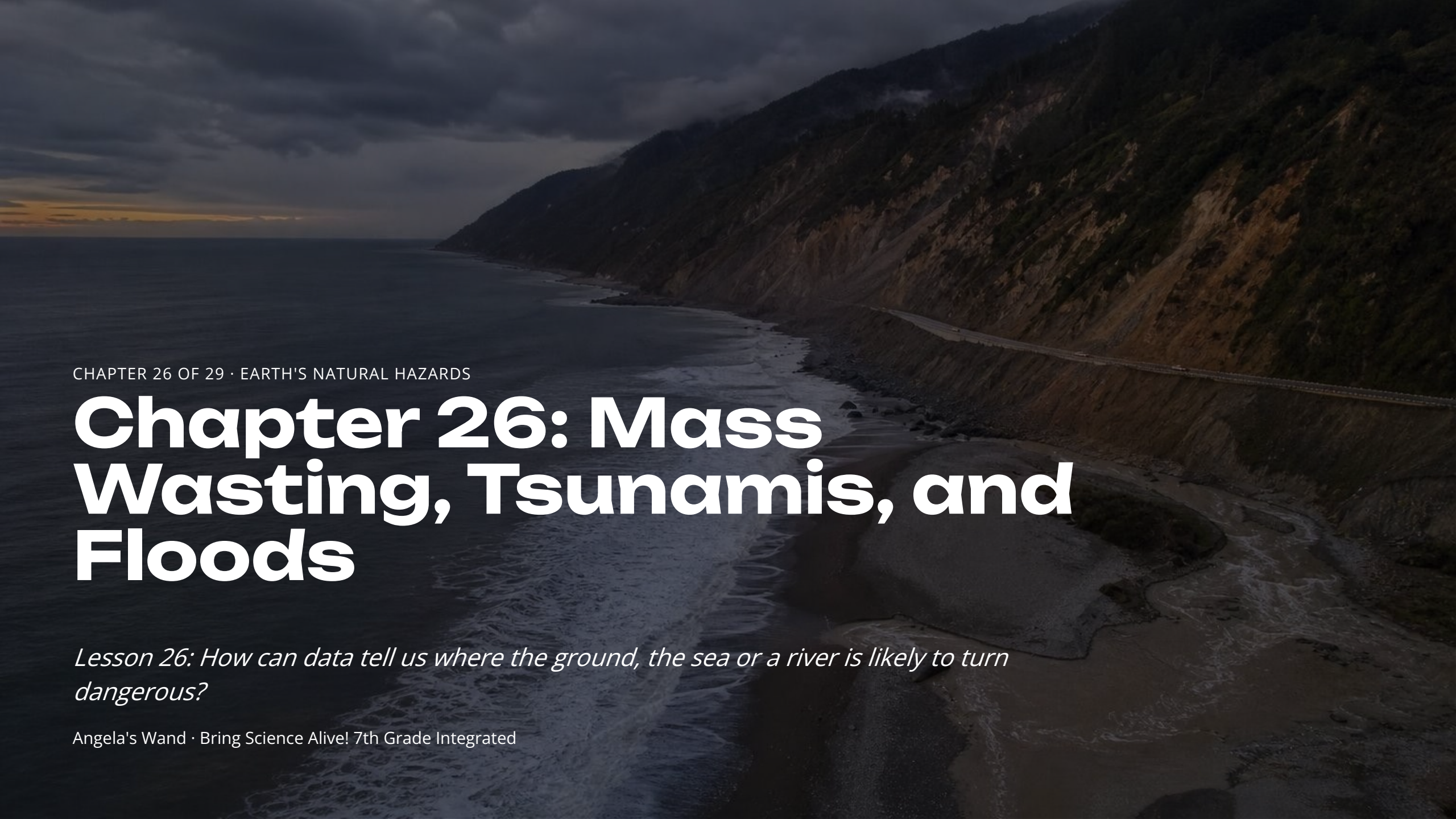




CHAPTER 26 OF 29 · EARTH'S NATURAL HAZARDS

Chapter 26: Mass Wasting, Tsunamis, and Floods

Lesson 26: How can data tell us where the ground, the sea or a river is likely to turn dangerous?

