Groundwater and Aquifers: Water Beneath Our Feet

- Course roadmap: what groundwater is, how aquifers store water, and how we use it
- Mental model: rain and snowmelt infiltrate, fill pores and fractures, move slowly underground
- Hidden water is easy to overlook, overpump, and contaminate
- Learning outcomes: explain groundwater plainly, read a cross-section, describe pumping and contamination
- Connect the science to your own local water supply



The Invisible Reservoir in the Water Cycle

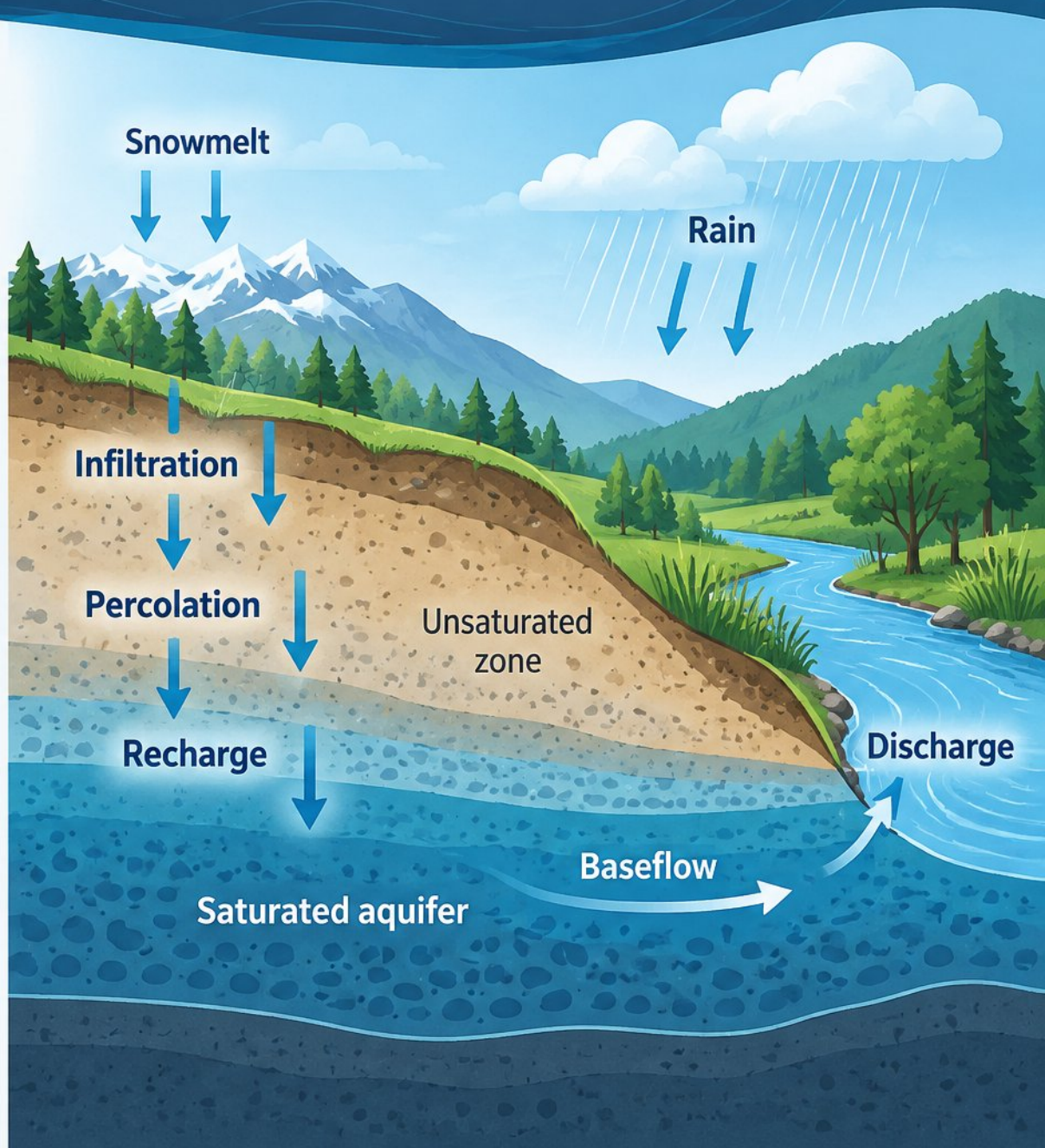
Infiltration and percolation: water moves down through the unsaturated zone

