

Earth's Natural Resources: Mastery Check

Learning target: I can classify resources by how fast nature replaces them, judge whether a use is sustainable, explain how geoscience processes concentrate water, oil, ore and geothermal heat, and write an evidence-based explanation of where one California resource is found.

Retrieval and mastery check

About 45 min

Individual

MS-ESS3-1 · assesses

MS-ETS1-2 · practice

independent practice

writing

Standards connections

MS-ESS3-1 (assesses, an evidence-based explanation of one resource's uneven distribution from past geoscience processes and current human removal (Part B); Part A items are retrieval that supports it): Part B gives real evidence for oil in Kern County or gold in the Sierra Nevada foothills and asks for the explanation the PE describes: the past processes that concentrated the resource, why the neighboring area lacks it, and how human removal is changing the pattern. Items q1, q4 and q11 check the clarification's emphasis on limited, mostly nonrenewable resources whose distribution is changing as people remove them.

MS-ETS1-2 (practice, sorting criteria and constraints and justifying a chosen design (q12)): Item q12 asks students to sort the Hoover Dam team's criteria and constraints and justify the arch-gravity choice against them. It is a retrieval check on systematic evaluation, not a full evaluation of competing solutions, which W9 and Lab 3 provide.

Purpose: assess · **Time:** about 45 minutes · **Format:** individual

Answers with reasoning

Part A: Retrieval (items 1-12, 33 points)

1. Sort each resource. In the first column write **renewable** or **nonrenewable** on a human timescale. 7 pts
In the second column write one short reason based on how long nature takes to replace it, compared with a human lifetime.

Answer: a. Renewable: rain and snowmelt refill the river every year. b. Nonrenewable: it took millions of years of burial and heating to form. c. Nonrenewable: magma and hot fluids took millions of years to concentrate it. d. Nonrenewable: a single centimeter of fertile topsoil takes centuries to build from weathered rock and organic matter. e. Renewable: a planted pine stand regrows in about 15 to 25 years, within a lifetime. f. Nonrenewable: refilling it would take thousands to more than a million years, because almost no water reaches it today. g. Renewable: heat flows up from Earth's interior continuously.

Why: Every label comes from nature's clock compared with a human lifetime, which is the chapter's definition. Row f is the deep desert aquifer case named in the chapter's evidence of learning: it is groundwater, yet nonrenewable on a human timescale. Row d tests that soil is not 'always there'. Row g separates the endless heat flow from any one reservoir, which q9 then tests.

Also acceptable: For row d accept 'nonrenewable on a human timescale, though careful farming can slowly rebuild organic matter'. For row e accept 'renewable if it is replanted and cut no faster than it regrows'; a student who adds this rate condition is also right. For row g accept 'renewable, but a single geothermal field can be drawn down'.

- Correct label in all seven rows (one point per row with a reason)
- Each reason names a replacement time or process and compares it with a lifetime, not just 'it runs out' or 'it is natural'
- Row f labeled nonrenewable because of slow or no recharge, not because 'all groundwater is nonrenewable'

Where Earth's water is (U.S. Geological Survey estimates, rounded)

Part of Earth's water	Share
Fresh water, as a share of all water on Earth	about 2.5 percent
Ice caps, glaciers and permanent snow, as a share of fresh water	about 69 percent
Groundwater, as a share of fresh water	about 30 percent
Lakes, rivers, soil moisture, air and living things, as a share of fresh water	about 1 percent

Real reference values. The rest of Earth's water, about 97.5 percent, is salty, mostly in the oceans.

2. Use the table. Imagine all of Earth's water shrunk to 1,000 liters. (a) How many liters would be fresh water? (b) How many liters would be fresh groundwater? (c) How many liters would be in lakes, rivers, soil, air and living things? Show your work, then finish this sentence: 'Of the fresh water that is not frozen, most is _____.'