Angela's Wand · Bring Science Alive! 7th Grade Integrated

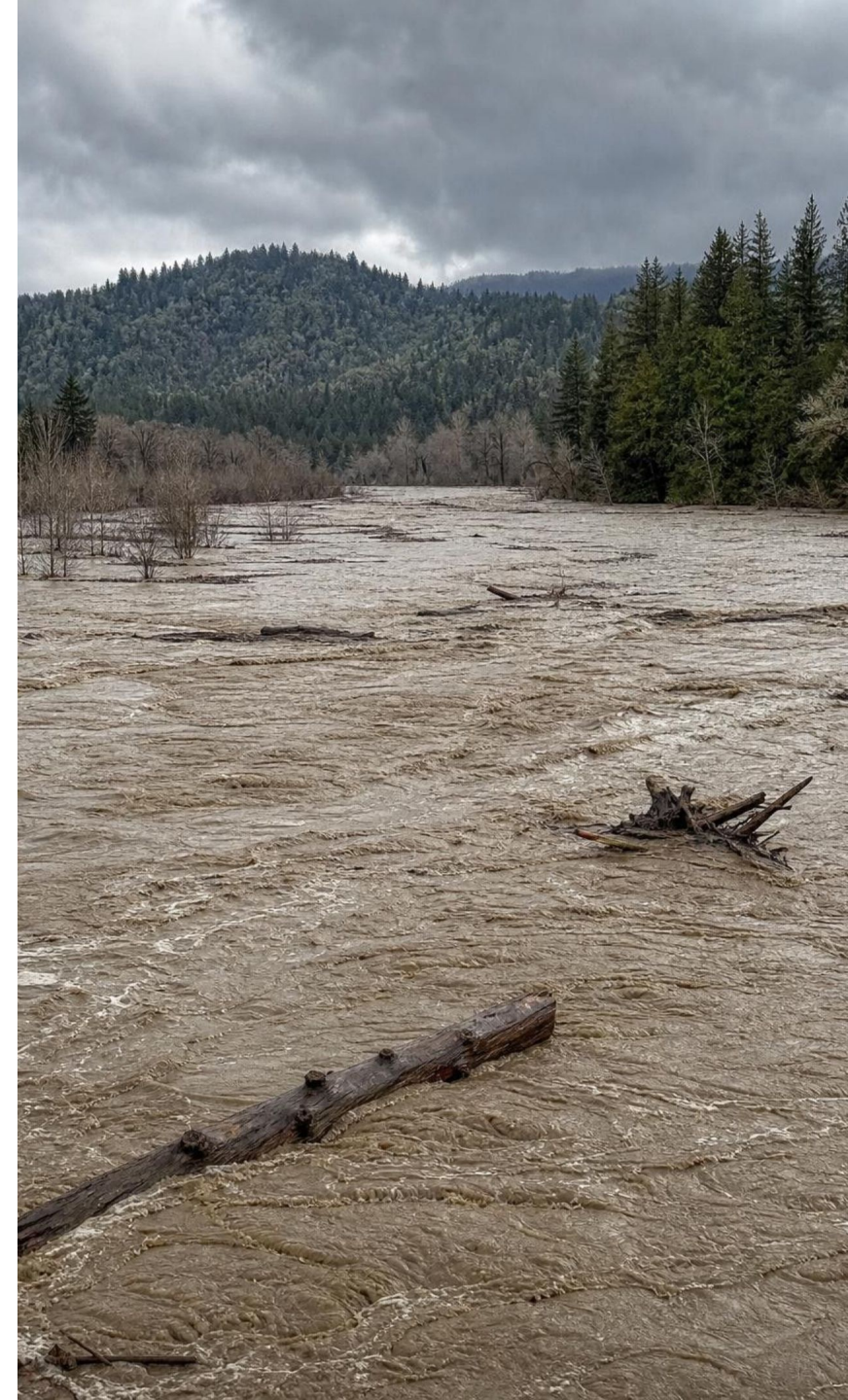
One county, one year, two kinds of killer water

Del Norte County, 1964. In March an earthquake in Alaska, **2,600 km away**, sent a tsunami to Crescent City. The first surge, about **four hours later**, only wet the waterfront; the fourth, about **6 m high**, wrecked about 30 blocks. In December, atmospheric-river storms swelled the Klamath River until logs and current knocked out the Highway 101 bridge. And south of town, that same highway keeps sliding.

Notice: which hazard started far away, and which started close to home?

Wonder: why was the fourth surge worse than the first?

Predict: which of the three could be forecast ahead of time, and how far ahead?



LEARNING TARGETS

What you will be able to do

- Explain how slope angle, water, shaking and lost roots make a slope fail, and name four kinds of movement.
- Explain what makes a tsunami and use depth to calculate when its waves will arrive.
- Explain runoff and storm-surge floods, and read flood records as yearly chances.
- Use maps, records, sensor readings and travel times to forecast where a hazard is likely and how soon.
- Evaluate competing designs against criteria and combine the best features into a better one.





Three hazards, one pull

- Mass wasting: gravity moves soil and rock downhill, from millimeters a year to meters per second.
- Tsunami: a sudden shove of the seafloor lifts or drops the whole column of water above it.
- Flood: more water arrives than the ground, the river channel or the coast can hold.
- Gravity drives all three; water and shaking are the usual triggers.
- Forecasting asks two questions: where is it likely, and how much warning will there be?

Four ways a slope can move

Model: Kinds of mass wasting, slowest to fastest

Creep: Too slow to watch, often millimeters to centimeters a year. Clues: tilted posts and walls, trees with curved trunks.

Slide or earthflow: A mass of soil and rock moves on a weak surface or flows as a soggy mass, slowly or fast, often after soaking rain.

Debris flow (mudflow): A water-soaked slurry of mud, rock and trees races down a channel after intense rain, often on burned slopes.

Rock fall: Rock breaks from a cliff and drops, bounces or rolls; set off by shaking, freezing and thawing, or waves undercutting the base.

Real slopes blend types. Geologists also name topples, spreads and slumps, and earthflows range from very slow to fast.