Recharge refills aquifers; discharge releases water to streams, springs, wells

Groundwater sustains baseflow between storms and supports wetlands and habitats

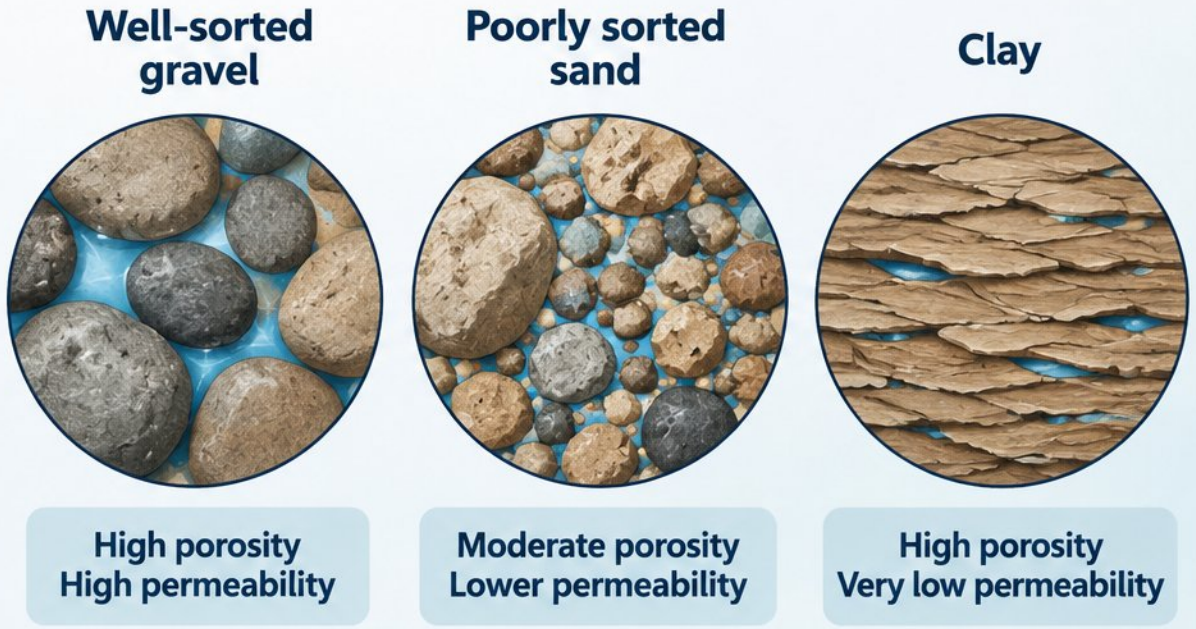
U.S. water budget: 5,000 billion gallons per day; 63% evaporates, 25% streamflow, 10% stored

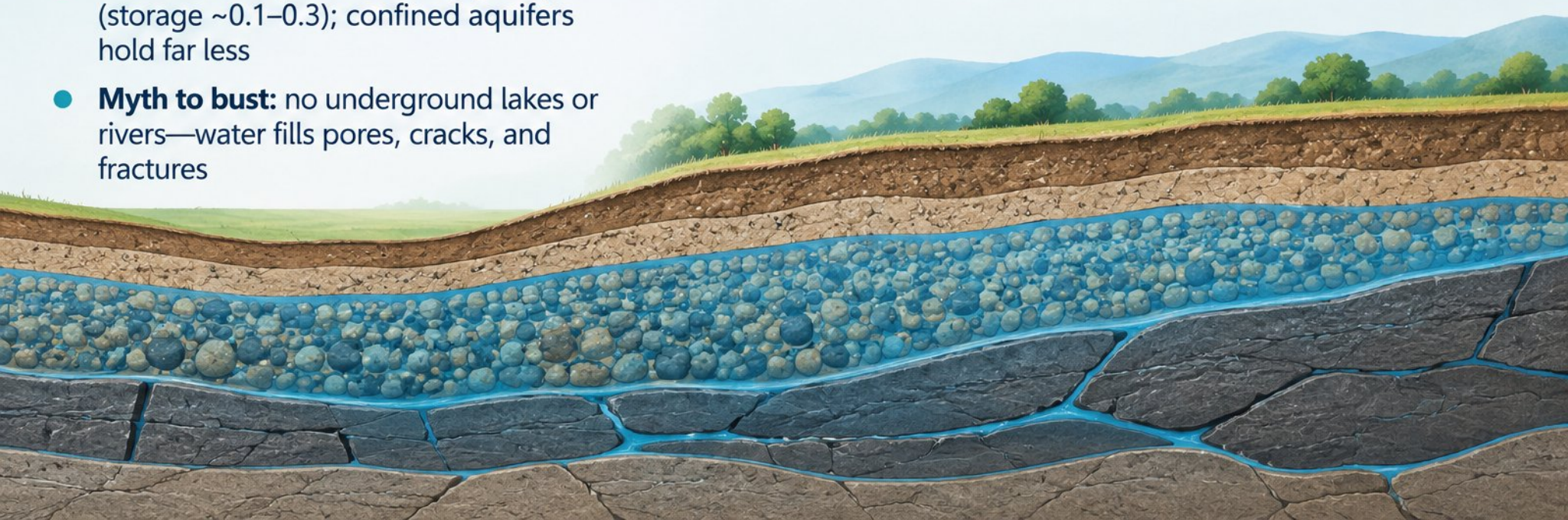
Drought buffer: deeper systems respond slowly, so effects can lag years



