

Dry Creek Decides: Aquifer Cups and a Twenty-Year Water Plan

Investigation question: Which of three competing water-supply plans should the town of Dry Creek adopt so that its wells still work in twenty years, and how do storage, recharge and pumping rates decide the answer?

Data-driven decision

Groups of 4

2 sessions

Setup 10 · Activity 85 · Cleanup 10 min

MS-ESS3-1 · assesses

MS-ETS1-2 · assesses

MS-ESS2-4 · supports

Name _____

Group _____

Date _____

Your role today

- ☐ **Hydrologist:** Runs the aquifer cups in session one: fills, pours, times and reads the cylinder. In session two, explains what each zone's sediment means for storage and well yield.
- ☐ **Data analyst:** Does the recharge-versus-pumping arithmetic for each plan and checks the years-of-supply calculations.
- ☐ **Engineer:** Leads the decision matrix: makes sure every plan is scored on every criterion and that any constraint violation is marked before scores are added.
- ☐ **Council reporter:** Writes the group's recommendation in the recording sheet and presents it to the class as a two-minute briefing to the 'town council'.

Safety

- Dry sand, soil and gravel raise dust; pour gently, keep the tray under the cups and do not blow on the materials. Students with asthma may wear a mask or take the data-analyst role.
- Garden soil can carry bacteria and fungi; no eating or drinking in the lab, wash hands afterward, and use potting soil instead of garden soil if anyone has a weak immune system.
- Water on the floor is a slip hazard; keep all pouring over the tray and wipe spills at once. Teacher punches the cup holes, not students; a heated nail is a burn hazard, so use a push pin where possible.
- Do not pour sand, gravel or soil down the sink; dry and reuse them or discard in the trash.

Procedure

1. Session 1, storage test. Fill one plain cup with dry gravel to the 200 mL line, tapping gently to settle it. Fill the graduated cylinder with a known volume of water. Pour slowly into the gravel until the water surface just reaches the top of the gravel. Record the volume of water that went in: that is the pore space. Repeat with sand and with the clay-rich soil in their own cups.
2. Compute porosity for each material: water added divided by 200 mL, times 100, as a percent. Record it in the cup table.

3. Drain test. Line each holed cup with a coffee filter and fill it to the 200 mL line with dry material. Hold it over the catch cup, pour 100 mL of water onto the surface all at once, and start the timer. Record how many seconds it takes for the first 25 mL to collect in the catch cup. Stop at 300 seconds and write 'more than 300 s' if it has not arrived; also note how much, if any, collected.
4. Discuss and record: which material stores the most water, which lets water through fastest, and which would make the best aquifer for a well. Match each material to a Dry Creek zone (gravel to Zone G, sand to the sandstone of Zone S, soil to the clay of Zone C) and note what the match leaves out (depth and the clay seal above Zone S).
5. Session 2, read the data. Study the Dry Creek data sheet and the three plans. For each zone, compute the sustainable pumping limit (the recharge) and the years the usable storage would last at the plan's pumping rate using $\text{years} = \text{usable storage} \div (\text{pumping} - \text{recharge})$; if pumping is no larger than recharge, write 'no decline'.
6. Check constraints first. For each plan, mark whether it stays within the \$32 million budget, diverts no more than 3 million cubic meters a year from the creek, and pumps Zone C no faster than its wells can give. A plan that breaks a constraint is marked 'fails' and is not scored further.
7. Score the surviving plans on each criterion from 1 (poor) to 4 (excellent) using the matrix guide, add the scores, and note any criterion on which a plan scores 1. Discuss whether a low score on sustainability should outweigh a high total.
8. Write the recommendation: the plan you choose, the two numbers that most support it, the strongest objection to it, and one change that would make it better. The council reporter presents it to the class.

Record your observations

Lab 3 recording sheet: Dry Creek decides

Session 1 asks a simple question with three cups: which material stores water, and which lets it flow?

Session 2 asks the town's question: three plans, one budget, twenty years. Keep the two parts connected: the cups are the zones under Dry Creek.

Session 1: aquifer cups

Material	Water added until full (mL)	Porosity (% of 200 mL)	Time for first 25 mL to drain (s)	Stores water? Flows to a well?	Dry Creek zone it stands for
Gravel					
Sand					
Clay-rich soil					

Dry Creek water data (teaching dataset)

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

Item	Zone G: river gravel, shallow, unconfined	Zone S: deep sandstone, under a clay seal	Zone C: clay-rich old lake beds	Dry Creek (surface water)
Usable stored water (Mm ³)	60	400	30	none in summer
Average yearly recharge (Mm ³ /yr)	5	0.5	0.5	winter flow 12
Recharge in a drought year (Mm ³ /yr)	2	0.5	0.3	winter flow 3
Most that wells can pump (Mm ³ /yr)	12	15	0.3	diversion limit 3
Depth to water (m)	20 to 60	300 to 500	10 to 40	surface
Age of the water	years to decades	more than 10,000 years	centuries	this winter
Ground sinks if overpumped?	slightly	yes: clay seal compacts	yes	no

Simulated data for a fictional town, invented for teaching. Volumes are in millions of cubic meters (Mm³); one Mm³ is about 400 Olympic swimming pools. Recharge values are long-term averages; drought years recharge less.