Why a slope fails: a tug-of-war

- Gravity pulls every grain downslope. Friction and grip between grains hold it back.
- The steeper the slope, the more of gravity's pull points downhill.
- A little water forms films that pull sand grains together: that is why damp sand builds steep castles.
- Saturated soil: water pressure in the gaps lightens grain-to-grain grip, and the water adds weight.
- Shaking, waves or road cuts removing the toe, and fire killing roots, can tip a slope past its limit.





VOCABULARY IN CONTEXT

Words for moving ground

- **mass wasting:** Any downhill movement of soil, rock or other earth material driven by gravity, whether it takes years or seconds. *The bluff showed mass wasting of every speed, from creep at the top to fresh slides at the base.*
- **saturated:** Holding as much water as the gaps between grains can take; saturated soil grips less and weighs more. *After a week of rain the hillside was saturated, and the road crew closed the highway below it.*
- **debris flow:** A fast, water-soaked slurry of mud, rock and often trees that pours down a channel like wet concrete. *The debris flow left boulders the size of cars in the creek bed below the burned slope.*

CHECK FOR UNDERSTANDING

Quick check: which hillside fails first?

Four hillsides have the same soil. Which is most likely to fail in the next big storm?

A. A 15-degree slope, dry, covered in deep-rooted shrubs

B. A 35-degree slope, damp after a light shower, roots intact

C. A 35-degree slope, soaked by a week of rain, burned last summer

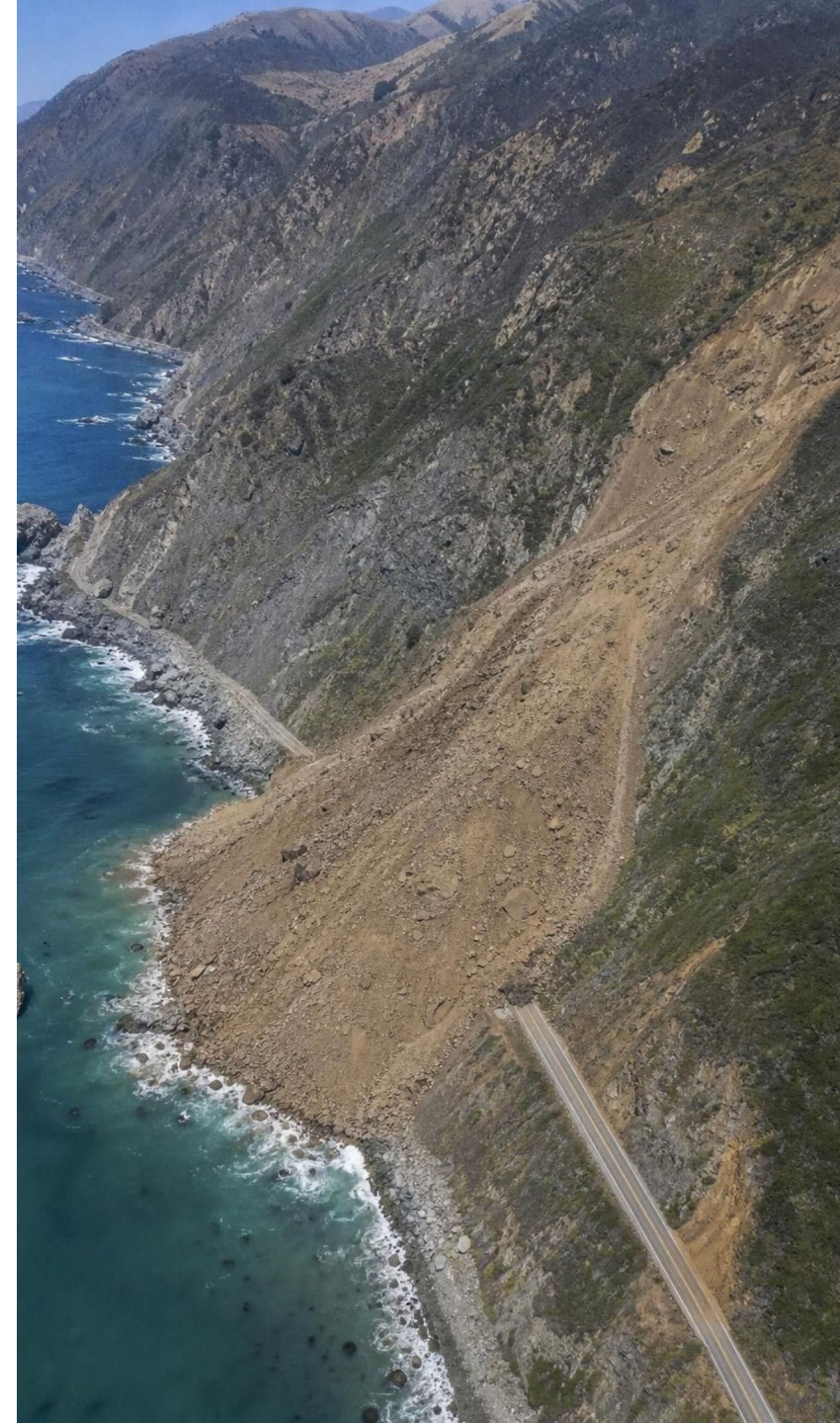
D. A 15-degree slope, soaked by a week of rain, grass-covered



California's restless coast

La Conchita sits below a 180 m bluff with slides recorded since 1865. In 2005, after about two weeks of heavy rain, part of the 1995 slide moved again, killing 10 people and destroying or damaging 36 houses. At Big Sur in 2017, the Mud Creek slide buried about a quarter mile of Highway 1. In Rancho Palos Verdes, slow-moving ground sped up to more than 30 cm a week in 2024.