2 pts

Answer: (a) $1,000 \text{ L} \times 0.025 = 25 \text{ L}$ of fresh water. (b) $25 \text{ L} \times 0.30 = 7.5 \text{ L}$ of fresh groundwater. (c) $25 \text{ L} \times 0.01 = 0.25 \text{ L}$ in lakes, rivers, soil, air and living things. Sentence: 'Of the fresh water that is not frozen, most is groundwater' (7.5 L underground compared with 0.25 L at the surface, about 30 times as much).

Why: Two percentages are applied in a chain: first the share of all water that is fresh, then the share of fresh water in each store. A common error is taking 30 percent of the whole 1,000 L (300 L) instead of 30 percent of the 25 L of fresh water.

Also acceptable: Accept 7.5 to 7.53 L (30.1 percent) for (b) and 0.25 to 0.3 L for (c). A student who uses the textbook's rounded 3 percent instead of the table gets 30 L, 9 L and 0.3 L; give the reasoning credit but point back to the values given.

- Correct values 25 L, 7.5 L and 0.25 L with the multiplication shown
- Sentence completed with 'groundwater' or 'underground'

3. Two wells are drilled in the same rainy valley. Well 1 stops in a thick layer of clay. Well 2 goes deeper, through the clay, into a layer of river gravel. Well 1 gives almost no water even though the clay is soaking wet. Which explanation is best?

2 pts

Answer: B. Clay's pores are tiny and poorly connected, so water barely flows out of it; gravel has large connected pores, so water flows freely into a well.

Why: An aquifer must store water and let it flow. Clay can hold a lot of water in its tiny pores but lets it move very slowly, so it does not supply a well. Option A is the common misconception that clay is dry. C and D are not supported: clay under a rainy valley holds fresh water, and rain soaks down into clay as well as gravel.

Also acceptable: None.

The Las Arenas aquifer (teaching dataset)

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

Quantity	Value
Recharge each year	12 million m ³
Pumping each year (farms and town together)	20 million m ³
Water the wells can still reach today	400 million m ³

Las Arenas is a made-up town. These numbers were invented for this quiz; they are not measurements.

4. Use the Las Arenas dataset. (a) By how much does the water stored in the aquifer change each year? Say whether it rises or falls. (b) If recharge and pumping stay the same, in how many years will the water the wells can reach be gone? (c) Is this use of the aquifer **sustainable**? State the rule you used and the largest yearly pumping that would be sustainable. Show your work. 3 pts

Answer: (a) $12 \text{ million m}^3 - 20 \text{ million m}^3 = -8 \text{ million m}^3$: the stored water falls by 8 million m^3 each year. (b) $400 \text{ million m}^3 \div 8 \text{ million m}^3 \text{ per year} = 50 \text{ years}$. (c) Not sustainable. Rule: a use is sustainable only when the amount used each year is no greater than the amount replaced each year. Here pumping (20 million m^3) is greater than recharge (12 million m^3). The largest sustainable pumping is about 12 million m^3 per year, equal to the recharge.

Why: This is the tap-and-drain comparison in numbers. Part (b) uses the yearly loss, not the pumping: $400 \div 20 = 20$ years ignores the recharge that keeps arriving. The aquifer does recharge, so it is being refilled; the problem is the rate at which people use it.

Also acceptable: Accept 'about 12 million m^3 or a little less' for the largest pumping, since a careful planner would leave a margin for dry years. Accept 'pumping is outpacing recharge' as the rule.

- Change of 8 million m^3 per year, stated as a fall
- 50 years, from $400 \div 8$
- Says 'not sustainable' and gives the rule comparing use with replacement
- Largest sustainable pumping about 12 million m^3 per year

5. Which statement about how **petroleum** forms is accurate? 2 pts

Answer: B. It formed from tiny marine organisms buried in low-oxygen mud, slowly heated by deep burial over millions of years, then held in porous rock under a seal.

Why: Nearly all petroleum comes from microscopic sea life such as plankton, not dinosaurs (A). It forms only where organic-rich mud is buried deep enough to be heated for millions of years and the oil is then trapped (C is wrong on both place and time). Temperature rises with depth because rock is hotter deeper in Earth; heat, not pressure alone, drives the change (D).

