

Four Hours or Twenty Minutes: Write a Tsunami Warning Procedure

Investigation question: Using earthquake data, deep-ocean sensor readings and the rule that tsunami speed depends on water depth, what step-by-step procedure should a coastal warning office follow so that its harbor town gets enough time to evacuate without crying wolf?

Data-driven decision

Groups of 4

1 session

Setup 5 · Activity 48 · Cleanup 2 min

MS-ESS3-2 · assesses

MS-ETS1-2 · practice

MS-ETS1-3 · practice

Name _____

Group _____

Date _____

Your role today

- ☐ **Chief forecaster:** Leads the decision steps, makes sure each decision uses only data available at that time, and has the final word on the procedure's wording.
- ☐ **Travel-time analyst:** Organizes the arrival-time calculations, splitting the segments among the group, and checks every division with a calculator.
- ☐ **Records analyst:** Leads the analysis of the twelve past events and derives the rule that turns a DART reading into a forecast height.
- ☐ **Tester and recorder:** Applies the written procedure to each past event exactly as written, fills the test table and totals misses, false alarms and late warnings.

Safety

- No physical hazards beyond ordinary classroom work.
- This lab discusses real tsunamis that took lives. Preview it, do not require personal stories, and allow a student who is upset to work on the calculation section alone or step out.
- Make clear that Port Alder and its record are invented; for real local guidance, students and families should use their county's tsunami information and official alerts.

Procedure

1. Read the scenario and the timing rules aloud as a group. Underline the three numbers that limit every decision: quake data arrive 5 minutes after the quake, a message takes 5 minutes to reach the public, and the harbor district needs 30 minutes to evacuate.
2. Arrival times: split the eleven path segments among the group. For each segment, look up the speed for its depth in the speed table and calculate time = distance / speed. Add the segments for each source and convert the totals to hours and minutes.
3. DART times: calculate when a tsunami from the North zone passes station D-North and when one from the West zone passes D-West (q1). No station lies between the Local zone and the coast.

- Analyze the record of twelve past events (q2): look for how wave height at Port Alder relates to magnitude, find the events that break the pattern and what they share, and divide each event's wave height by its DART reading for the North and West zones to find a rule for forecasting height.
- Write your procedure in the procedure table: no more than six steps, each with when it happens, which data it uses and an if-then rule that ends in an alert level. Every decision may use only data available at that time.
- Test the procedure: for each of the twelve events, apply your steps exactly as written, without looking at the actual wave until your alert is recorded. Then compare with the alert the actual wave needed, and mark the result correct, miss (alert lower than needed) or false alarm (alert higher than needed). Mark whether each needed advisory or warning reached the public at least 35 minutes before the first surge.
- Total your misses, false alarms and late warnings, post them on the class chart, and answer q3.
- Meet your partner group. Compare your procedures event by event, find the step in each that prevented a miss or a false alarm, and write a combined procedure. Test the combined procedure on the events where the two disagreed.
- Answer q4 through q10 individually, in class or for homework.

Record your observations

Lab 3 recording sheet: the Port Alder warning office

Port Alder is an imagined harbor town on a Pacific coast. Its harbor district is low and flat, and its seafloor and harbor shape focus tsunami energy, much like Crescent City's. Three zones can send it tsunamis: the **North** subduction zone (far), the **West** trench (very far) and the **Local** fault zone just offshore. **Timing rules:** earthquake location, depth and magnitude reach the office 5 minutes after a quake; any message takes 5 minutes to reach the public; the harbor district needs 30 minutes to evacuate. **Alert needed:** warning if the wave is 1 m or more; advisory if 0.3 m up to 1 m; none if under 0.3 m. A watch means 'prepare while we check' and does not evacuate anyone.

Tsunami speed at each depth (calculated from speed = square root of 9.8 x depth; not simulated)

Water depth (m)	Speed (km/h)
10	36
50	80
100	113
200	159
500	252
1000	356
2000	504
3000	617
4000	713

Water depth (m)	Speed (km/h)
5000	797
6000	873

Paths from each source zone to Port Alder, and DART station locations

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

Segment	Distance (km)	Typical depth (m)
North 1: deep ocean	2500	4000
North 2: continental slope	150	1000
North 3: continental shelf	40	100
North 4: harbor approach	5	10
West 1: deep ocean	7200	5000
West 2: continental slope	200	2000
West 3: continental shelf	40	100
West 4: harbor approach	5	10
Local 1: slope above the fault	40	2000
Local 2: continental shelf	20	100
Local 3: harbor approach	3	10
DART station D-North: on the North path, 1,000 km from the source	1000	4000
DART station D-West: on the West path, 3,000 km from the source	3000	5000

Teaching dataset for an imagined coast; distances and depths are invented but realistic.