- Same recipe each time: steep slopes, weak rock and a lot of water.
- Waves cutting the base of sea cliffs remove the slope's support.
- Last Chance Grade, US 101 in Del Norte County: decades of slides; Caltrans plans a tunnel to bypass it.





After the fire: debris flows

- Fire burns the plants, roots and leaf litter that held soil and soaked up rain.
- Burned soil can shed water, so rain runs off fast and sweeps up ash, sand and boulders.
- Montecito, Jan. 9, 2018: on slopes burned by the Thomas Fire weeks before, intense rain set off debris flows.
- The flows killed 23 people and damaged more than 400 homes.
- On burned slopes, the danger depends most on how hard rain falls in about 15 minutes, not the daily total.
- USGS maps burned watersheds and rain thresholds; the National Weather Service issues the warnings.

Think, pair, share

Discuss: wall, drain, monitor or move?

- Think about: what each option protects, and against which kind of movement.
- Think about: what happens if a slide is bigger than the wall was built for.
- Think about: who pays, and who decides whether people must leave their homes.

A town sits below a bluff that has slid twice in ten years. The county can afford one: a taller wall at the base, drains that pump water out, sensors with alerts, or buying out the homes. Which would you choose, and why?





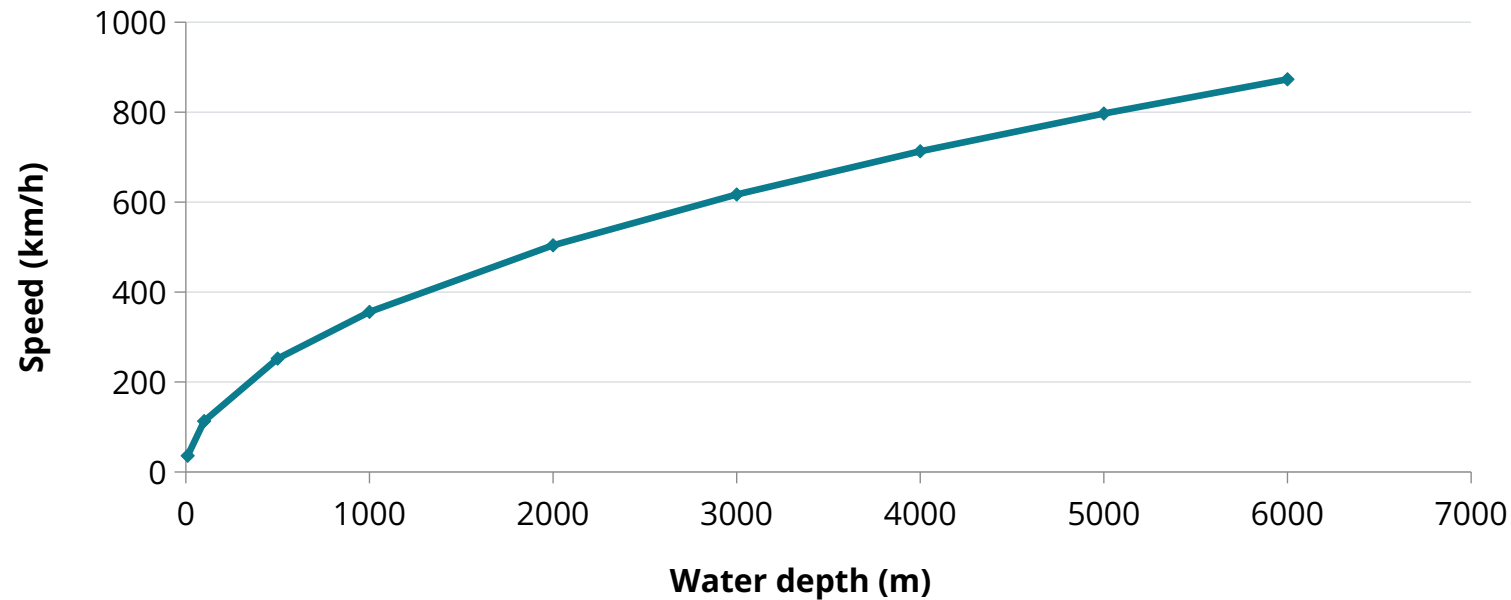
What makes a tsunami

- A tsunami starts when a huge volume of seawater is suddenly lifted or dropped.
- Most come from large undersea earthquakes where one plate dives under another.
- In those quakes the edge of the upper plate springs up, raising the seafloor and the sea above it.
- Undersea landslides, volcanic eruptions and asteroid impacts can also make tsunamis.
- Tides do not make them, and neither does wind; 'tidal wave' is the wrong name.
- Most tsunamis happen in the Pacific, around the Ring of Fire.

MODEL

A tsunami's speed depends on water depth

Model: Tsunami speed at different ocean depths



Calculated from the long-wave rule: speed in m/s = square root of $(9.8 \times \text{depth in m})$, converted to km/h. Calculated values, not measurements.