Also acceptable: None.

6. Draw a side view (a cross-section) of a **geologic trap** that holds an oil field, with the rock layers bent upward into an arch. Label the **source rock**, the **reservoir rock**, the **cap rock (seal)**, the **oil** and the **water**. Add an arrow showing which way the oil moved after it formed, and write a few words beside the arrow saying why it moved that way. 4 pts

Answer: A cross-section with layers bent up into an arch. From bottom to top: source rock (dark shale) at the base; a porous reservoir rock (sandstone) above it, arched; a cap rock or seal (shale or salt) over the reservoir. Inside the reservoir at the top of the arch is oil (gas may be shown above it), with water below the oil in the same layer. An arrow runs from the source rock up into the reservoir and toward the top of the arch, labeled with a reason such as 'oil is lighter than water, so it rises through the pores until the seal stops it'.

Why: The drawing checks the full trap model from the chapter: source, reservoir and seal in the right order, oil floating on water at the crest, and buoyancy as the reason oil migrates upward. It is the 'sealed trap' step of the oil recipe in q5.

Also acceptable: A fault trap, where a tilted reservoir is cut off by a fault against sealing rock, earns full credit if it is labeled correctly, even though the prompt asks for an arch. Gas above the oil is a bonus, not a requirement.

- Layers arched upward with source rock below the reservoir and the cap rock directly above the reservoir
- Oil drawn at the top of the arch inside the reservoir, with water below it
- All five labels present
- Arrow pointing upward from the source rock or along the reservoir toward the crest, with a buoyancy reason

7. Many of the world's largest copper deposits lie along the Andes of South America, a mountain belt where one tectonic plate sinks beneath another. Which chain of processes best explains why the copper is there? 2 pts

Answer: A. A plate sinks, magma forms and rises into the crust, hot fluids from the magma carry dissolved copper through cracks, and copper minerals are left behind as the fluids cool.

Why: This is the hydrothermal-fluid model for porphyry copper, the type of deposit that supplies most of the world's copper. It explains why big copper deposits line up along present and past subduction zones. B describes placer deposits, which are not how large copper ores form; C mixes up the oil recipe with ore; D denies the uneven distribution the question describes.

Also acceptable: None.

8. A company wants to build a new **geothermal energy** power plant. Which site has the best evidence of a strong geothermal resource? 2 pts

Answer: B. A valley near a plate boundary with young volcanic rock, hot springs and steam vents.

Why: Geothermal energy is concentrated where magma or very hot rock lies near the surface, mostly at plate boundaries and volcanic regions. Hot springs and steam vents show that groundwater is already meeting hot rock. A and C are far from any heat source; D has plenty of water and porous sediment but no unusual heat.

Also acceptable: None.

9. True or false: 'Geothermal energy is renewable, so a geothermal field can never be used up.' Circle one, then explain your answer using what happened at The Geysers in northern California. 2 pts

Answer: False. The heat flowing up from Earth's interior keeps coming, so geothermal energy is renewable, but each field depends on the hot water or steam stored in its rock. At The Geysers, operators took out more steam than nature replaced, and the steam pressure fell in the 1980s. Treated wastewater is now piped in and injected to refill the field. Renewable does not mean unlimited: the field lasts only if it is used no faster than it is replenished.

Why: This is the chapter's central misconception. The textbook calls Earth's heat inexhaustible; the accurate statement separates the endless heat flow from a reservoir that can be drawn down.

Also acceptable: Accept 'the field cooled or lost pressure' for the fall in output, and 'they pump water back down' for the injection. A student who does not remember the 1980s date still earns full credit for the mechanism.

- Circles false
- Separates the continuing heat supply from the water or steam in one field
- Uses The Geysers: pressure or output fell when more steam was taken than returned
- Mentions injecting water (or using the field no faster than it is replaced) as the fix

10. Cattle overgraze a hillside farm, and in ten years wind and rain strip away 2 centimeters of topsoil. 2 pts
- (a) Explain how soil forms and why the farmer cannot expect those 2 centimeters to come back within a lifetime. (b) Name one practice that would protect the soil that is left.