Arrival-time calculations (time = distance / speed)

Segment	Distance (km)	Depth (m)	Speed from table (km/h)	Time (h, to 3 decimals)
North 1	2500	4000		
North 2	150	1000		
North 3	40	100		
North 4	5	10		
North total				___ h = ___ h ___ min
West 1	7200	5000		
West 2	200	2000		
West 3	40	100		

Segment	Distance (km)	Depth (m)	Speed from table (km/h)	Time (h, to 3 decimals)
West 4	5	10		
West total				___ h = ___ h ___ min
Local 1	40	2000		
Local 2	20	100		
Local 3	3	10		
Local total				___ h = ___ min

1. How long after a North-zone earthquake does the tsunami pass D-North? How long after a West-zone earthquake does it pass D-West? Show the calculations and give each answer in hours and minutes.

Port Alder record: twelve past earthquakes

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

Event	Zone	Magnitude	Depth (km)	Fault motion	Largest DART reading (cm)	Largest wave at Port Alder (m)
E1	North	7.2	25	up-down	0.5	0.05
E2	North	7.9	30	up-down	3	0.3
E3	North	8.3	20	up-down	12	1.2
E4	North	8.8	25	up-down	35	3.5
E5	North	9.1	25	up-down	60	6.0
E6	West	7.6	30	up-down	1	0.06
E7	West	8.2	20	up-down	6	0.36
E8	West	9.0	25	up-down	40	2.4
E9	West	8.4	15	sideways	2	0.12
E10	Local	7.0	20	up-down	no station in time	0.2
E11	Local	7.8	15	up-down	no station in time	1.5
E12	North	8.0	300	deep, inside the sinking plate	1	0.1

Teaching dataset invented for this lab. 'Up-down' faults lift or drop the seafloor; a 'sideways' fault slides the plates past each other.

2. (a) How does the wave at Port Alder generally change as magnitude increases? (b) Which two large earthquakes broke the pattern, and what is unusual about each? (c) Divide each North event's wave height by its DART reading, then do the same for the West events. What rule could the office use to forecast the wave from a DART reading?

Our warning procedure (no more than six steps)

Step	When (time after the quake)	Data used	Rule: if ... then ... (alert level)
1			
2			
3			
4			
5			
6			

Testing our procedure against the record

Event	Alert at 5 minutes	Alert after DART (if any)	Final alert	Alert needed (from actual wave)	Correct, miss or false alarm?	Needed alert out at least 35 min before arrival? (Y/N, or none needed)
E1						
E2						
E3						
E4						
E5						
E6						
E7						
E8						
E9						

Event	Alert at 5 minutes	Alert after DART (if any)	Final alert	Alert needed (from actual wave)	Correct, miss or false alarm?	Needed alert out at least 35 min before arrival? (Y/N, or none needed)
E10						
E11						
E12						

Scores

Procedure	Misses	False alarms	Late warnings
Ours			
Partner group's			
Combined			

3. Summarize how your procedure scored. Which event gave it the most trouble, and why?

Analysis questions

4. Give the arrival time at Port Alder for a tsunami from each zone in hours and minutes. For a North-zone tsunami, if the office waits for the D-North reading and then takes 5 minutes to send the message, how much time is left before the first surge, and is that enough for the 30-minute evacuation?

5. On the North path, the last 45 km (segments North 3 and North 4) take about as long as the first 350 km of deep ocean would. Use the speed table to explain why, and explain why the wave also grows taller over those last 45 km.

6. Test a magnitude-only rule on the record: 'warning if magnitude is 8.0 or more; otherwise no alert.' Count its misses and false alarms. Use events E9, E11 and E12 to explain why a good procedure needs more than magnitude.

7. For a Local-zone earthquake, show with numbers that no procedure can give the harbor district 30 minutes to evacuate. What should Port Alder do instead? Name at least two actions taken before any earthquake happens.

8. Describe the combined procedure you and your partner group wrote. Which step came from each group, what problem did each step solve, and how did the combined procedure score compared with both originals?

9. Write a rule for when your office should end a warning, and explain it using what happened at Crescent City in 1964.

- 10.** Lowering your thresholds would catch every dangerous wave but cause more false alarms. Why is a false alarm a real cost and not just an inconvenience? Use the Crescent City story to support your answer.
