

Tap Versus Drain: Aquifer Balance and Ore Grade by the Numbers

Learning target: I can graph and calculate from resource data to decide whether a use of a resource is sustainable (no faster than it is replenished), and show how human removal changes where a resource remains.

- Data and graphing
- About 45 min
- Individual
- MS-ESS3-1 · practice
- MS-ESS3-4 · supports
- data analysis
- independent practice

Name

Date

Period

Directions

This sheet has two parts. Both use teaching datasets: the numbers were invented to be realistic, not measured in a real place. Part A is about a town's groundwater. Part B is about four copper deposits. Graph with a ruler, show every calculation with units, and write complete sentences for the interpretation questions. The two parts come together in the last question.

You will need: This worksheet, Pencil, Ruler, Calculator

Part A: Is the Red Mesa aquifer being used faster than it refills?

The town of Red Mesa (a made-up town) pumps all of its water from one shallow sand-and-gravel aquifer that rain and snowmelt refill every year. Each year the water agency estimates two numbers: recharge, the volume of rain and snowmelt that soaks down into the aquifer, and pumping, the volume the town's wells remove. It also measures the depth from the ground surface to the top of the groundwater, the water table. The table gives every fourth year.

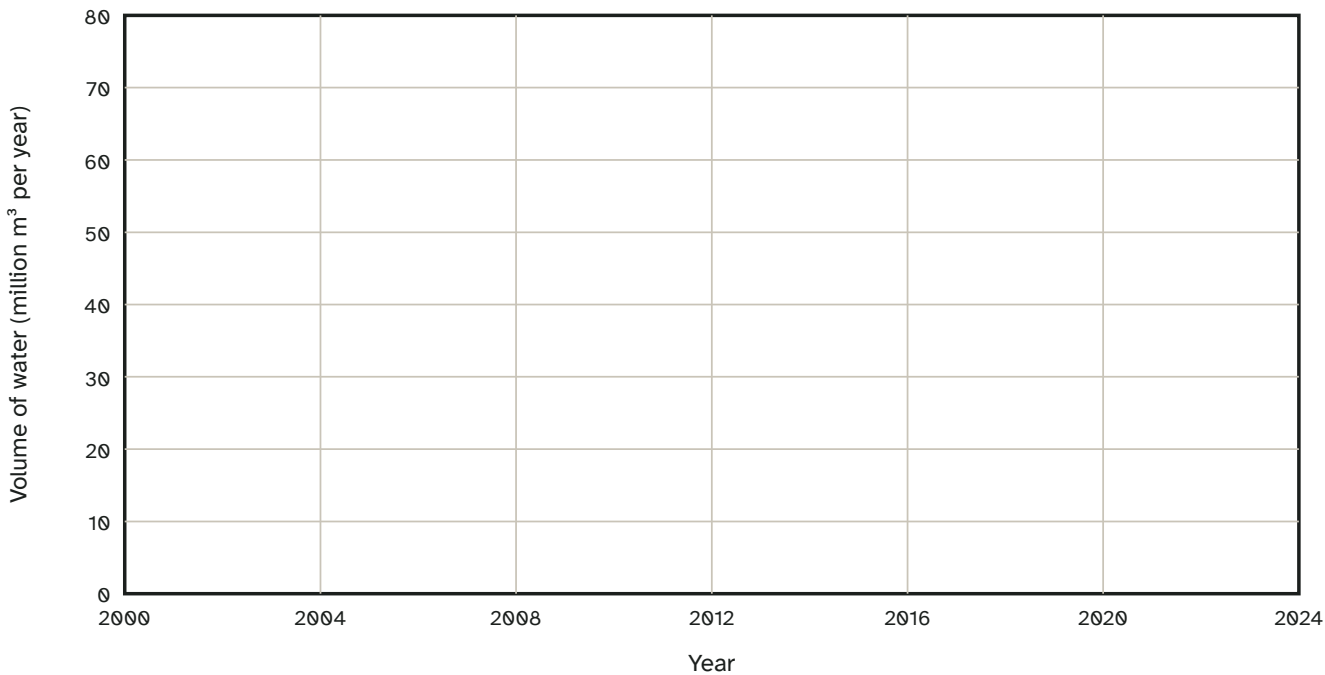
Red Mesa aquifer, 2000-2024 (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Year	Recharge (million m ³)	Pumping (million m ³)	Depth to water table (m)
2000	42	30	18.0
2004	38	38	18.0
2008	45	46	18.4
2012	31	55	20.1
2016	40	62	22.3
2020	36	70	25.0
2024	39	78	28.4

Simulated data for teaching. Volumes are in millions of cubic meters per year; depth is meters below the ground surface at the agency's monitoring well.

