer our basins to handle if space is not an issue?" The volume of rain from a 100-year storm event. Have students follow the directions on the slide or do so through projection for the whole class.

- In Santa Fe, we need to size our basin to handle a 2.0" rain event.



Review:
Again, how do we calculate that amount of water that comes off our collection area in a 100-year storm event? We use the ***same formulas*** we used in Lesson 5 except we plug in the rainfall for our hundred-year event to help us determine how big our basins need to be.



Basin Size

So, how can we determine basin size? Basin size is based upon Volume.

Volume = Length X Width X Height (Depth)

What information do we have?

Surface area: Length x Width of the basin.

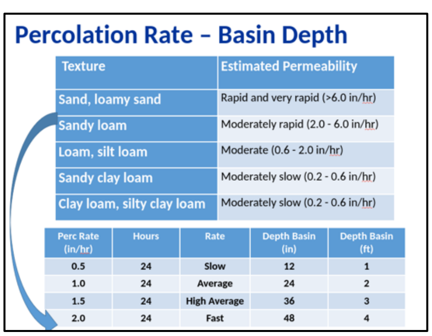
What are the units for surface area? Feet^2

What dimension are we missing from our equation? **Depth**

What are the units? Feet.

Ask students "What else should we consider when figuring out what depth our basins should be?" How hard is the ground? What depth would cause sides to be too steep? Are there safety considerations?

Examples of percolation rates with Basin Depth

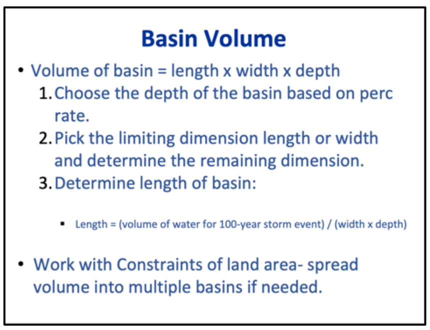


This takes us back to our infiltration or Perc test based upon soil type. What is an infiltration rate? It is how many inches of water go into the ground over time. This slide is an example of infiltration rates.

What this tells us is the maximum depth of our basin based on how fast water moves through the soil. Let's physically think about these numbers (pull out a yard stick or measuring tape). Do we want a basin 4 feet deep, on a school ground where kids run around? No, it is safety risk. Is this a constraint? Yes, we need to look at our perc rate and think of safety issues when designing our basin depths.

Remember from Lesson 4, we discussed Slope Safety:

Steeply sloped basins can be hazardous to people and pets. A general rule of thumb is to maintain 3:1 slope ratio, or less, when creating berms and basins. This means for every 3 units of horizontal distance; you go down 1 unit vertically on slopes. If you have Average or Slow infiltration rates, your basin should be shallower, requiring even less slope in your basin design.



Basin Design: This is an iterative process. Have students us the Santa Fe Basin Sizing Worksheet as they go through this process. Use grid paper and scale models to think about dimensions with students.

- Volume of basin = Length x Width x Depth
  1. Choose the depth of the basin based on perc rate.
  2. Pick limiting dimension (length or width) and determine the remaining dimension.
  3. Determine length (or width if limiting) of basin:
     - Length = (Vol water 100 year storm event) / (width x depth)
- Work within Constraints of land area - spread volume into multiple basins as needed.

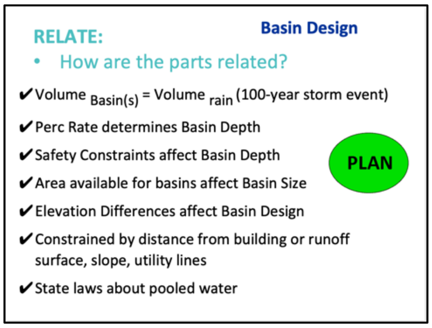
Plan for Overflow to Accommodate Excess Water

Take into account the actual area of land space and spread its volume into multiple basins as needed.

Give students time to figure out their basin configuration and dimensions. Make sure that they plan for overflow.

Optional: Have students think about plant placement when determining their basin depth - Check out Brad Lancaster's site: https://www.harvestingrainwater.com/resources/rain-garden-planting-zones/

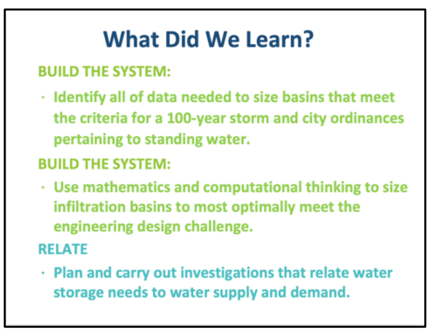
Note: *At this point students should realize that the most effective system needs to account for large storms. They may not be able to store all of* *that water due to space and safety factors, but they still need to know that amount and make sure that their system provides overflow to a safe region at a lower elevation. The last thing they want to do is cause a flood due to concentrating the water from their collection area in a certain space!*



RELATE: How are the parts related?

- Volume Basin(s) = Volume rain (100-year storm or flood event)
- Perc Rate determines Basin Depth
- Safety Constraints affect Basin Depth
- Area available for basins affect Basin Size
- Elevation Differences affect Basin Design
- Constrained by distance from building or runoff surface, slope, utility lines
- State laws about pooled water

Conclusions



BUILD THE SYSTEM:

- **Identify all of data needed to size basins to sustain plants year-round through the most efficient use of available water and meet state laws pertaining to standing water.**

- **Use mathematics and computational thinking to size infiltration basins to most optimally meet the engineering design challenge for the chosen site.**

RELATE

- **Plan and carry out investigations that relate water storage needs to water supply and demand.**