

Forecast Desk Jigsaw: How Much Warning Does Each Hazard Give?

Learning target: I can use evidence cards to compare how far ahead different hazards can be forecast, explain why some come with hours or days of warning and others with almost none, and match mitigation to the warning time.

Collaborative investigation

About 55 min

Jigsaw

MS-ESS3-2 · practice

collaboration

discussion

reading

Standards connections

MS-ESS3-2 (practice, which hazards are preceded by measurable signals and how that shapes mitigation): The clarification statement stresses that some hazards are preceded by phenomena that allow reliable forecasts while others, such as earthquakes, strike without notice. Groups sort real monitoring tools and California cases by warning time and match mitigation to each. The cards give descriptions rather than datasets, so the sheet builds the PE's reasoning without fully assessing it.

Purpose: practice · **Time:** about 55 minutes · **Format:** jigsaw

Answers with reasoning

Twelve evidence cards from California's hazard forecasters

1 Card 1 (Slopes): Maps of where slopes fail

The California Geological Survey combines maps of slope steepness, rock type and the scars of old landslides to show which areas are most likely to have landslides. The maps are made years before any event. Counties use them to decide where building is allowed and which roads to reinforce, but no map can tell anyone the day a slope will fail.

2 Card 2 (Slopes): Burn scars and rain thresholds

After a wildfire, USGS scientists estimate how likely debris flows are in each burned canyon and how intense the rain must be to set them off, often a burst lasting only about 15 minutes. When weather forecasts call for rain that intense, forecasters can issue watches and warnings hours to a day or two ahead, and counties can order evacuations before the storm arrives.

3 Card 3 (Slopes): A creeping slope speeds up

The Portuguese Bend landslide in Rancho Palos Verdes, Los Angeles County, has crept downhill for decades. GPS stations showed parts of it moving many times faster after the very wet winters of 2022-23 and 2023-24, cracking homes and roads. Monitoring like this shows a slope changing days to months ahead, but it cannot say exactly when, or whether, a slope will suddenly give way.

4 Card 4 (Slopes): Slides set off by shaking

The 1994 Northridge earthquake set off more than 11,000 landslides across the hills and mountains north of Los Angeles as the ground shook. No one can forecast the date of an earthquake, so slides set off by shaking come with no warning beyond the shaking itself. Protection has to be planned in advance: knowing which steep slopes would fail in strong shaking and keeping roads and homes away from them.

5 Card 5 (Ocean): Seismic networks

Seismometers around the world detect a large undersea earthquake within minutes and estimate its location and size. Tsunami warning centers, including the National Tsunami Warning Center in Palmer, Alaska, which serves California, send their first alerts based on that information alone. At that moment they do not yet know for sure whether a tsunami formed or how big it is.

6 Card 6 (Ocean): DART buoys

Pressure sensors on the deep seafloor feel the extra weight of water as a tsunami passes and send the readings by sound to a buoy, then by satellite to the warning center. These readings confirm whether a tsunami formed and how large it is, so forecasters can update arrival times and expected wave heights for each coast, or cancel an alert that was not needed.

7 Card 7 (Ocean): A distant source

In 1964 an earthquake in Alaska sent waves to Crescent City about four hours later. The fourth wave was the largest, and 11 people died in the town. In 2011 an earthquake off Japan sent waves that reached Crescent City about 10 hours later. That time, warnings had cleared the waterfront hours ahead; the harbor was wrecked, but the town lost no one.

8 Card 8 (Ocean): A source next door

The Cascadia Subduction Zone runs offshore from Cape Mendocino in Northern California to Vancouver Island in Canada. Its last great earthquake, in January 1700, sent a tsunami all the way to Japan. A similar earthquake today could send waves onto parts of the North Coast within minutes. California's tsunami hazard maps, evacuation-route signs and school drills treat strong shaking that lasts a long time as the warning itself.

9 Card 9 (Rivers): River forecasts

The National Weather Service's California Nevada River Forecast Center combines rain and snow forecasts with streamgauge readings to forecast how high rivers will rise, often several days ahead on large rivers. Those forecasts give time to release water from reservoirs, close roads, move livestock and evacuate low areas.

10 Card 10 (Rivers): Atmospheric rivers

Most of California's largest floods come from atmospheric rivers: long, narrow bands of water vapor that flow in from the Pacific and can drop days of heavy rain. Satellites and weather models often spot one several days before it reaches land. In 2023 a series of them flooded towns including Planada in Merced County and Pajaro in Monterey County, where a river levee broke.