Inside an Aquifer: Porosity, Permeability, and Storage

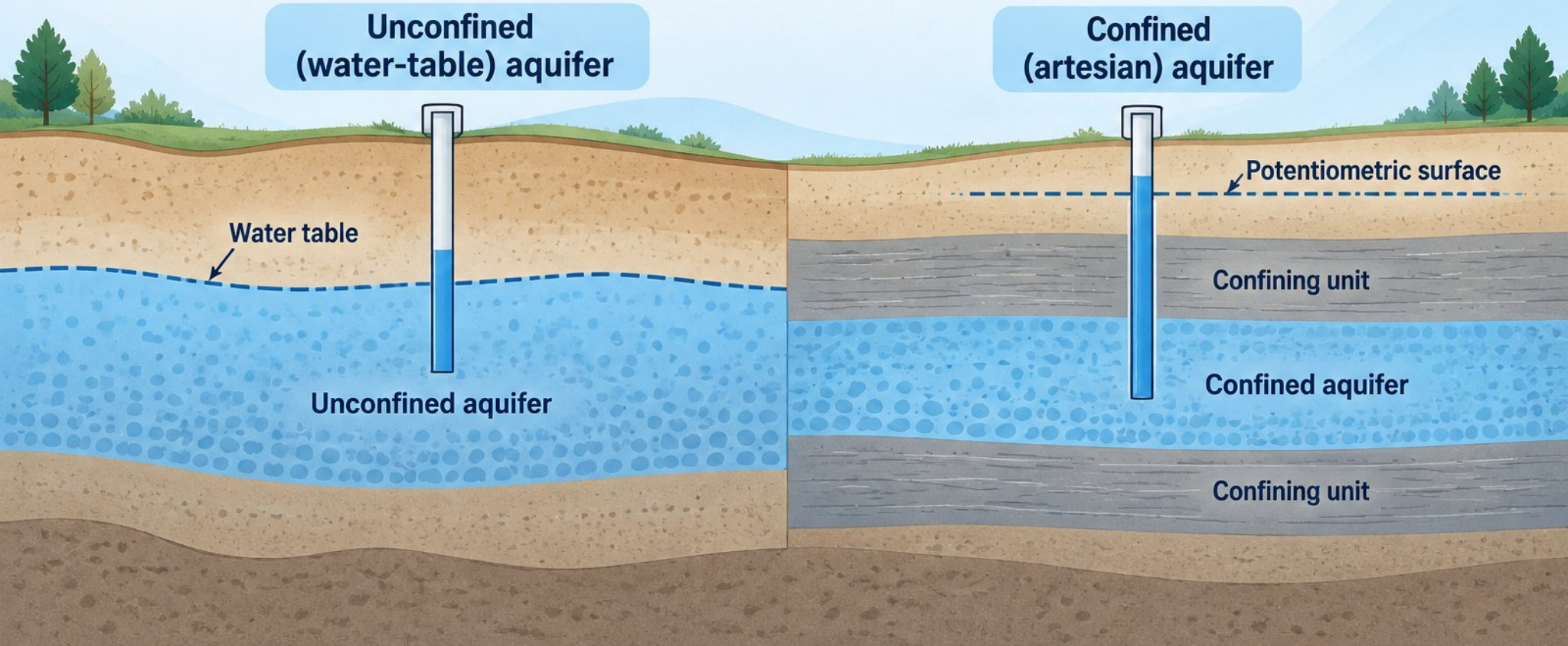
- **Aquifer:** saturated, permeable rock or sediment that yields usable water to wells and springs
- **Porosity** = how much water a material can hold; **permeability** = how easily it flows
- **Clay** is highly porous but nearly impermeable—tiny pores hold water but block flow
- Well-sorted sand and gravel store and transmit more water than poorly sorted mixes
- Unconfined aquifers drain by gravity (storage ~0.1–0.3); confined aquifers hold far less
- **Myth to bust:** no underground lakes or rivers—water fills pores, cracks, and fractures





