Keep Up the Pressure

A Solidify Understanding Task

Purpose: In this lesson students will work on an engineering project to consider the height of a water storage tank and its relationship to water pressure and the weight of a water storage tank and the capacity of the ground beneath it to support the structure.

Career Field: Civil Engineering

Company: Highfill Infrastructure Engineering

WTCC Associate Program of Study and Contact Person:

NC Math 3 Standards:
NC.M3.G-MG.1 Apply geometric concepts in modeling situations

Unit Alignment:

NC Math 3 - Unit 4 Modeling with Geometry

- I can use geometric formulas and algebraic functions to model relationships and solve problems.
- I can solve optimization problems.

WTCC Math 121 Unit 3:

- Determine the volume of 3-D objects given volume formulas
- Solve application problems using volume formulas

Common Core State Standards for Mathematical Practice

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
4. Model with mathematics.
5. Use appropriate tools strategically.

Prerequisite Skills

- Finding the area of a circle.
- Finding the volume of
- Converting units.

Time Required
The time required to complete this activity is approximately 90 minutes.

Materials Needed

- Student Activity Sheet
- Desmos
- Calculator

The Teaching Cycle:

Launch: Students should work in groups of 3 to complete this activity. Have students individually complete the Desmos Activity. In the activity students will review finding the volume of cylinders, cones and spheres and conversion of square feet to square inches. The launch video is embedded in the Desmos Activity.
Water Tank Desmos Link
The video will introduce students to Highfill Infrastructure Engineering, P.C., a civil engineering firm specializing in community and municipal water infrastructure engineering. The water that you use everyday is pumped through a network of underground pipes that connect consumers to a water treatment plant (WTP). While the water moves through this underground system at a constant rate, the demand for water by residential homes, businesses, and schools is constantly changing. Water storage tanks are located in the distribution system as a buffer between the supply and demand of potable water.

There are two types of water towers: elevated water storage tanks and ground storage tanks. Most students will have seen an elevated water storage tank before, but they may not know that water is stored in them. The video will show students examples of the different types and how the design of the effects water pressure. The video will focus on the relationship between the height of an elevated water tank and water pressure and the weight of a filled ground level water tank and the ability of the ground to support such a structure.

After students have watched the launch video, ask if students have questions about the Desmos Activity or the video. This may be a good place to ask students what they wonder about the design of a water tower. This will help them to begin focusing their thoughts as they prepare to answer the first question in Task 1. Distribute the Student Activity Sheet.

Explore: Students will work in groups of 3 to complete.

Task 1: Elevated Water Storage Tank Height and Water Pressure

Question 1 should be asked after the students have watched the video. Give students a few minutes to discuss in their groups and then share out to the full class. The purpose of this question is to get students to think about the type and size of the water storage system needed for a community (elevated or ground), water pressure desired, and whether a site is suitable for a water tower/tank. Other considerations might be cost of materials and labor, impact on community, etc.

Question 2 asks students to guesstimate the height needed for an elevated water tower to produce water pressure of PSI. This is purely a guess. Students will return to their guess later to evaluate whether their guess was too high or too low. Remind students that PSI stands for Pounds per square inch. Paying attention to units is important throughout the lesson.

Question 3 asks students to compare the height of a water tower producing 50 PSI to one that has a water pressure of 65.6 PSI. Students should assume that the two water towers have the same size tanks and therefore the volume of water tanks is the same. In this case, the height of the water tower with 50 PSI should be lower than that of the water tower with 65.6 PSI.

Question 4 gives the formula for calculating PSI. Students should use the formula, but note that the unit weight of water is in lbs/cubic feet. They will need to convert to lbs/square inc.

Question 5 asks them to look at their guess from question 2 and tell whether their guess was too low or too high.

Task 2: Weight and Soil Bearing Capacity:

Question 1 prompts students to begin to think about what an engineer must consider when designing a water tower. They can draw on what they have learned from the launch video.

Question 2 has students calculate the **weight of the water** using the formula:

$$Water\ Weight = Volume\ of\ water \times unit\ weight\ of\ water$$

*Water at 70℉ has a unit weight of 62.4 lbs/ft^3

Students will need to use the drawing to calculate the volume of the cylindrical water storage tank. Note that this tank is a **ground storage tank**. Water **does not** go into the dome roof of the storage tank.

Question 3 has students to calculate the **weight of the concrete container w/roof itself**. Students must find the volume of the concrete tank by finding the volume of the whole structure including the thickness of the walls and the thickness of the floor. They will then have to subtract the inner volume (volume of the water) to calculate the volume of the concrete by itself. The volume of the concrete is multiplied by the unit weight of the concrete (150 lbs/cubic feet to find the weight of the concrete. You may need to remind students to add in the weight of the dome roof that was given to get the total weight of the water storage tank. Students may need additional support with calculating the weight of the concrete structure.

Question 4 asks students to calculate the bearing pressure of the water storage tank and introduces the idea of bearing capacity, the soil's ability to support the weight of the structure.

Question 5 asks students to explain why increasing the area of the footing will improve the soils ability to support the tank. This provides the student with the opportunity to explain the mathematical reasoning that increasing the denominator of a fraction will decrease the fraction which means the bearing pressure decreases.

Question 6 asks students to determine where the storage tank can be built and why.

Questions 7 and 8 provide students the opportunity to put everything together and provide a context for maximizing the volume of a 3-dimensional figure. When calculating the volume of this "spherical" elevated water tower students will need to convert the diameter to all feet (Given diameter is 74 feet **1 in**) Students must find the weight of the water in the spherical tank when it is full. They will need to use the unit weight of water given to them in Task 2 Question 1. To find the maximum volume for the tank to be constructed on very good soil students must write a formula for the bearing pressure of the spherical tank. The bearing capacity of very good soil is 5000. I suggest using DESMOS to find the maximum volume of the tank.

Discuss:

- Discuss what engineers should consider when designing a water tower.
- Discuss how the volume of water impacts the bearing pressure of a site.
- Discuss what changes can be made to the design of a water storage tank that will lower the bearing pressure of a site.

Student Activity Sheet

Answer Key