

Activity #7:

The Basics of Groundwater

Groundwater makes up a very large portion of the Earth's fresh water resources. It represents between 50 and 60 percent of available fresh water for human use. Groundwater aquifers are our largest holding basins for available fresh water. Refer to the table of Earth's Water Resources and note that glaciers and icecaps hold large amounts of fresh water, but remember that it is frozen and not available for use. It is estimated that the total amount of groundwater available in our country is about equal to the total precipitation for a 10-year period or the total surface runoff to streams and rivers for a period of 35 years. Groundwater storage exceeds the capacity of all surface reservoirs and lakes, including the Great Lakes. The movement of this groundwater is dependent upon the permeability and slope of the water table. This varies with the type of aquifer. Water may move as swiftly as surface waters (2-3 feet per second) or as slowly as one inch per day.

Objective: Upon completion of this activity, students will be able to use math knowledge and calculation skills to complete conversions regarding volumes of groundwater.

NEVADA SCIENCE STANDARDS 16, 19, 22

Time: One or two class periods

Materials: (per group) a copy of *Student's Conversion Table*, copies of *Groundwater Conversion Problems*, a copy of the *Hint Page* for conversions, a copy of *The Earth's Water Resources*, a copy of the *Table of Porosities*

Procedure:

1. Each work group should review and discuss the copy of *The Earth's Water Resources* before beginning calculations for problems.
2. Use the *Student Conversion Table*, *Table of Porosities* and *Hint Page* to solve the problems.
3. Work through the calculations as a group. Consider the final answer and discuss.

Activity #7:

Groundwater Conversion Problems

Use the *Student's Conversion Table*, *The Earth's Water Resources* chart and the *Table of Porosities* to successfully calculate the answers to the following problems. The solutions to B, C and D are oversimplifications of these types of determinations, but will demonstrate the principles involved in recharge, yield and infiltration calculations.

Problem A: How many gallons are represented by $4.2 \times 10^6 \text{ km}^3$ of global groundwater?

Problem B: If $1 \times 10^6 \text{ mi}^3$ of subsurface water exists in a volume of the earth's crust that covers $5 \times 10^7 \text{ mi}^2$ of the land surface that is $\frac{1}{2}$ mile deep, what is the average porosity (in percent) of the upper layer of the Earth's crust? (Assume that the entire depth is saturated.)

Problem C: If a recharge area of a water well measures 1,000 acres and the well is 800 meters deep, and soil porosity is that of a sand and gravel mixture, what volume of water might theoretically supply the well?

Problem D: In C above, what is the annual recharge rate (gallons/year) if precipitation is 55 inches per year, seven inches of which will become groundwater?
[Southern Nevada receives an average of only four inches of rain annually.]

Activity #7:**The Earth's Water Resources**

SOURCE	SURFACE AREA (mi²)	WATER VOLUME (mi³)	% OF TOTAL WATER
Surface water freshwater lakes = ½ mi. deep	330,000	30,000	.009
Saline lakes	270,000	25,000	.008
Stream channels	---	500	.0001
Subsurface water >½ mi. deep	50,000,000	1,000,000	.31
Subsurface water ≤½ mi. deep	50,000,000	1,000,000	.31
Soil moisture + water in vadose zone	50,000,000	16,000	.005
Glaciers/ice caps	6,900,000	7,000,000	2.15
Atmosphere	197,000,000	3,100	.001
Oceans	139,500,000	317,000,000	97.2
TOTAL		326,000,000	

Activity #7:

Table of Porosities

The approximate ranges of porosities of specific materials are:

Materials	Porosity (percentage)
Silts and clays (that have not been significantly compacted)	50 - 60
Fine sand	40 - 50
Medium sand	35 - 40
Coarse sand	25 - 35
Gravel	20 - 30
Sand and gravel mixes	10 - 30
Glacial till	25 - 45
Dense, solid rock	<1
Fractured and weathered igneous rock	2 - 10
Permeable, recent basalt	2 - 5
Vesicular lava	10 - 50
Tuff	30
Sandstone	5 - 30
Carbonate rock with original and secondary porosity	10 - 20

Activity #7:

Student's Conversion Table

The conversions below may be of help in making calculations and solving groundwater problems.

$$1 \text{ yd}^3 = 27 \text{ ft}^3$$

$$1 \text{ acre} = 4047 \text{ m}^2$$

$$1 \text{ hectare} = 10,000 \text{ m}^2$$

$$1 \text{ meter} = 3.28 \text{ feet}$$

$$1 \text{ acre} = 43,560 \text{ ft}^2$$

$$1 \text{ ft}^3 = 7.48 \text{ gallons}$$

$$1 \text{ m}^3 = 35.31 \text{ ft}^3$$

Activity #7:

HINT PAGE - Use Student's Conversion Table

A. To start this problem, look at the conversion sheet.

1. Convert km^3 to m^3 .
2. Convert m^3 to ft^3 .
3. Convert ft^3 to gallons.

B.

