

What Holds a Hillside Up? Slope, Water and Earth Material

Learning target: I can use evidence from a reading to explain how slope steepness, saturation and earth material decide whether a hillside fails, and how communities use that knowledge to forecast landslides and reduce harm.

Reading with evidence

About 40 min

Individual

MS-ESS3-2 · practice

MS-ESS2-2 · supports

reading

writing

Standards connections

MS-ESS3-2 (practice, which data forecast mass wasting and how mitigation targets each cause): Students use the passage to identify the data that forecast where slopes fail (steepness, material, old slides, shaking, rainfall intensity after fire) and to match mitigation to each cause. This builds the reasoning the PE asks for; students are not yet analyzing a dataset themselves.

MS-ESS2-2 (supports, rapid landslides as catastrophic surface events): The PE's clarification names rapid landslides as a small-scale, sudden process that changes Earth's surface. The California cases show slopes that held for years and then failed in minutes, but students do not construct the full explanation this PE asks for.

Purpose: build · **Time:** about 40 minutes · **Format:** individual

Answers with reasoning

The Tug-of-War on Every Slope

[1] Every hillside is in a quiet tug-of-war. Gravity pulls each grain of soil and each block of rock toward lower ground. Holding material in place are friction between grains, the grip of plant roots, and the natural cement and clay that bind particles together. While the holding side is stronger, the slope stays put. When gravity wins, soil and rock move downhill, and geologists call that mass wasting. To judge which side is winning, they look at three things: how steep the slope is, how much water is in the ground, and what the slope is made of.

[2] **Steepness.** On flat ground, gravity pulls straight down into the earth, so nothing slides. Tilt the ground and part of that pull now points along the surface, downhill. The steeper the slope, the larger that downhill part becomes, and the smaller the part that presses grains together, which is what creates friction. Pour dry sand into a pile and its sides settle at roughly 30 to 35 degrees; extra grains simply slide off. Natural slopes steeper than that stay up only because roots, cement or interlocking rock add strength. Anything that steepens a slope moves it closer to failure: a river cutting into the bottom of a hill, waves undercutting a sea cliff, or a bulldozer carving a road.

[3] **Water.** A small amount of water can actually help. Damp sand lets you build a tall sandcastle wall because thin films of water pull neighboring grains together. Once rain soaks in until every space between grains is full, though, the soil is saturated, and the help turns into harm. The water adds weight.

Even more important, water trapped in those pore spaces pushes outward on the grains and partly lifts them apart, so the friction between them drops. A hillside that held firm all summer can give way after a week of storms. That is why most California landslides happen in the wet months, and why many start a day or more after a storm begins.

[4] **Earth material.** Loose sand, weak shale and clay-rich soil fail more easily than solid granite. Clay causes extra trouble: it absorbs water and turns slick, and a clay layer underground can stop water from draining deeper, so water builds up in the soil above it. Rock shattered by faults or cracked by weathering has many weak surfaces to slide along. Wildfire changes the material too. It burns away the plants whose roots hold the soil, and it can leave the surface water-repellent, so rain rushes off instead of soaking in and carries ash, soil and rock with it.

[5] **California cases.** The beach town of La Conchita, in Ventura County, sits below a steep bluff of weak, broken sedimentary rock. In 1995 part of the bluff slid and destroyed several homes. In January 2005, after about two weeks of very heavy rain, part of that old slide moved again, and 10 people died. In January 2018, a short burst of extremely intense rain fell on mountains above Montecito that the Thomas Fire had burned weeks before, and debris flows raced down the canyons, killing 23 people. In May 2017, after an extremely wet winter, a huge slide at Mud Creek on the Big Sur coast buried about a quarter mile of Highway 1, which stayed closed for 14 months.

[6] **Forecasting and reducing harm.** No one can name the exact day a hillside will fail, but scientists can map where failures are most likely by combining slope steepness, rock and soil types, the locations of old landslides and expected earthquake shaking. After a wildfire, they estimate how likely debris flows are in each burned canyon and how intense the rain must be to set them off, so forecasters can warn people when a storm that strong is coming. Engineers attack each cause: drains pull water out of a slope, retaining walls and anchored nets hold material back, new plants protect the surface, and debris basins catch flows before they reach homes. The strongest plans combine several defenses with warnings, so people can leave before a slope lets go.