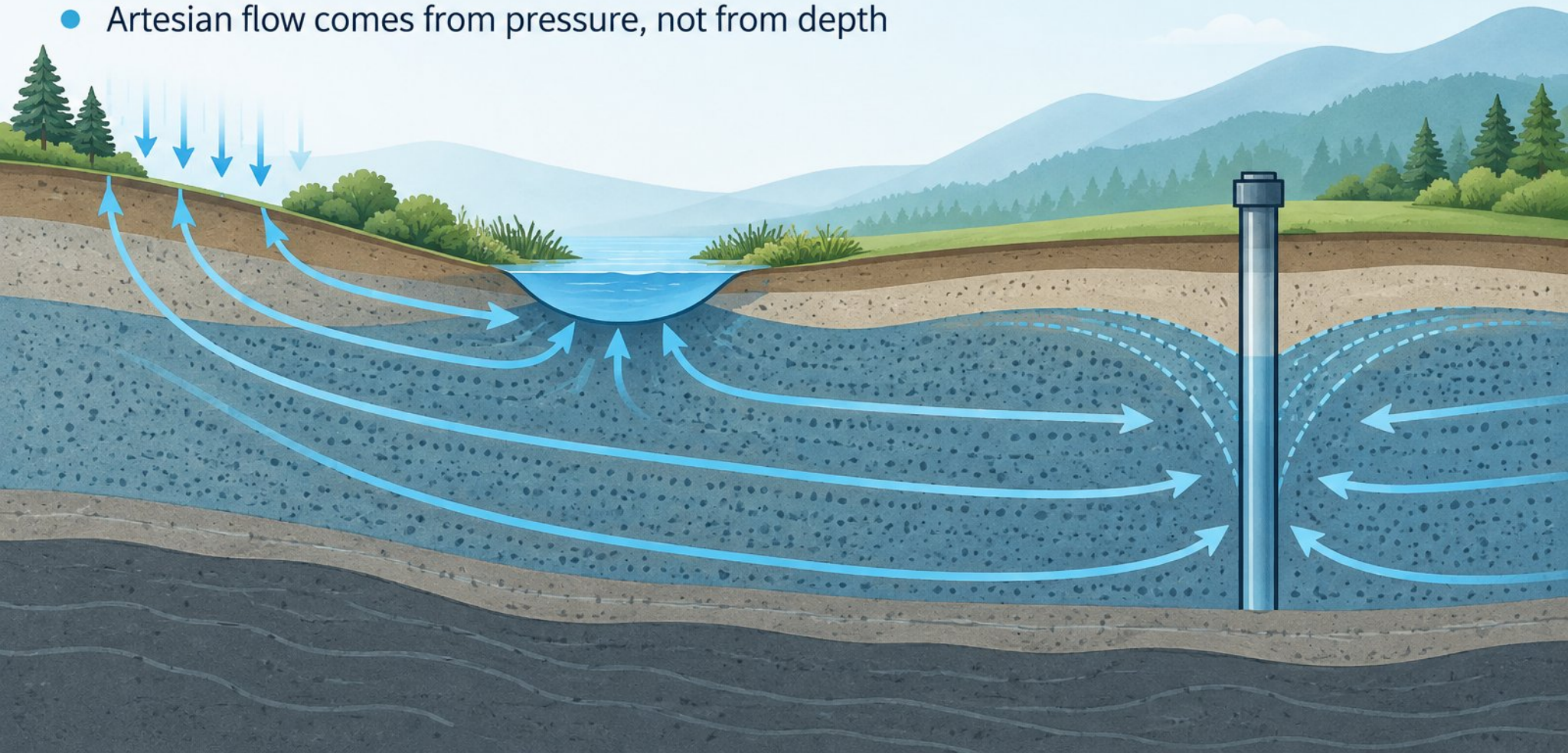
Unconfined vs. Confined Aquifers and the Water Table

- **Unconfined (water-table) aquifer:** upper saturated surface at atmospheric pressure; rises and falls with recharge and drought
- **Confined (artesian) aquifer:** sandwiched between low-permeability layers; water rises above the aquifer top in a well
- **Water table** = water level in a shallow well; **potentiometric surface** = level in a tightly cased confined well
- **Confining units** restrict flow and protect confined aquifers, but recharge slowly and are hard to clean
- From a water-supply view, rocks are either aquifers or confining beds