From deep ocean to shore: slower, shorter, taller

Deep ocean: often under 1 m tall, crests 100 km or more apart, moving 700-800 km/h. Ships barely notice.

Over the shallow shelf the front slows first, and the water behind catches up.

The same energy is squeezed into less length and depth, so the water piles up higher.

Near shore it moves about 30-50 km/h and can reach many meters high in big events.

It comes as a series of surges over hours; the sea may pull back first.

Run-up is how high the water climbs on land above normal sea level.





CHECK FOR UNDERSTANDING

Quick check: how long until it arrives?

A tsunami must cross 2,800 km of ocean that is about 4,000 m deep. The chart gives about 710 km/h at that depth. About how long will the trip take?

A. About 40 minutes

B. About 4 hours

C. About 10 hours

D. About 40 hours

Crescent City, March 1964: the fourth surge

On March 27, 1964, a magnitude 9.2 earthquake struck Alaska. About four hours later the first surge reached Crescent City and flooded the waterfront lightly. In a lull after the early surges, some people went back downtown. The fourth surge, about 6 m high, came after the sea drained from the harbor; about 30 blocks were wrecked and 11 people in the town died.

- A tsunami arrives as several surges, and the first is often not the largest.
- Crescent City's seafloor and harbor shape focus tsunami energy there, so it is hit harder than most coasts.
- A U.S. tsunami warning center in Palmer, Alaska, was set up in response to this disaster.



From earthquake to warning

Model: How a tsunami warning is built

1

Seismometers locate the quake and estimate its size (minutes)

2

(within minutes) First message from earthquake data alone

3

(as waves pass sensors) DART buoys and tide gauges show whether waves formed

4

(data feed the models) Models forecast arrival times and heights for each coast

5

(messages to the public) Coasts get a warning, advisory or watch; local officials evacuate

6

(hours later) Alert ends only after the dangerous surges are over

Warning centers forecast a tsunami after an earthquake happens. No one can predict the earthquake itself.