1. Porosity = $\frac{\text{mi}^3 \text{ of H}_2\text{O}}{\text{mi}^3 \text{ of soil}}$ $\frac{(\text{volume of H}_2\text{O})}{(\text{volume of soil})}$

2. Volume = area x depth

$$(\text{mi}^3 \text{ of soil} = \text{mi}^2 \text{ of land} \times \text{depth in miles})$$

C.

1. Convert acres to meters.
2. Volume = area x depth.
3. Water yield = volume x porosity (convert to decimal).

D.

1. Convert inches to feet.
2. Convert feet to meters.
3. Convert acres to m^2 .
4. Multiply area (m^2) x rainfall that becomes groundwater (m) = m^3 .
5. Convert m^3 to ft^3 .
6. Convert ft^3 to gallons.

Activity #7:

Teacher's Answer Sheet, Page 1

A. To start this problem, you must look at the conversion sheet.

1. Convert to m^3 .

$$4.2 \times 10^6 km^3 \times \frac{1 \times 10^9 m^3}{1 km^3} = 4.2 \times 10^{15} m^3$$

2. Convert m^3 to ft^3 .

$$4.2 \times 10^{15} m^3 \times \frac{35.31 ft^3}{1 m^3} = 1.483 \times 10^{17} ft^3$$

3. Convert ft^3 to gallons.

$$1.483 \times 10^{17} ft^3 \times \frac{7.48 gal}{1 ft^3} = 1.11 \times 10^{18} gal$$

B.

1. Porosity = $\frac{mi^3 \text{ of } H_2O}{mi^3 \text{ of soil}}$ $\frac{(\text{volume of } H_2O)}{(\text{volume of soil})}$

2. Volume = area x depth.

$$\begin{aligned} Mi^3 \text{ of soil} &= mi^2 \text{ of land} \times \text{depth in miles} \\ Mi^3 \text{ of soil} &= (5 \times 10^7) \times 0.5 = 2.5 \times 10^7 mi^3 \end{aligned}$$

$$\text{Porosity} = \frac{1 \times 10^6}{2.5 \times 10^7} = 0.04 \text{ or } 4\%$$

C.

1. Convert acres to meters.

$$1,000 \text{ acres} \times \frac{4074 m^2}{1 \text{ acre}} = 4.074 \times 10^6 m^2$$

2. Volume = area x depth.

$$4.074 \times 10^6 m^2 \times 800 m = 3.26 \times 10^9 m^3$$

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Teacher's Answer Sheet, Page 2

3. Water yield = volume x porosity (convert to decimal).

$$3.26 \times 10^9 \text{ m}^3 \times 0.20 = 6.52 \times 10^8 \text{ m}^3$$

D.

1. Convert inches to feet.

$$7 \text{ in} \times \frac{1 \text{ ft}}{12 \text{ in}} = 0.58 \text{ ft}$$

2. Convert feet to meters.

$$0.58 \text{ ft} \times \frac{1 \text{ m}}{3.28 \text{ ft}} = 0.177 \text{ m of rain into groundwater}$$

3. Convert acres to m².

$$1,000 \text{ acres} \times \frac{4047 \text{ m}^2}{1 \text{ acre}} = 4.047 \times 10^6 \text{ m}^2$$

4. Multiply area (m²) x rainfall that becomes groundwater (m) = m³.

$$4.047 \times 10^6 \text{ m}^2 \times 0.177 \text{ m} = 7.16 \times 10^5 \text{ m}^3$$

5. Must convert m³ to ft³ first.

$$7.16 \times 10^5 \text{ m}^3 \times \frac{35.31 \text{ ft}^3}{1 \text{ m}^3} = 2.53 \times 10^7 \text{ ft}^3$$

6. Convert ft³ to gallons.

$$2.53 \times 10^7 \text{ ft}^3 \times \frac{7.48 \text{ gal}}{1 \text{ ft}^3} = 1.89 \times 10^8 \text{ gal}$$