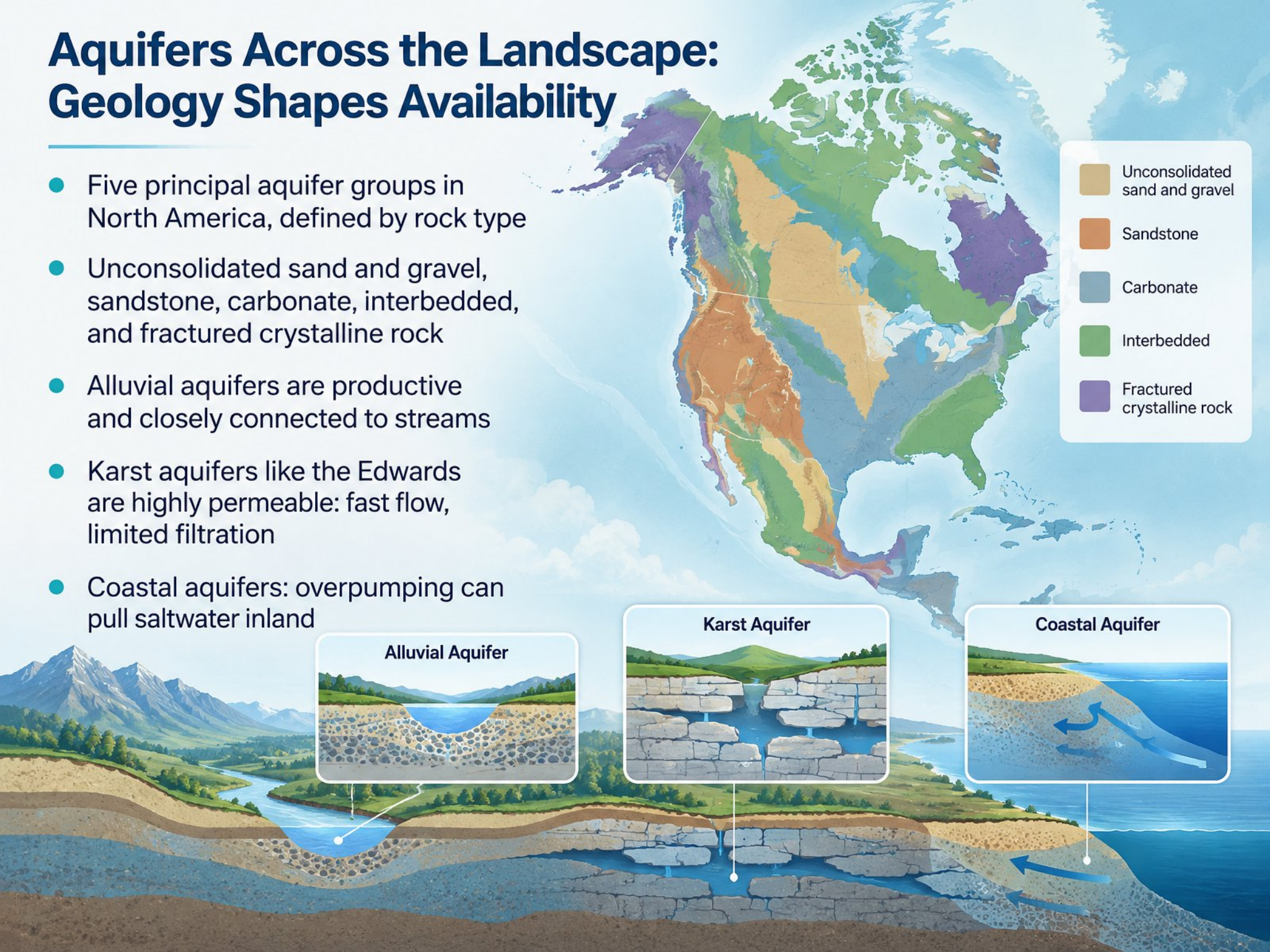
Wells, Springs, and How Water Moves Underground

- Flow runs from recharge areas to springs, streams, and wells
- Near-stream paths: tens to hundreds of feet, days to years
- Deep regional paths: miles long, decades to millennia
- Darcy's law: flow depends on permeability and hydraulic gradient
- Pumping draws down water and forms a cone of depression
- Artesian flow comes from pressure, not from depth



Aquifers Across the Landscape: Geology Shapes Availability

- Five principal aquifer groups in North America, defined by rock type
- Unconsolidated sand and gravel, sandstone, carbonate, interbedded, and fractured crystalline rock
- Alluvial aquifers are productive and closely connected to streams
- Karst aquifers like the Edwards are highly permeable: fast flow, limited filtration
- Coastal aquifers: overpumping can pull saltwater inland



What We Use Groundwater For

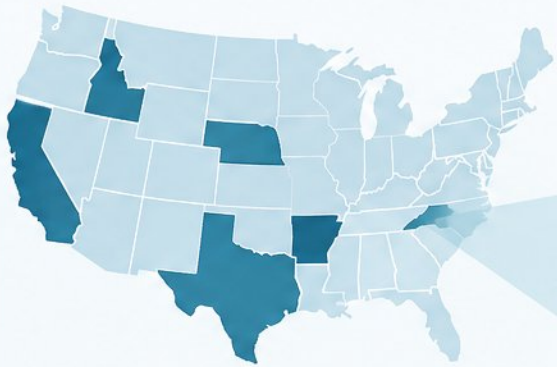
- Eight use categories: irrigation, public supply, domestic, power, industry, livestock, aquaculture, mining
- 2015 U.S. groundwater withdrawals: ~84,700 Mgal/d, 97% freshwater
- Top states: California, Arkansas, Texas, Nebraska, Idaho
- Water years 2010–20: groundwater ≈38% of freshwater withdrawals for top three uses
- High Plains: ~20,800 of 30,000 Mgal/d from groundwater
- Beyond price: rural drinking water, food, drought resilience
- Compare like with like: definitions and reporting years vary