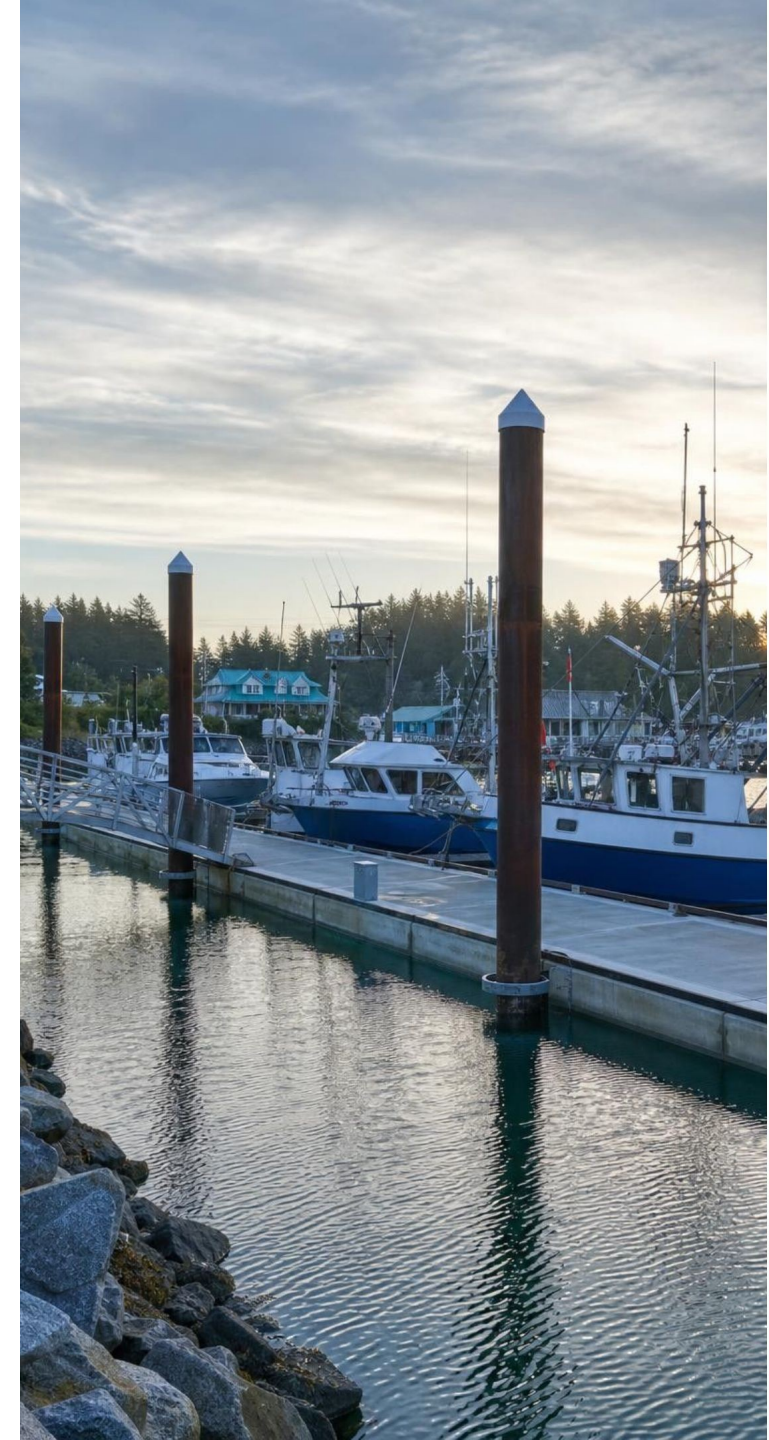


Engineering the DART: test, diagnose, combine

- Goal: measure a tsunami under 1 m tall in deep water, fast enough to warn coasts.
- Seafloor pressure sensor, then sound through the water, then a surface buoy, a satellite, the warning center.
- Tests of a prototype off Oregon showed data dropouts: readings that never reached the buoy.
- Two likely causes: a sound beam that missed the buoy, and software limits.
- Three fixes: a wider beam, a tiltmeter to check the sensor's alignment, software that asks for lost data.
- Each fix helped; combined, they made the system more reliable than any single one.

Words for waves and warnings

- **tsunami:** A series of very long ocean waves made when a large volume of water is suddenly lifted or dropped, usually by an undersea earthquake. *The tsunami crossed the Pacific at jet speed, then slowed and grew as it crossed the shelf.*
- **DART system:** NOAA's deep-ocean tsunami stations: a seafloor pressure sensor sends readings by sound to a buoy, which relays them by satellite. *When the wave passed overhead, the DART system station recorded a rise of a few centimeters, enough to confirm a tsunami had formed.*
- **mitigation:** Action that reduces the harm a hazard can do, such as warnings, walls, drains and evacuation plans; it lowers risk but cannot remove it. *After 2011, Crescent City rebuilt its harbor as mitigation, with deep-driven piles and one dock designed to absorb surge energy.*





Think, pair, share

Discuss: when the earthquake is the warning

- Think about: how long the shaking lasts, and how long a message takes.
- Think about: who can still get to high ground in time, and who cannot.
- Think about: what a town could build or teach years before the earthquake.

A big Cascadia earthquake off the North Coast could send surges ashore in well under half an hour. Why can't a warning center protect people as it can for an Alaska or Japan tsunami? What should the plan be?