Part A: What the passage says

1. Using P2, explain why making a slope steeper brings it closer to failing. Your answer must mention both parts of gravity's pull that the paragraph describes.

Answer: P2 says that on a tilted slope part of gravity's pull points downhill along the surface and part presses the grains together, which creates friction. Making the slope steeper makes the downhill part larger and the pressing part smaller, so there is more force pulling material down and less friction holding it, which moves the slope closer to failure.

Why: Full credit needs both components: the downhill pull grows and the friction-producing squeeze shrinks.

Also acceptable: Accept 'more of gravity pulls it down the hill and less holds the grains tight' as a plain-language version.

- Downhill part of gravity grows with steepness
- Part pressing grains together (friction) shrinks
- Cites P2

2. Which statement about water best matches P3?

Answer: B. A little water can hold grains together, but saturated soil is heavier and has less friction between its grains.

Why: P3 describes damp sand holding a sandcastle wall, then saturation adding weight and lowering friction. A contradicts the sandcastle example; C is never claimed; D leaves out the reduced friction, which P3 calls even more important.

Also acceptable: None.

3. P4 says a clay layer underground can make a slope more dangerous. Give the two reasons the paragraph offers.

Answer: Clay absorbs water and becomes slick, and a clay layer underground can block water from draining deeper, so water builds up in the soil above it.

Why: Both reasons appear in P4: slipperiness and trapped water above the layer.

Also acceptable: Accept 'it gets slippery and holds water in the soil on top of it'.

- Clay becomes slick when wet
- Clay layer stops water draining, so water builds up above it

4. According to P4, name two ways a wildfire makes debris flows more likely on the burned slopes.

Answer: Fire burns away the plants whose roots hold the soil, and it can leave the ground surface water-repellent, so rain runs off quickly instead of soaking in and carries ash, soil and rock with it.

Why: P4 gives exactly these two effects.

Also acceptable: Accept 'no plants to hold the dirt, and the ground sheds water'.

- Loss of roots or plants holding soil
- Water-repellent surface causes fast runoff that carries loose material

Part B: Use the evidence

5. For each California case in P5, write the evidence the passage gives about steepness, water and earth material. Write 'not stated' if the passage gives no evidence for that factor.

Answer: La Conchita 2005: steepness, the town sits below a steep bluff; water, about two weeks of very heavy rain; material, weak, broken sedimentary rock (and an old slide mass). Montecito 2018: steepness, mountains and canyons above the town (the passage implies steep ground but gives no angle); water, a short burst of extremely intense rain; material, slopes burned weeks before by the Thomas Fire. Mud Creek 2017: steepness, not stated directly (Big Sur coast); water, an extremely wet winter; material, not stated.

Why: The table checks careful reading: P5 states all three factors only for La Conchita. Students should not invent evidence that the passage does not give.

Also acceptable: Accept 'mountains and canyons' as steepness evidence for Montecito, and accept a clearly labeled inference for Mud Creek's steepness (a coastal mountain slope) if the student marks it as an inference.

- All three factors filled for La Conchita
- Intense rain and burned slopes for Montecito
- Wet winter for Mud Creek, with 'not stated' (or a clearly marked inference) for the missing factors

6. P3 says many slides start a day or more after a storm begins. Use the idea of saturation to explain why a slope might not fail during the first hours of rain.

Answer: At first the rain only dampens the soil, and a little water can even help hold grains together. It takes time for water to soak in until every pore space is full. Only when the soil becomes saturated does the trapped water add enough weight and push grains apart enough to cut friction, so failure often waits until the storm has gone on for a day or more.

Why: This applies P3's distinction between damp and saturated soil to timing.

Also acceptable: Accept 'the ground has to fill up with water first' with the friction or weight idea.

- Soaking in takes time
- Damp soil can still be strong
- Failure comes once the soil is saturated and friction drops

7. La Conchita's 2005 slide happened where part of an old slide moved again. Use P6 to explain why scientists include the locations of old landslides when they map where future failures are likely.