U.S. Groundwater Withdrawals by Use Category



Top States for Groundwater Withdrawals

- California
- Arkansas
- Texas
- Nebraska
- Idaho



High Plains

~20,800 of 30,000 Mgal/d from groundwater



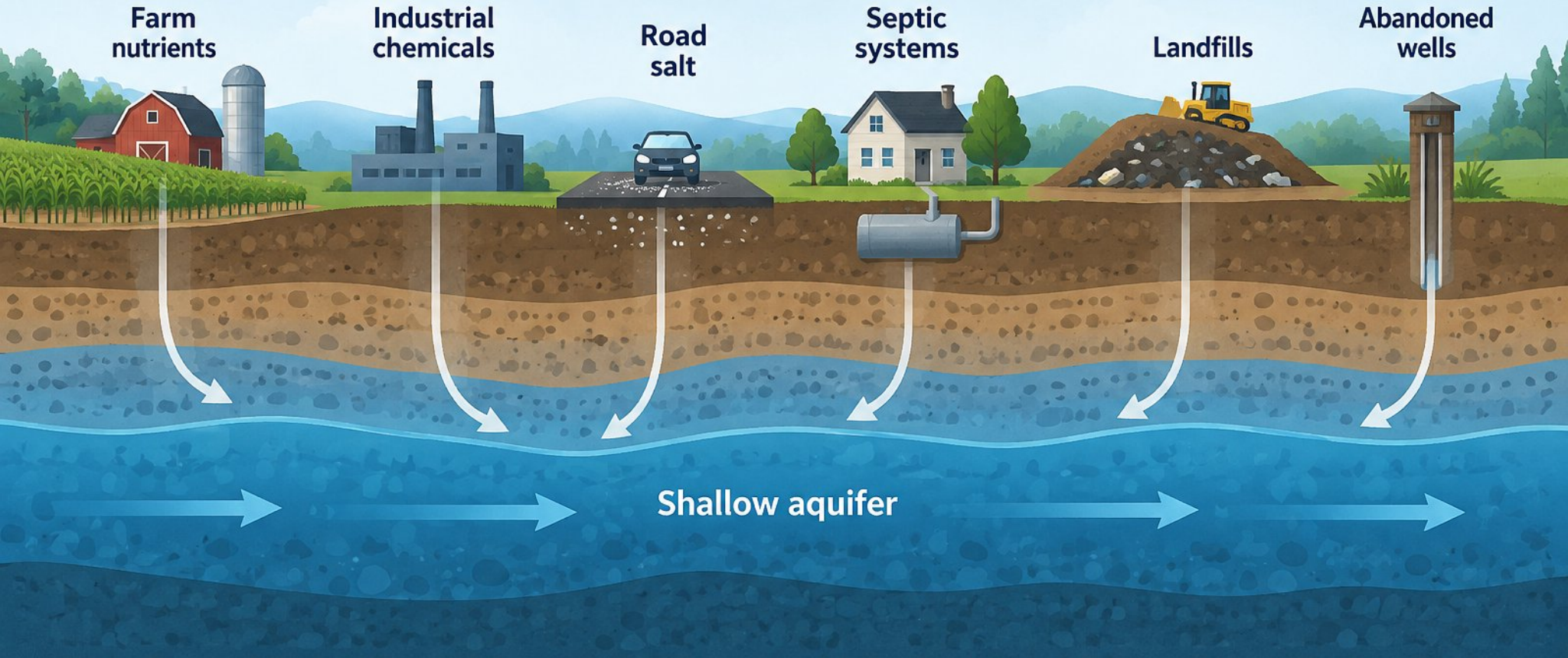
When Groundwater Is Withdrawn Too Fast

- **Overdraft:** pumping faster than recharge replaces; stored water is depleted first
- **Symptoms:** falling water tables, dry wells, less baseflow, degraded water quality
- **Land subsidence:** San Joaquin Valley among world's greatest human-induced sinking
- **Subsidence** permanently reduces aquifer storage capacity—damage is not recoverable
- **Saltwater intrusion:** coastal boundary case where overpumping pulls saltwater inland
- **Remedies:** conjunctive use, managed aquifer recharge, irrigation efficiency, demand management
- **MAR caveat:** surface application in San Joaquin Valley was relatively ineffective; deeper injection shows promise