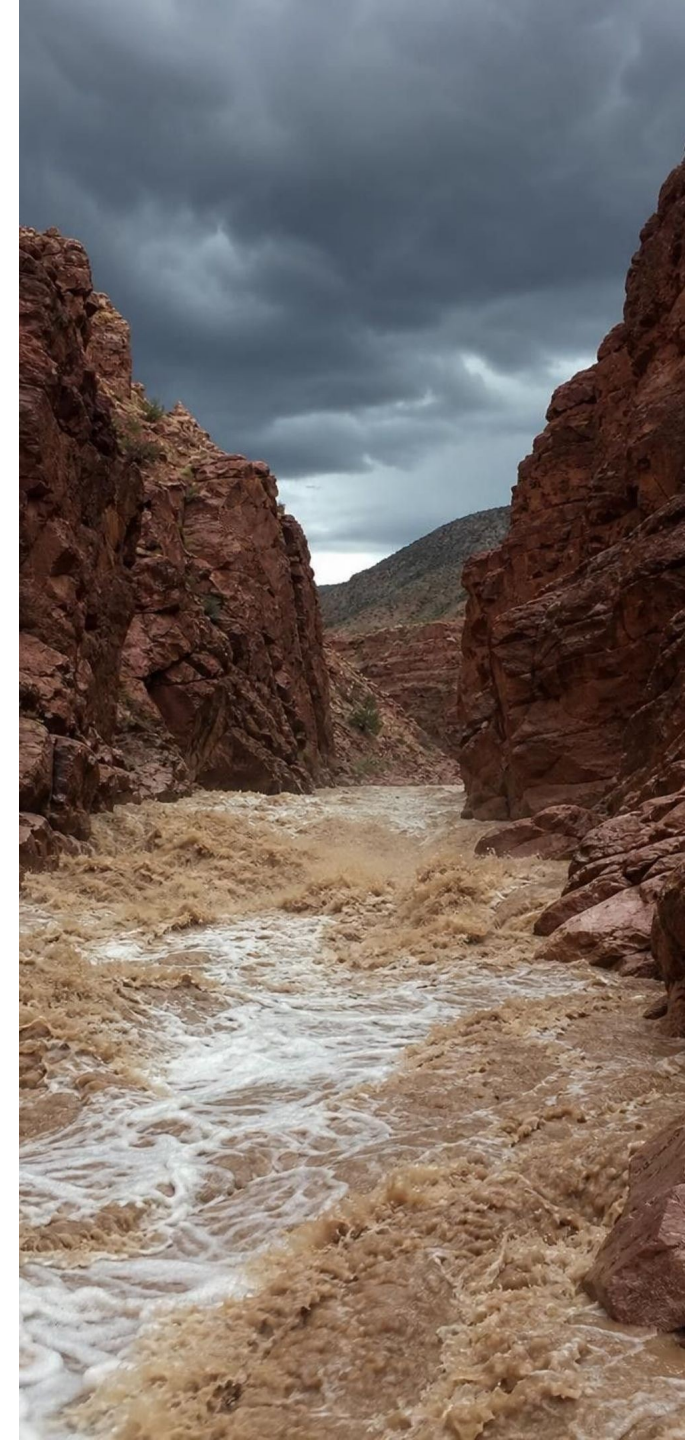
MODEL

Two ways to flood

Model: Runoff floods and storm-surge floods

Runoff (river and flash) floods	Storm-surge floods
Rain or snowmelt arrives faster than the ground can soak it up	Storm winds pile seawater against the coast
Worse on saturated, frozen, paved or burned ground	Worst on low, gently sloping coasts at high tide
Water gathers in streams; rivers rise over hours to days	Hurricanes bring the biggest surges on Gulf and Atlantic coasts
Flash floods can strike within minutes, even in deserts	In California, winter storms add a smaller surge to high tides and big waves

Houston, 2017: Hurricane Harvey flooded the city mainly with runoff from days of extreme rain, not with storm surge.



California's atmospheric rivers: our water and our floods

Atmospheric rivers are long, narrow bands of water vapor flowing in from the Pacific. A few each year bring about 30 to 50 percent of the West Coast's precipitation. In 1861-62, weeks of them flooded the Central Valley into a lake about 480 km long. In December 1964, they swelled the Klamath River. In March 2023, the Pajaro River broke through a levee during one and flooded the town of Pajaro.

- Mountains force the moist air up; it cools and drops heavy rain and snow.
- Forecasters can often see one coming several days ahead.
- At Lake Mendocino, operators use those forecasts to decide when to hold or release water.





Check for understanding

Quick check: what does '1 percent a year' mean?

A town sits where a flood of a certain size has a 1 percent chance each year (a '100-year flood'). One hit last year. Which statement is correct?

A. The next flood that size will come in about 99 years.

B. This year's chance of a flood that size is still about 1 percent.

C. The chance is zero for the next century.

D. The chance is now 2 percent, because big floods come in pairs.

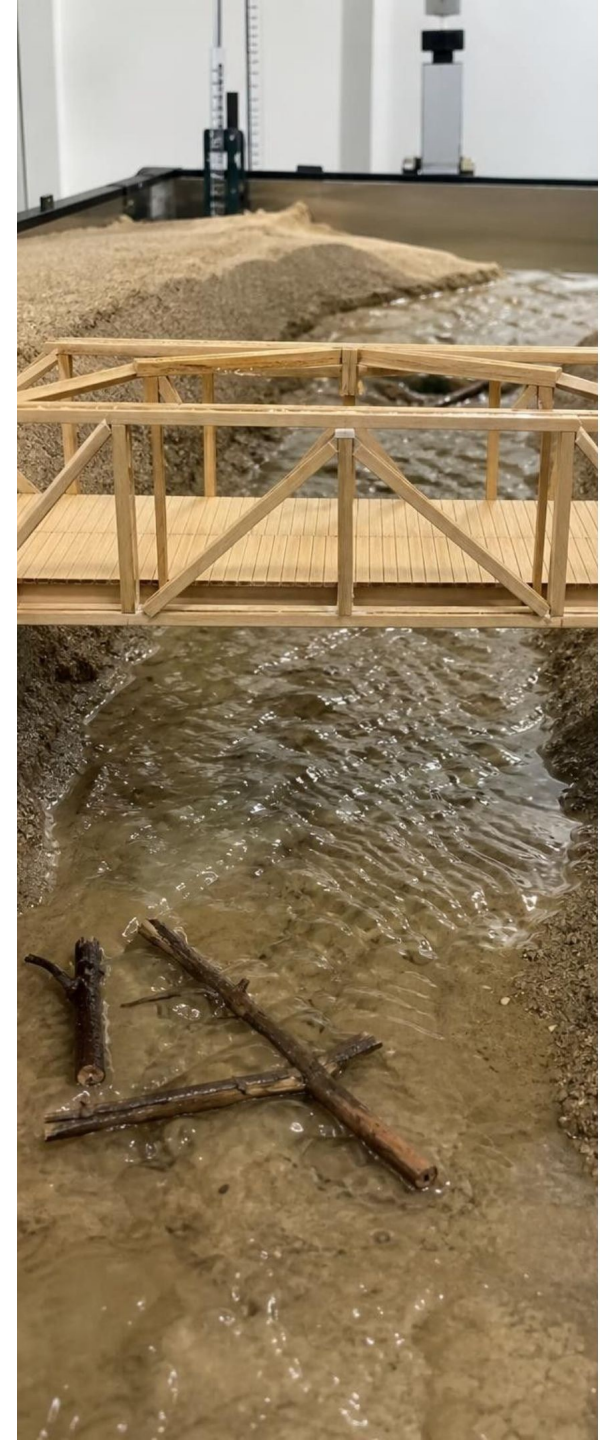
APPLY IT

Task: three bridges, four tests. Which features win?

Rank the three designs against the criteria, then name the best feature of each that you would combine into a new bridge within the 20-point budget.

Design	Deck above bed (cm)	Piers in channel	Logs trapped (of 10)	Deepest scour (mm)	Held 200 g after flood?	Cost (points)
A: low beam	3	2	7	12	No	14
B: high arch	6	0	1	2	Yes	22
C: truss on gravel- armored pier	5	1	4	3	Yes	18

Simulated data for practice.

