

Three Crossings, One Bridge: Rank the Sites by Hazard Risk

Investigation question: Which of three possible crossings of the fictional Rio Ventana should carry the new lifeline bridge to the county hospital, and what must the design include there, given each site's earthquake, ground, volcano and tsunami data and a 90 million dollar budget?

Data-driven decision

Groups of 4

1 session

Setup 5 · Activity 50 · Cleanup 2 min

MS-ESS3-2 · assesses

MS-ETS1-1 · practice

MS-ETS1-2 · practice

Name _____

Group _____

Date _____

Your role today

- ☐ **Seismic analyst:** Works the earthquake catalog: frequencies, the magnitude comparison and the two shaking rows of the scoring table.
- ☐ **Ground and volcano analyst:** Scores the ground-failure, volcanic and tsunami rows and explains each score to the group.
- ☐ **Cost engineer:** Fills the cost table for every site, checks each total against the budget, and flags any hazard the site fixes cannot fully remove.
- ☐ **Decision lead:** Runs the final discussion, drafts the recommendation from the group's numbers, and presents it to the class in under two minutes.

Safety

- Paper and calculator only; there are no physical hazards.
- Ventana County, its fault, volcano and sites are fictional and every number is simulated. Remind students not to draw conclusions about real places from this dataset; real hazard maps come from the USGS and the California Geological Survey.

Procedure

1. Read the scenario, the criteria and the budget together. Make sure everyone can say what a lifeline bridge must do (no damage in frequent shaking, minor damage at most and still open after rare strong shaking, usable by emergency vehicles after the strongest shaking).
2. Seismic analyst leads q1 to q4: convert the catalog into M5.0+ earthquakes per decade at each site, then compare the two great-earthquake sources logarithmically and explain why two different sources can give the same intensity.
3. Score every hazard at every site using the scoring rules exactly as written. Each analyst scores their own rows and the group checks each other's work. Add up each site's total.
4. Draw a stacked bar graph of the totals, one color per hazard, so the group can see which hazard dominates each site. Answer q5.

5. Cost engineer fills the cost table for a lifeline bridge at every site, including the site fixes, and checks each total against the 90 million dollar budget.
6. Discuss and decide. Which site would you recommend, and why? Name at least one hazard that remains even after the fixes. Write the recommendation (q6) and present it.
7. Answer the analysis questions individually.

Record your observations

Lab 3 recording sheet: Three Crossings, One Bridge

Ventana County is **fictional**, and every number below is a **teaching dataset**. The Rio Ventana flows west from Mount Ventana, a volcano that has been restless lately, to the sea. The Ventana Fault, a strike-slip fault like the San Andreas, runs north-south through the middle of the county, and an offshore subduction zone lies 60 km west of the coast. The county will build **one** bridge on the only ambulance route to its regional hospital, so it must be a **lifeline** bridge: no damage in frequent moderate shaking, minor damage at most and still open after rare strong shaking, and usable by emergency vehicles after the strongest shaking. **Budget: 90 million dollars.** Risk combines a hazard with what is exposed to it. The same bridge would carry the same traffic at any site, so comparing hazards here also compares risks.

Earthquakes within 50 km of each site in the last 100 years

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

Magnitude range	Site A: Upper Ford	Site B: Middle Gorge	Site C: Bay Mouth
4.0 to 4.9	52	75	28
5.0 to 5.9	6	14	6
6.0 to 6.9	0	3	1
7.0 or more	0	0	0
Largest recorded	5.6	6.8	6.2

Simulated teaching data. Most of Site A's small earthquakes come from swarms beneath Mount Ventana.