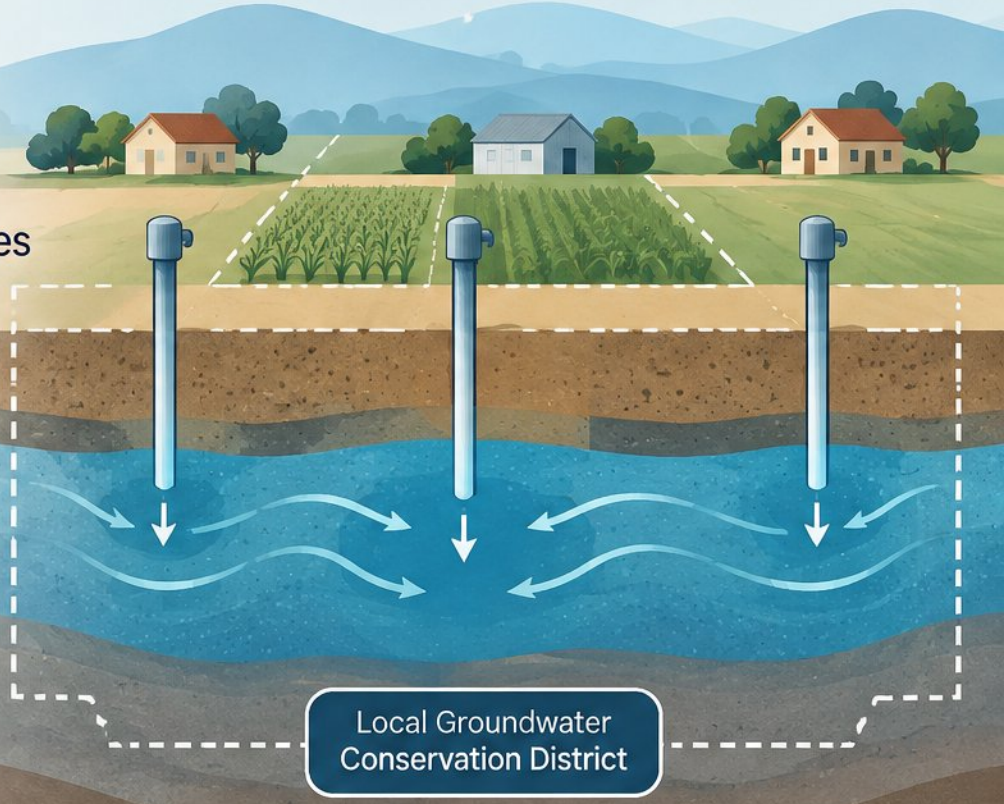
Keeping Groundwater Clean

- **Contamination pathways:** farm nutrients, industrial chemicals, road salt, septic systems, landfills, abandoned wells
- **Nitrate common:** over 40% of shallow farm wells in Minnesota exceed 10 mg/L
- **PFAS:** persistent, mobile, regulated at parts-per-trillion; in-situ destruction still lacking
- **Cleanup slow and costly:** pump-and-treat contains plumes but removes mass slowly
- **Prevention cheaper:** wellhead protection, land-use planning, monitoring, public reporting

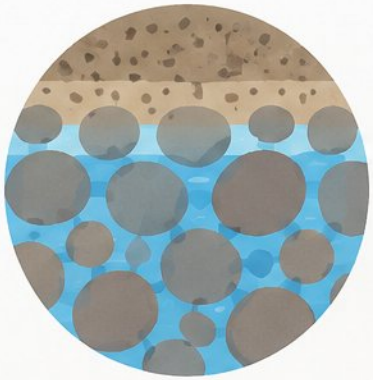


Managing a Shared, Invisible Resource

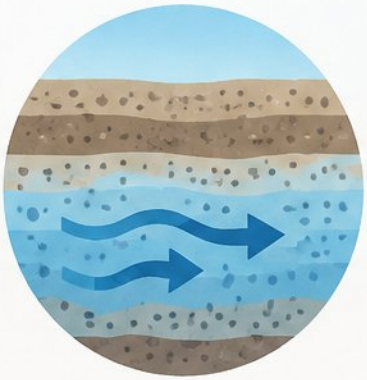
- Groundwater is a common-pool resource: one user's pumping affects neighbors
- Legal approaches vary widely by state and district—from land-ownership doctrines to permit-based areas
- Local groundwater conservation districts set plans, desired future conditions, and withdrawal rules
- California's SGMA: 80 high- and medium-priority basins now operate under approved plans
- Merced Subbasin assigns parcel allocations through Allocation Management Accounts
- Evidence-based options: measure recharge, adapt limits, monitor outcomes, address equity



Teachable Takeaways: Five Core Ideas



- Groundwater fills pores and fractures below the water table—not underground rivers or lakes



- It moves slowly, connects to streams and wetlands, and can be depleted or contaminated



- Each idea in one sentence a student could repeat to a family member



- Link to local observations: stream baseflow, a neighborhood well, a water notice

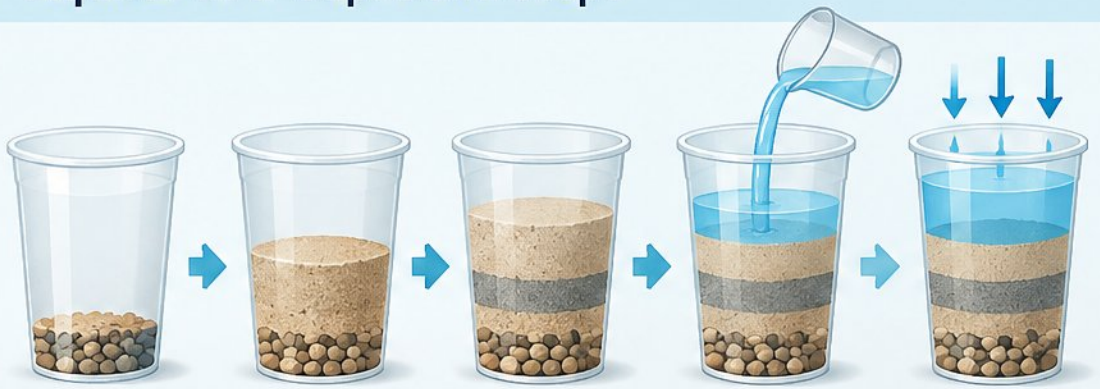


- Confront misconceptions directly: “deep means artesian” and “aquifers are unlimited”