Answer: P6 lists the locations of old landslides as one of the data layers. An old slide mass is already broken and loosened, and the conditions that made it fail (steep ground, weak material, water) are usually still there, so it is more likely to move again, as part of the 1995 La Conchita slide did in 2005.

Why: Past events are data for forecasting: the same location tends to have the same conditions.

Also acceptable: Accept 'where it happened before it can happen again, because the ground there is already weak'.

- Cites P6
- Old slides mark places where conditions already led to failure
- Connects to La Conchita moving again

8. Choose two engineering defenses from P6. For each one, name which factor from P2 to P4 (steepness, water or earth material) it works against and explain how.

Answer: Examples: Drains pull water out of the slope, so the soil cannot become saturated; they work against the water factor. Retaining walls and anchored nets hold material back, adding strength the weak earth material lacks and resisting the downhill pull on a steep slope; they work against material and steepness. New plants grow roots that bind soil and slow runoff; they work against weak material and water. Debris basins do not stop the slope from failing; they catch the flow before it reaches homes.

Why: Each defense targets a specific cause, which is the link the PE makes between hazard data and mitigation technology.

Also acceptable: For debris basins, accept the answer that they reduce harm rather than prevent failure; this is a sharp observation, not an error.

- Two defenses named from P6
- Each matched to steepness, water or material
- Explains how each one works

9. A county can pay for only one landslide program this year: (1) a map of where slides are most likely, or (2) a rainfall warning system for canyons below last summer's burn scar. Using evidence from at least two paragraphs, argue which program you would choose for a town at the foot of those burned canyons, and explain why either program gives a forecast rather than an exact prediction.

Answer: Example: For a town at the mouth of recently burned canyons, I would choose the rainfall warning system. P4 explains that burned slopes shed water and loose material, and P5 shows that in Montecito the deadly debris flows came from a short burst of intense rain on burned slopes. P6 says scientists can estimate how intense the rain must be to set off debris flows, so a warning tied to the forecast storm gives people time to leave. A slide-likelihood map (P6) is valuable for deciding where to build, but this town already knows its canyons are dangerous. Both programs give forecasts, not exact predictions: the map says where failure is more likely, and the warning says a dangerous storm is coming, but neither can say which slope will fail or at what minute.

Why: Either choice can earn full credit if it is justified with passage evidence and the student explains why the result is a likelihood rather than an exact prediction.

Also acceptable: Choosing the map earns full credit if the student argues that it guides long-term decisions for the whole county (where to build, which roads to reinforce) and acknowledges what it cannot do for this town during the next storm.

- Clear choice
- Evidence from at least two paragraphs, named
- Reasoning connects the program to the town's situation
- Explains why the program forecasts likelihood rather than an exact time and place

Teacher notes

The passage has 679 words. Facts were checked against USGS and news sources: La Conchita's 2005 slide followed about 15 days of near-record rain, killed 10 people and destroyed or seriously damaged 36 houses (USGS Open-File Report 2005-1067); the Montecito debris flows of January 9, 2018 killed 23 people after intense rain on the Thomas Fire burn area; the Mud Creek slide of May 20, 2017 buried about a quarter mile of Highway 1, which reopened on July 18, 2018. The 30 to 35 degree figure is the usual range for the angle at which dry sand piles settle. The explanation of saturation (water in the pores pushes grains apart and reduces friction) is the middle-school version of what engineers call pore-water pressure; it is accurate as stated. Watch for students who read P3 as 'water is always bad'; q2 and q6 target that.

Scaffold offered to students: A three-column reading guide

Before answering, fold a scrap of paper into three columns labeled Steepness, Water and Material. As you reread P2 to P6, write a few words in the right column each time the passage explains how that factor helps or hurts a slope, along with the paragraph number. Most answers in Part B can be built straight from your columns.

Extension: Why not just pave it?

A neighbor suggests covering a whole hillside with concrete so rain cannot soak in. Using the passage's ideas about water and earth material, write a paragraph about what this would fix and what new problems it could cause, such as where the runoff would go and what happens if water still seeps in from above or behind the concrete. Propose a better combination of defenses and explain your reasoning.