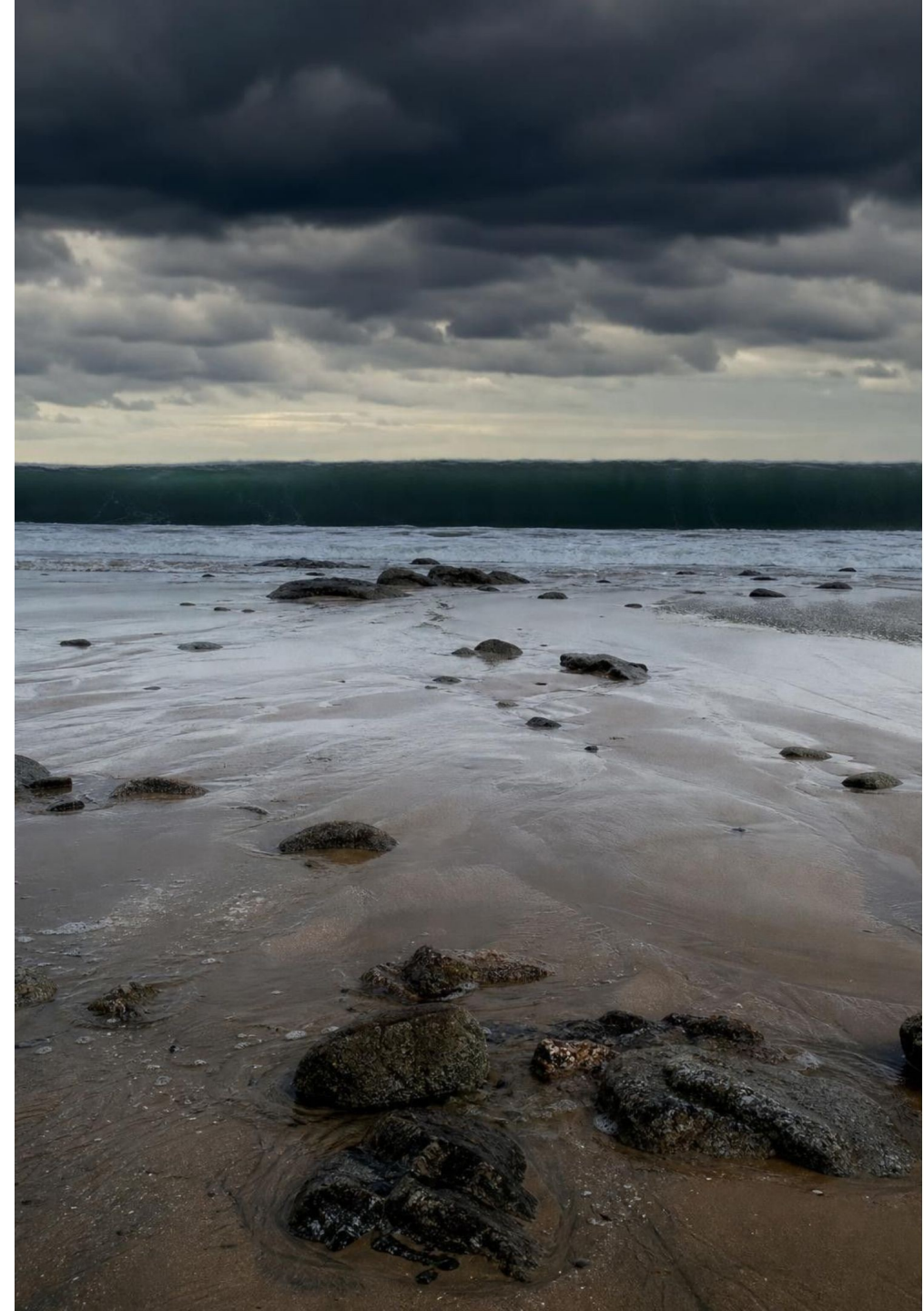


MISCONCEPTION CHECK

True or false? The first wave is the big one

"A tsunami is one huge wave. Once it has hit and the water drains away, it is safe to go back down to the shore."

True or false? Explain your reasoning.





PUTTING IT TOGETHER

Putting it together

- Gravity moves soil, seawater and rivers; water and shaking set them off.
- Slopes fail when steepness, saturation, shaking or lost roots tip the tug-of-war.
- A tsunami's speed depends on depth, so distance and depth give its arrival time.
- Floods come from runoff or storm surge; flood risk is a yearly chance, not a schedule.
- Forecasts range from days ahead (atmospheric rivers) to none (local quakes and many slides).
- Good mitigation combines tested designs, warnings and plans; no single fix removes the risk.

EXIT TICKET

Exit ticket

1. Name two conditions that made the Montecito or La Conchita slopes fail, and explain one of them.
2. A tsunami must cross 1,500 km of 5,000 m deep ocean (about 800 km/h). About how long will that take?
3. A flood has a 2 percent chance each year. Can it happen two years in a row? Explain.
4. Name one hazard that can be forecast days ahead and one that gives almost no warning, and explain why.