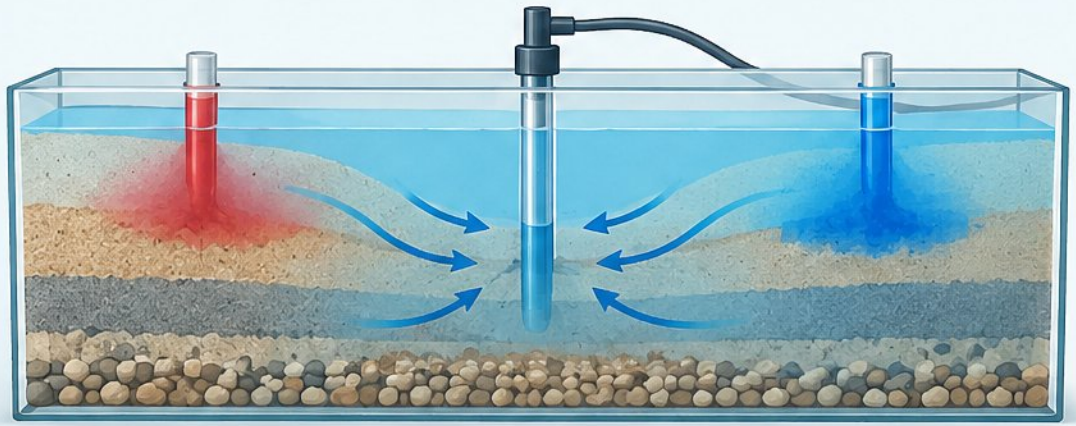
Hands-On Models: Aquifer in a Cup and Flow Tanks

- Aquifer-in-a-cup: clear cup, sand or gravel, water; 15–20 minutes
- Shows water table, saturated and unsaturated zones, and recharge
- Edible aquifer: build unconfined and confined models to compare vulnerability
- Flow tank with dye wells and pump shows flow paths, drawdown, and contamination
- Low-cost, allergy-friendly alternatives; debrief with guided questions
- Kits: Groundwater Foundation Awesome Aquifer, USGS lessons, EPA Build Your Own Aquifer

Aquifer-in-a-Cup: Build Steps



Flow Tank Model



Everyday Actions and Local Investigation

Household habits matter: fertilizer, pesticides, septic care, chemical disposal, road salt, drought conservation

Find your water source: ask your utility about groundwater vs. surface water and local aquifer names

Student investigation: locate your watershed, gaining vs. losing streams, and local monitoring wells

Share short, local, solutions-oriented messages with neighbors, school boards, and community meetings









Assessment and Discussion Prompts for Three Audiences

Students recall:
define groundwater, aquifer, water table, porosity, permeability

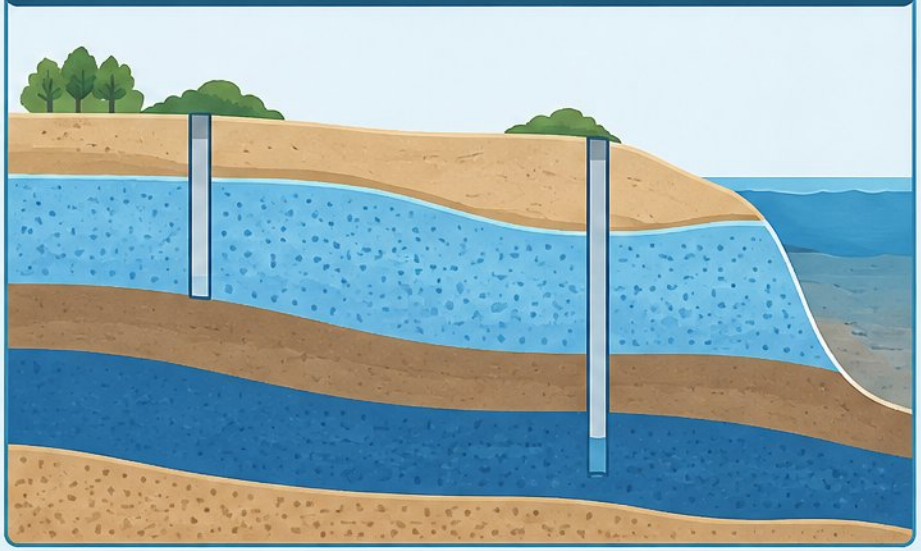
Students apply:
sketch confined and unconfined aquifers; predict water-table change

Adults decide:
new impervious development plus well drawdown—propose monitoring steps

Educators:
surface misconceptions with a model; assess against NGSS ESS2.C, ESS3.A

Wrap-up:
revisit five core ideas; name one action or one thing to teach

Sketch: Confined and Unconfined Aquifers





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