11 Card 11 (Rivers): Flash floods

In steep canyons, desert washes and heavily paved neighborhoods, a short, intense downpour can turn a dry channel into a deep, fast torrent within minutes. Such storms are small and hard to pin down exactly, so flash flood warnings may come less than an hour ahead, and the rain may fall miles upstream of the place that floods.

12 Card 12 (Rivers): Flood maps

FEMA flood maps shade the areas with a 1 percent chance of flooding in any year, often called the 100-year floodplain. The maps are made years ahead from river records and the shape of the land. They guide where to build, how high to raise buildings and who must buy flood insurance, but they do not say when the next flood will come.

Part A: Expert round (with the others who have your set)

1. For each of your four cards, write: the hazard, the first signal or data that forecasters can use, and how far ahead that signal comes (seconds, minutes, hours, days, or 'where but not when'). Agree on one sentence you will use to teach each card.

Answer: Slopes: card 1, landslides in general, slope and geology maps, where but not when (years ahead); card 2, debris flows on burned slopes, forecast rainfall intensity above a threshold, hours to a day or two; card 3, creeping landslide, GPS movement measurements, days to months of change but no exact failure time; card 4, earthquake-triggered slides, no forecastable signal, none or seconds. Ocean: card 5, tsunami, seismic detection of the earthquake, minutes after the quake; card 6, tsunami, DART pressure readings, which confirm the waves as they pass a sensor, often within an hour of the earthquake, while distant coasts still have hours to go; card 7, distant tsunami, travel time from far away, hours (about 4 hours from Alaska, about 10 hours from Japan); card 8, Cascadia tsunami, the shaking itself, minutes. Rivers: card 9, river floods, river forecasts from rain forecasts and streamgages, days; card 10, atmospheric-river floods, satellites and weather models, several days; card 11, flash floods, radar and rain gauges, less than an hour; card 12, floods in general, flood maps, where but not when (years ahead).

Why: Each expert set includes both long-warning and short-warning cases so that every expert can show the contrast to the home group.

Also acceptable: Accept 'minutes to hours' for card 6 and 'hours to days' for card 2.

- Hazard, signal and warning time for all four cards in the set
- A teachable sentence for each card

Part B: Home group task

1. Each expert teaches their four cards in about three minutes. Listeners write one note per card.
2. Together, complete the warning ladder in q2. Every row must cite at least one card number.
3. Copy each hazard onto a sticky note and place it on the timeline in Figure 1 under its warning time.
4. Discuss q3 and q4 and write one group answer for each. Every member must be able to explain at least two rows of the ladder.

2. Group answer: complete the warning ladder. Cite card numbers in every row.

Answer: Earthquake-triggered landslides: no forecastable signal, only the shaking (card 4); none or seconds; plan in advance by mapping slopes likely to fail in shaking and keeping homes and roads off them (cards 1, 4). Debris flow below a burn scar: forecast of intense rain above the threshold (card 2); hours to a day or two; evacuation orders before the storm, debris basins cleared in advance (card 2). Creeping landslide speeding up: GPS movement data (card 3); days to months of change; monitoring, drainage of the slope, moving people out of the fastest-moving areas (card 3). Distant tsunami: seismic detection, then DART confirmation (cards 5, 6, 7); hours; official warnings and evacuation of harbors and low coastal areas (card 7). Cascadia tsunami: the long, strong shaking itself (card 8); minutes; hazard maps, evacuation-route signs and drills prepared ahead (card 8). Atmospheric-river flood: satellite and model forecasts, then river forecasts (cards 9, 10); days; release reservoir water, close roads, move livestock, evacuate low areas, strengthen levees (cards 9, 10). Flash flood: radar and rain gauge readings of an intense storm (card 11); less than an hour; keep people out of canyon channels during storms, warning sirens and alerts, floodplain building limits (cards 11, 12).

Why: The ladder is the group's main product. The key pattern is that hazards driven by weather have precursors that can be tracked for hours to days, while hazards driven by earthquakes can be forecast only after the shaking begins.

Also acceptable: Accept other mitigations if they fit the warning time; for example, retaining walls for earthquake-triggered slides or vertical evacuation structures for a Cascadia tsunami.