Site profiles

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

Feature	Site A: Upper Ford	Site B: Middle Gorge	Site C: Bay Mouth
Ground under the bridge supports	Loose sand and gravel from old mudflows, beside the river	Solid bedrock gorge	Soft bay mud and artificial fill
Distance to the Ventana Fault	25 km	1.5 km (the fault does not cross the site)	35 km

Feature	Site A: Upper Ford	Site B: Middle Gorge	Site C: Bay Mouth
Strongest expected shaking: source	Ventana Fault, magnitude 7.5	Ventana Fault, magnitude 7.5	Offshore subduction zone, magnitude 9 (60 km away)
Chance of that shaking in the next 100 years	about 40 percent	about 40 percent	about 20 percent
Expected intensity at the site	VII	IX	IX
Second shaking source	none	none	Ventana Fault, magnitude 7.5: about 40 percent, intensity VIII
Distance to Mount Ventana	14 km	32 km	55 km
Volcanic mudflow (lahar) layers found at the site, last 2,000 years	5	0	0
Chance a mudflow or thick ash reaches the site in 100 years	about 20 percent (mudflow)	about 5 percent (ash only)	about 3 percent (ash only)
In the mapped tsunami zone?	No	No	Yes (from the great subduction earthquake, about 20 percent in 100 years)
Bridge length needed	90 m	140 m	300 m

Simulated teaching data. Chances come from average intervals in the geologic record (for example, 6 ruptures of the Ventana Fault in 1,200 years; 7 great subduction earthquakes in 3,500 years) and are estimates, not schedules.

- For each site, find the number of magnitude 5.0 or larger earthquakes in the 100-year catalog and convert it to earthquakes per decade. Show your work.

- Which site has the most frequent moderate earthquakes? Give one reason why that alone does not make it the most hazardous site for the bridge.

3. Site C's great-earthquake source is magnitude 9 and Site B's is magnitude 7.5. About how many times more energy does the magnitude 9 release? (Hint: the difference is 1.5 steps. One step multiplies energy by about 32; half a step multiplies it by about 5.6.)

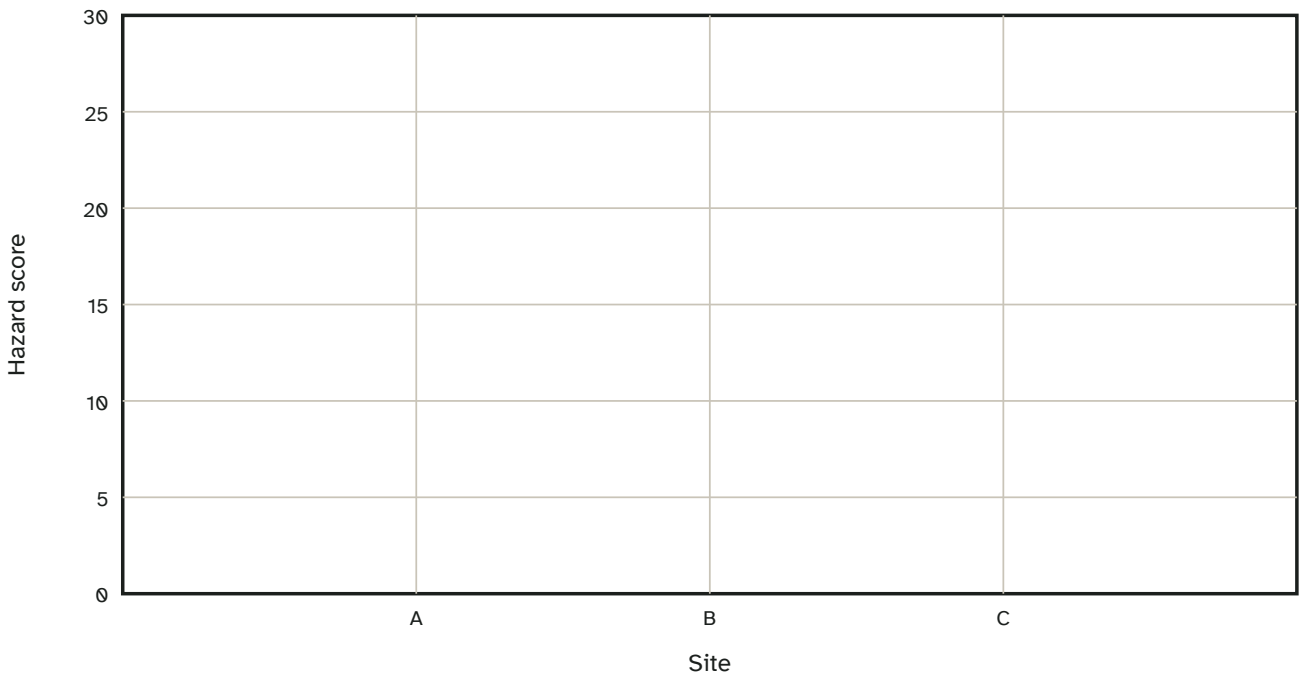
4. Even though the magnitude 9 releases far more energy, both sites expect intensity IX. Use distance and ground type to explain how that can be true.