Recharge and pumping at Red Mesa, 2000-2024



1. For each year, subtract pumping from recharge and write whether the aquifer gained water, stayed balanced, or lost water that year.
- | Net balance = recharge – pumping (million m ³) | Gaining, balanced, or losing? |
|--|-------------------------------|
| 2000 | |
| 2004 | |
| 2008 | |
| 2012 | |
| 2016 | |
| 2020 | |
| 2024 | |
2. Describe your graph. Which line changes a lot and which stays roughly level? In which year do the lines cross, and what does crossing mean for the aquifer?
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3. Calculate the average pumping for 2016, 2020 and 2024 and the average recharge for the same three years. Then calculate how many times larger the pumping is than the recharge. Show your work.

4. Look at the depth column. Explain how the depth data support (or do not support) what your net-balance column says is happening. Why does the water table keep dropping even in a year like 2024 when recharge went up?

5. Between 2020 and 2024 the water table dropped from 25.0 m to 28.4 m. Calculate the drop per year. The town's wells reach 40 m. If the drop continues at that rate, in about what year will the water table reach the bottom of the wells? Show your work.

6. Is Red Mesa's 2024 rate of pumping **sustainable**? Use the numbers to answer. Then state the largest yearly pumping the town could use and still be roughly balanced, and explain how you chose it. Finally, say whether the aquifer's water is still a **renewable** resource, and why that is a separate question.

Part B: How much rock for a tonne of copper?

Ore grade is the percentage of a rock's mass that is the metal you want. A grade of 1 percent means 1 tonne of copper in every 100 tonnes of ore. Mining companies dug the richest ore first, so the average grade of copper ore mined worldwide has been falling for more than a century. The table describes four imaginary deposits in the same mountain range.

Four copper deposits in the Saddleback Range (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Deposit	Ore grade (% copper)	Ore mined per year (million tonnes)	Year mining began
Ridge	2.0	10	1905
Saddle	1.0	25	1950
Basin	0.5	60	1985
Flat	0.25	80	2015

Simulated data for teaching. Grades of 0.25 to 2 percent span the realistic range for copper mines today.

7. Complete the table. Show one full calculation for each column below the table.

Tonnes of ore per tonne of copper ($100 \div \text{grade}$)	Copper produced per year (million tonnes) = ore $\times$ grade $\div 100$
Ridge	
Saddle	
Basin	
Flat	

8. Which deposit produces the most copper per year, and which one digs up the most rock? Use the numbers to explain why the deposit that produces the most copper is not the one with the richest ore.

9. Look at the 'year mining began' column next to the grade column. Describe the pattern and explain what it tells you about how human choices change which copper is left in Earth's crust.

- 10.** Both parts of this sheet show a resource distribution changing because people remove the resource. Compare the two cases: what is being removed, what (if anything) replaces it, and what single number from each part best shows that the change is happening. Then say which case could be made sustainable by changing the rate of use, and why the other cannot.

Keep the units on every line

For Part A, write every subtraction as 'recharge – pumping = net', with 'million m³' after each number; a negative net means the aquifer lost water. For the drop-per-year question, first find the total drop (final depth – starting depth), then divide by the number of years between the two readings (4). For Part B, the tonnes-of-ore column is 100 divided by the grade; check it with the 1 percent row, which must come out to 100. The copper column is the ore mined times the grade, divided by 100 to turn the percent into a fraction.

Finding the sustainable yield

Hydrologists call the pumping rate an aquifer can support over the long run its sustainable yield, and it is usually a little less than the average recharge, because some groundwater must keep flowing out to springs and streams. Using all seven recharge values, compute the average recharge, then propose a sustainable yield that leaves 10 percent of the recharge for springs. Estimate how many years, at the 2024 drop rate, Red Mesa has before it must reach that yield, and write a three-sentence recommendation to the town council that names at least two ways to cut pumping.