- All seven rows have a signal, a warning time and a matching mitigation
- Every row cites at least one card
- Warning times are consistent with the cards
- Mitigation for short-warning hazards is something prepared in advance

How much warning? From none to years

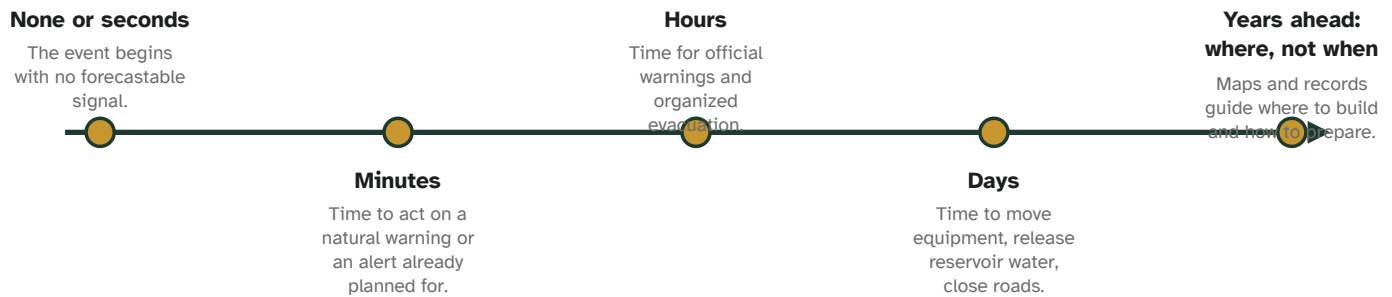


Figure 1. A warning-time scale. Place each hazard from the ladder under the warning time forecasters can usually give. Maps made years ahead tell where a hazard is likely, not when.

3. Group answer: Which hazards on your ladder have a signal that comes **before** the event starts, and which can be forecast only **after** the trigger has already happened? What do the hazards with the most warning have in common?

Answer: Signals before the event: debris flows below burn scars, atmospheric-river floods and river floods (weather forecasts show the storm coming), creeping landslides (movement measured before any sudden failure) and, partly, flash floods (radar sees the storm, but warning time is short). Forecast only after the trigger: earthquake-triggered landslides and tsunamis, because the earthquake that starts them cannot be forecast; once it happens, tsunami arrival can be forecast. The hazards with the most warning are driven by weather or slow ground movement that can be measured as it builds, while the ones with the least warning are set off suddenly by earthquakes.

Why: This is the distinction in the PE's clarification statement.

Also acceptable: Accept placing flash floods in either group if the short warning is explained.

- Sorts weather-driven hazards as having precursors
- Sorts earthquake-triggered hazards as forecastable only after the trigger
- States the common feature: a measurable signal that builds up before the event

4. Group answer: For the two hazards with the least warning, explain why mitigation must be built or practiced before anything happens. Give one example of such mitigation for each, from the cards.

Answer: Earthquake-triggered landslides (no warning) and the Cascadia tsunami (minutes) leave no time to build anything or organize an evacuation after the event starts, so the protection must already exist. Examples: mapping slopes likely to fail in shaking and keeping homes and roads away from them (cards 1 and 4); tsunami hazard maps, evacuation-route signs and school drills that teach people that strong, long shaking is the warning (card 8).

Why: When warning time is close to zero, mitigation shifts entirely to planning, building and practice done in advance.

Also acceptable: Accept flash floods as one of the two if the student argues that warnings are often under an hour.

- Identifies the two shortest-warning hazards
- Explains that there is no time to act after the event starts
- Gives one card-based example of advance mitigation for each

Part C: Individual accountability (complete alone)

5. Why can California get hours of warning for a tsunami from Alaska or Japan but only minutes for one from a Cascadia earthquake? Use evidence from two cards.

Answer: Tsunami travel time depends on distance from the source. Card 7 shows that waves from Alaska took about four hours and waves from Japan about 10 hours to reach Crescent City, so warning centers had time to detect the earthquake (card 5), confirm the waves with DART buoys (card 6) and send warnings. Card 8 shows that the Cascadia Subduction Zone is right offshore, so waves could arrive within minutes, before an official warning could reach everyone.

Why: Distance from the source sets the warning time for tsunamis.

Also acceptable: Accept mention of tsunami speed (hundreds of km per hour) as part of the reasoning.

- Distance from the source explains the difference
- Uses evidence from two cards with specific times

6. A neighbor says, 'Debris flows are like earthquakes: nobody can warn us.' Use cards 2 and 4 to explain what is wrong with that comparison.

Answer: Earthquakes give no forecastable warning, so slides set off by shaking come with none (card 4). Debris flows below burn scars are different: they need rain of a known intensity, and weather forecasts can show that rain coming hours to a day or two ahead, so forecasters can issue warnings and counties can order evacuations before the storm (card 2).

Why: The trigger determines the warning time: weather can be forecast, earthquakes cannot.

Also acceptable: Accept the point that Montecito's 2018 debris flows came after warnings and evacuation orders had been issued for some areas, if the student knows it.