Scoring rules: score = likelihood (L) x severity (S) — Likelihood from a chance in 100 years: under 10 percent = 1; 10 to 30 percent = 2; over 30 percent = 3. **1. Frequent shaking:** L from the number of M5.0+ earthquakes in the catalog (0 = 0, 1 to 5 = 1, 6 to 15 = 2, 16 or more = 3); S from the ground (bedrock = 1, sand and gravel = 2, soft mud or fill = 3). **2. Strongest shaking:** L from its chance; S from the intensity (VII or less = 1, VIII = 2, IX or more = 3). If a site has two sources, score both and use the larger. **3. Ground failure** (liquefaction or rockfall): bedrock L = 1, S = 1; loose sand and gravel beside water L = 2, S = 2; soft mud or fill L = 3, S = 3. **4. Volcanic:** L from the chance; S = 3 if a mudflow reaches the site, 1 for ash only. **5. Tsunami:** 0 outside the zone; inside, L from the chance and S = 3.

Hazard scoring table

[illegible]

Total hazard score by site (stack the five hazards, one color each)



5. Rank the three sites from highest to lowest total hazard score. For each site, which single hazard contributes the most?
-

Cost menu (millions of dollars)

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

Item	Site A	Site B	Site C
Basic bridge for the length needed	40	56	80
Lifeline upgrade for shaking (add 50 percent of the basic cost)	add 50%	add 50%	add 50%
Site fixes (needed at every performance level)	Longer, higher spans to keep supports out of the mudflow channel: 25	Rockfall netting and anchors on the gorge walls: 4	Ground improvement and deep piles: 30; tsunami-resistant supports and raised approaches: 12
What the fixes cannot remove	A very large mudflow can still bury the approach roads	Shaking itself, which the lifeline design is built to handle	Some settling of the approaches on soft ground

Simulated teaching data. Costs are invented round numbers for a fictional county.

Cost table for a lifeline bridge

Cost item	Site A	Site B	Site C
Basic bridge			
Lifeline upgrade			
Site fixes			
Total			
Within the 90 million dollar budget? (Y/N)			

6. Recommendation. Which site should the county choose? Use your scores, your cost table and at least one calculation. Explain why you rejected the other two sites, and name one hazard that remains at your chosen site even after the fixes.

Analysis questions

7. Site B is only 1.5 km from the Ventana Fault, yet it has the lowest total score. Explain why, and describe one thing the total score hides that an engineer would still care about.

8. A council member says, 'The Ventana Fault has a magnitude 7.5 about every 200 years, and the last one was 170 years ago, so we have about 30 years.' Use what you know about forecasts to respond.

- 9.** If the county chose Site A, what kinds of monitoring could give warning before a mudflow reaches the bridge? Explain why this kind of warning is possible for a volcano but not for the Ventana Fault.

- 10.** Suppose the bridge were an ordinary farm-road bridge instead of the hospital route (no lifeline upgrade, but the site fixes are still needed). Calculate the cost at each site. Would your choice change? Explain.

- 11.** Name two limitations of this decision method or its data, and one extra piece of information you would want before the county spends 90 million dollars.