Answer: (a) Soil forms as rock at the surface weathers, physically and chemically, into small grains, and living things add organic matter as dead plants and animals decay. Building even one centimeter of fertile topsoil usually takes centuries, so 2 centimeters could take several hundred years or more to replace, far longer than a lifetime, while erosion removed it in ten years. (b) Any one: limit grazing or rotate the cattle so plant cover grows back; plant cover crops or grass; build terraces or plow along the contour; plant windbreaks; reduce tillage.

Why: On a human timescale fertile topsoil is nonrenewable because it is lost far faster than it forms. The textbook's Ethiopia example and the chapter's accuracy note both stress that good practices can protect and slowly rebuild soil.

Also acceptable: Accept 'hundreds to thousands of years' for the formation time. Accept 'keep plants on the soil' as the practice.

- Formation names weathering of rock and added organic matter
- Compares a formation time of centuries with the ten-year loss or with a lifetime
- Names one realistic protective practice

11. Copper mines today dig up rock with much less copper in it than the rock miners dug a century ago. (a) Explain why, using the words **ore** and **nonrenewable**. (b) Name one way people now get copper without digging new ore, and say why it helps. 2 pts

Answer: (a) The richest, easiest copper ore was mined first and is now used up. Copper ore is nonrenewable because magma and hot fluids took millions of years to concentrate it, so mined deposits are not replaced. Companies therefore mine lower-grade deposits, rock that now counts as ore only because large machines and higher demand make it pay. Human removal has changed where minable copper is found. (b) Recycling copper from old wires, pipes, motors and electronics. The copper is already concentrated, so no new ore has to be dug, less waste rock is left behind and less energy is used.

Why: This applies the PE's emphasis that resource distributions are changing through human removal. Ore is defined by whether mining pays, so the line between ore and ordinary rock moves as rich deposits run out.

Also acceptable: For (b) accept 'reusing copper parts' or 'using less copper'; recycling is the expected answer.

- Uses 'ore' correctly (rock with enough metal to mine at a profit)
- Uses 'nonrenewable' with the reason (millions of years to form, not replaced)
- Explains that the rich deposits were removed first
- Names recycling (or reuse) and why it helps

12. The Hoover Dam team compared five types of dam. Write C (criterion: what success required) or K 3 pts
(constraint: a limit the design had to fit) beside each: (a) store enough Colorado River water for the growing Southwest ___ (b) the cost to build and maintain the dam ___ (c) protect towns downstream from floods ___ (d) the shape of the canyon and its rock ___ (e) harm to the river's ecosystems ____.
Then explain in one or two sentences why the team chose an arch-gravity dam even though it cost more than an earth or rockfill dam.

Answer: (a) C (b) K (c) C (d) K (e) K. The project's criteria, storing a huge reservoir, making electricity and protecting towns from floods, needed the strongest design for this canyon. The arch curves upstream so part of the water's push goes into the canyon walls, and the wide concrete base resists by its own weight. The cheaper earth and rockfill designs were judged unable to meet those criteria at this site, so the team accepted the higher cost.

Why: Criteria define what success looks like; constraints are limits on the solution. The lesson lists water storage, electricity and flood protection as the criteria, and cost, the landscape and environmental harm as the constraints. A systematic evaluation keeps the design that meets the criteria within constraints the team can accept.

Also acceptable: Accept 'it was the strongest design' as the core reason. Do not require the arch-and-weight mechanism, but credit it. A student who notes that earth dams hold big reservoirs elsewhere and that the comparison was for this canyon is reading the evidence well.

- All five labels correct
- Says the arch-gravity dam was chosen because it met the criteria (strength for storage, power and flood control) at this site
- Treats cost as a constraint that was accepted, not ignored

Part B: Synthesis (item 13, 7 points)

Two California resources are described below. Every numbered fact is a real reference fact, simplified for this quiz. Choose **one** set, A or B, and use its facts as your evidence.