- Earthquake-triggered slides give no warning (card 4)
- Debris flows have a forecastable trigger, intense rain, giving hours of warning (card 2)

7. Cards 1 and 12 both describe maps made years ahead. What can such a map do that a warning cannot, and what can a warning do that the map cannot?

Answer: A map made years ahead shows where a hazard is likely, so it can keep new homes, schools and roads out of dangerous places, set building heights and decide who needs insurance, things that cannot be done in the hours before an event. A warning tells people when the danger is coming so they can leave or act, which a map cannot do because it gives no date.

Why: Long-term maps and short-term warnings are complementary forms of mitigation.

Also acceptable: None.

- Map: guides long-term decisions about where and how to build
- Warning: tells when, so people can act
- Neither replaces the other

8. Choose one hazard from the ladder that was **not** on your expert set. Write a forecast statement for it (a chance or a time window, not an exact date), then describe a mitigation plan that matches its warning time. Cite two cards.

Answer: Example (river flood from an atmospheric river): 'A strong atmospheric river expected Thursday to Saturday gives the low areas along the river a high chance of flooding this weekend.' Plan: with several days of warning (cards 9 and 10), the county can release water from the reservoir to make room, check and reinforce levees, close low roads, move livestock and order evacuations a day ahead; in the long term, flood maps (card 12) keep new homes off the 100-year floodplain.

Why: Any hazard from another set earns full credit if the forecast is a likelihood or time window and the mitigation fits the warning time.

Also acceptable: Accept short-warning hazards with mitigation done in advance, such as tsunami drills for Cascadia.

- Hazard is from a different expert set
- Forecast is a chance or time window, not an exact date
- Mitigation fits the warning time
- Cites two cards

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
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Expert teaching	Teaches all four cards accurately, with the hazard, the signal and the warning time for each, and answers group questions about them.	Teaches all four cards with one small error or omission.	Teaches some cards or reads them aloud without explaining the signal and warning time.	Does not teach the expert set.
Warning ladder	All seven rows complete and consistent with the cards, with card citations, and every mitigation fits its warning time.	Six or seven rows correct; one warning time or mitigation does not fit.	Four or five rows correct, or card citations missing.	Fewer than four rows, or times and mitigations guessed.
Forecastable versus not	Clearly separates weather-driven hazards with precursors from earthquake-triggered hazards forecast only after the trigger, and explains why mitigation for the latter must be in place in advance.	Separates the two groups correctly but the explanation of advance mitigation is thin.	Sorts some hazards correctly without explaining the pattern.	Treats all hazards as equally predictable or unpredictable.
Individual reasoning (Part C)	All four answers accurate, each supported by specific card evidence, including a forecast stated as a chance or time window.	Three answers fully supported; one is vague or lacks card evidence.	Two answers supported, or answers are correct but without evidence.	Part C mostly missing or inaccurate.

Teacher notes

Card facts were checked: Northridge (1994) triggered more than 11,000 landslides (USGS); the National Tsunami Warning Center in Palmer, Alaska, serves the continental United States including California; the 1964 Alaska tsunami reached Crescent City about four hours after the earthquake and its fourth wave, the largest, contributed to 11 deaths in the town; the 2011 tsunami reached Crescent City about 10 hours after the earthquake and destroyed most of the small-boat harbor after the area had been evacuated (one man drowned near the mouth of the Klamath River, not in Crescent City); the Cascadia Subduction Zone runs from Cape Mendocino to Vancouver Island and last ruptured in January 1700; Planada (January 2023) and Pajaro (levee break, March 2023) flooded during atmospheric-river storms; FEMA's Special Flood Hazard Area is the 1 percent annual chance floodplain. Portuguese Bend movement accelerated after the wet winters of 2022-23 and 2023-24; avoid quoting a single speed, since rates varied by place and month. Debris-flow thresholds are rainfall intensities over short periods, often 15 minutes, which is why warnings depend on forecasts of how hard rain will fall, not just how much.

Scaffold offered to students: Card-reading frame

For each card, underline three things in different ways: the hazard (circle it), the tool or data (underline it), and any time word such as minutes, hours, days, years or 'no warning' (box it). Then fill in this frame: 'For ___, forecasters watch ___, which gives about ___ of warning, so the best protection is ___.' Use the frame to teach your home group.

Extension: When the warnings stack up

A strong earthquake on the North Coast happens during a week of atmospheric-river storms, on hills burned the summer before. Using at least four cards, describe the chain of hazards that could follow over the next minutes, hours and days, and design a short emergency-planning checklist for the county that covers each time scale. Explain which item on your checklist would save the most lives and why.