Demand and the three plans (teaching dataset)

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

Item	Plan A: Go deep	Plan B: Bank the winter	Plan C: Use less, bank, keep a backup
Town demand in 20 years (Mm ³ /yr)	9	9	7 after conservation (drip irrigation, lawn rules)
Main supply	4 deep wells in Zone S pump 9 Mm ³ /yr	Wells in Zone G pump 9 Mm ³ /yr	Wells in Zone G pump 7 Mm ³ /yr in normal years
Creek diversion	none	3 Mm ³ /yr of winter flow spread in a recharge basin, adding 3 to Zone G recharge in normal years (0 in drought years)	same recharge basin as Plan B
Drought backup	none needed; Zone S is unaffected by drought	none; keep pumping Zone G	2 small Zone S wells pump up to 3 Mm ³ /yr only in drought years, so Zone G wells pump 4
Cost (\$ millions)	18	28	31
Current demand today (Mm ³ /yr), for reference	6	6	6

Simulated plans for the fictional town of Dry Creek, invented for teaching; costs are totals for building and running each plan.

Criteria, constraints and the scoring guide — Constraints (must pass): budget no more than \$32 million; creek diversion no more than 3 Mm³/yr; Zone C pumping no more than 0.3 Mm³/yr. Criteria (score 1 to 4): (1) Meets demand for 20 years, including two drought years in a row. (2) Sustainable: average pumping from each zone no larger than that zone's recharge, so storage does not decline over 20 years; 4 = no decline, 3 = less than 10 percent decline, 2 = 10 to 30 percent, 1 = more than 30 percent. (3) Low risk of the ground sinking. (4) Cost: 4 = under \$20 million, 3 = \$20 to 25, 2 = \$25 to 30, 1 = over \$30.

Session 2: calculations

Quantity	Plan A	Plan B	Plan C
Zone pumped most, and its recharge in a normal year (with any banking)			
Normal-year change in that zone's storage per year (recharge – pumping)			
Years until usable storage is gone (storage ÷ yearly decline), or 'no decline'			
Storage change after 20 normal years (Mm ³) and as a percent			
Change in Zone G storage during two drought years in a row (Mm ³)			
Constraints: budget / diversion / Zone C (pass or fail)			

Decision matrix

Criterion	Plan A score (1-4)	Plan B score (1-4)	Plan C score (1-4)
1. Meets demand for 20 years, incl. two drought years			
2. Sustainable (storage does not decline)			
3. Low risk of the ground sinking			
4. Cost			
Total			
Any score of 1? (criterion number)			

- From the cups: which material stored the most water, which drained fastest, and which would you drill a well into? Use your numbers.

- Our recommendation to the council: the plan, the two numbers that most support it, the strongest objection, and one change that would improve it.

Analysis questions

3. Plan A pumps $9 \text{ Mm}^3/\text{yr}$ from Zone S, which recharges $0.5 \text{ Mm}^3/\text{yr}$ and holds 400 Mm^3 . How many years until the usable storage is gone, and what fraction is used in 20 years? Show the calculation.

4. In a normal year under Plan B, Zone G recharge is 5 plus 3 banked = 8 Mm^3 and pumping is 9. Compute the yearly change, the change over 20 normal years, and the change during two drought years in a row (recharge 2, no banking). Is Plan B sustainable by the scoring guide?

5. Explain why Zone S holds far more water than Zone G yet cannot be pumped sustainably at the town's demand, using the words recharge, storage and age of the water.

6. Use your cup results to explain why Zone C stores 30 Mm^3 but its wells can give only $0.3 \text{ Mm}^3/\text{yr}$, and why the ground above Zone C and Zone S can sink when they are overpumped.

- 7.** Plan A is the cheapest and scores well on cost and on surviving a drought. Give the strongest argument for choosing it anyway and the strongest argument against, and say which should win for a town planning for its grandchildren.

- 8.** The data show what geologic history put under Dry Creek: river gravel, deep sandstone filled in a wetter past, and old lake clay. Explain in two or three sentences how past processes made the three zones so different, and how the town's choice is a current process that will change them.