Evidence sets for Part B (real reference facts)

Fact	Set A: oil in Kern County	Set B: gold in the Sierra Nevada foothills
1	Oil fields crowd into the southern San Joaquin Valley in Kern County, around and west of Bakersfield. The Sierra Nevada, just to the east, is made mostly of granite and has no oil fields.	Gold-bearing quartz veins, called the Mother Lode, form a narrow belt in the western foothills of the Sierra Nevada. There are no hard-rock gold mines on the flat floor of the Central Valley just to the west.
2	Much of the oil formed in the Monterey Formation, a layer of shale built largely from the remains of microscopic marine plankton, laid down in sea basins roughly 6 to 16 million years ago.	The Sierra Nevada is built mostly of granite that cooled from magma. The magma rose above an ancient subduction zone, where an ocean plate sank beneath the western edge of North America.
3	In the deepest part of the basin, several kilometers of younger sediment buried the shale. At those depths the rock is hot enough, roughly 60 to 120 °C, to turn organic matter into oil over millions of years.	The veins formed more than 100 million years ago, when hot water moving through cracks in the rock deposited quartz and gold as it cooled.
4	The oil moved upward through porous sandstone and collected where sandstone layers are bent into folds or cut by faults, beneath layers of shale or clay that seal them.	Gold is about seven times denser than quartz sand. Where weathering broke the veins apart, streams carried the gold and dropped it in gravel where the water slowed. Flakes found in this gravel at Sutter's Mill on the American River in 1848 started the Gold Rush.
5	The Kern River field near Bakersfield has produced oil since 1899. California now produces less than half as much oil each year as it did in the mid-1980s.	Within about ten years, miners had taken most of the gold that was easy to reach in stream gravel. Hydraulic mining then washed whole hillsides into rivers until a federal court ruling largely ended it in 1884.

Real reference facts, rounded and simplified for this quiz.

13. Write a scientific explanation (6-8 sentences) of why the resource in your chosen set is concentrated where it is and not in the neighboring area named in Fact 1. Your explanation must: (1) state a claim; (2) cite at least three numbered facts as evidence; (3) name the past geoscience processes that concentrated the resource, in the order they happened; (4) explain why the neighboring area lacks the resource; (5) describe how a current process, human removal, is changing where the resource is found; and (6) say whether the resource is renewable on a human timescale, and why. Write the letter of your set at the start.

7 pts

Answer: Model for Set A: A. Oil is concentrated under the southern San Joaquin Valley because every step of the oil recipe happened there, while the granite Sierra Nevada never had the ingredients (Fact 1). First, microscopic plankton settled into sea-floor mud and became the organic-rich Monterey shale roughly 6 to 16 million years ago (Fact 2). Next, kilometers of younger sediment buried that shale deep enough to heat it to about 60 to 120 °C, which slowly turned the organic matter into oil (Fact 3). Then the oil rose through porous sandstone until folds, faults and shale seals trapped it (Fact 4). The Sierra Nevada lacks oil because granite cooled from magma: it contains no buried marine mud to make oil and no porous sealed layers to hold it. Today people are removing the oil far faster than it formed: Kern River has produced since 1899 and the state's output has fallen by more than half since the mid-1980s (Fact 5), so fields are being drained. Petroleum is nonrenewable because it took millions of years to form and is being used up in decades. Model for Set B: B. Lode gold is concentrated in a belt along the western Sierra foothills because that is where hot fluids moved through the rock during the magmatism that built the range (Facts 1 and 2). Magma rose above a subduction zone and cooled into the Sierra's granite, and more than 100 million years ago hot water moving through cracks deposited quartz and gold as veins (Facts 2 and 3). Later, weathering broke the veins apart, and because gold is about seven times denser than sand, streams dropped it in gravel close to the veins, forming the placer deposits found at Sutter's Mill in 1848 (Fact 4). The floor of the Central Valley has no hard-rock mines because it is a basin of younger sediment, not rock that the hot fluids passed through, so there are no veins at the surface to mine (Fact 1). People changed the map fast: within about ten years most easy placer gold was gone, and hydraulic mining washed whole hillsides away until 1884 (Fact 5). Gold ore is nonrenewable because the veins took millions of years to form and placers take thousands of years to collect, far longer than a lifetime.

Why: This item is the chapter's PE in miniature: an evidence-based explanation of an uneven distribution from past processes, plus the current process of human removal. Score the required elements, not the model wording. Suggested points: claim 1; at least three facts cited accurately 1; past processes named in a correct order 2; why the neighboring area lacks it 1; current human removal changing the distribution 1; renewable or not, with a replacement-time reason 1.

Also acceptable: Six sentences that cover every element earn full credit; extra length does not. For Set B, accept an explanation of the placer gold alone if it still traces the gold back to the veins and the veins to hot fluids above the subduction zone. For Set A, accept 'the Sierra Nevada is igneous rock' or 'formed from magma, not from sea mud' as the reason it lacks oil.

- States a claim about why the resource is here and not in the neighboring area
- Cites at least three numbered facts accurately
- Names the past processes in a correct order (A: plankton mud, burial and heating, migration, trap; B: subduction and magma, hydrothermal veins, weathering and stream concentration)
- Explains the neighboring area's lack with a missing process or ingredient (A: granite has no source rock or trap; B: valley floor is younger sediment with no veins at the surface)
- Describes human removal as a current process that is changing the distribution, with evidence from Fact 5
- States nonrenewable on a human timescale with a formation-time reason

Teacher notes

Points: q1 7, q2 2, q3 2, q4 3, q5 2, q6 4, q7 2, q8 2, q9 2, q10 2, q11 2, q12 3, q13 7; total 40. Misconception sentinels: q1 row f (groundwater can be nonrenewable on a human timescale), q1 row d (soil is not always there), q5 options A and D (dinosaurs; pressure without heat) and q9 (renewable means unlimited); a miss on any of these points back to W7 and the slide 25 misconception. The quiz uses the chapter's two separate questions: q1 asks for the renewable label from nature's replacement time compared with a lifetime, and q4 and q9 ask whether a use is sustainable by comparing the use rate with the replacement rate, so students should answer the Las Arenas item with 'not sustainable' rather than with a label for groundwater in general. The water-budget values in q2 are rounded USGS estimates, as on slide 8; the textbook rounds fresh water to 3 percent. The Las Arenas numbers are invented and labeled as a teaching dataset. Part B uses real, rounded reference facts; students need no outside knowledge beyond the processes taught in the chapter. For q13, score the six elements in the reasoning rather than matching the model; both sets are equally demanding, and Set B asks students to connect two kinds of deposit (lode veins and placers).

Scaffold offered to students: Two rules and a clue strip

Rule 1, renewable or nonrenewable: can nature replace it within about a human lifetime? Rule 2, sustainable or not: is it used no faster than nature replaces it? Clue strip: buried plankton-rich marine shale + deep burial + porous sandstone under a seal → oil. Old volcanoes or granite with quartz veins above a sinking plate → copper or gold. Young volcanic rock, hot springs, plate boundary → geothermal heat. Thick gravel or sand + rain or snowmelt → groundwater. Part B frame: 'The resource is concentrated in ___ because ___. Fact __ shows ___. First ___, then ___, finally ___. The neighboring area lacks it because ___. Today people are changing the pattern by ___ (Fact 5). On a human timescale it is ___ because ___.'

Extension: Same map, different eras

Kern County's oil and the Mother Lode's gold lie only a few hundred kilometers apart on a map of California. Using both evidence sets, explain how they can be neighbors even though they formed in different eras by different processes, one in rock built from magma and the other in a sediment-filled basin beside it. Then pick the set you did not use in Part B, name the one fact that is the weakest evidence for why the neighboring area lacks the resource, and describe a new measurement (for example a rock core, a temperature log or a map of vein ages) that would make the explanation stronger.