# Tsunami activity 7: Introduction to tsunamis

**Description:** An introduction to tsunami waves and tsunami hazard in Canada, followed by a student activity involving calculations of wave velocity, amplitude and travel time and explanation of the results.

**Materials:** 3 overheads

1. 1929 Grand Banks Tsunami
2. Tsunamis hazard potential in Southern British Columbia
3. Tsunami waves

Student worksheets

1. Part A: Calculating tsunami wave velocity and amplitude
2. Part B: Calculating travel time of a tsunami
3. Grand Banks Tsunami

calculators

**Duration:** 1 class for the lesson (may require homework) and part of next class for discussion.

**Teacher instructions and notes:**

1. Introductory discussion:

   - Begin the discussion with waves that students are more familiar with – ordinary beach waves. Ask if these waves speed up or slow down as they approach the beach and whether the waves increase or decrease in size. Why? Then introduce tsunamis. First, have students share what they know about tsunamis. Ask if they think Canada has experienced tsunamis and where (both east and west coasts). Use the overhead maps for illustration. (Canadian events are described in **Atlas of Canada: Tsunamis** [PDF] - included as part of these resources.
   - Unlike normal waves, whose source is at the surface (wind, boat), the source of a tsunami is at the base of the water column when there is a sudden displacement of part of the ocean floor. (Note: although unusual, tsunami can be generated in a large lake by bed displacement.)
   - This displacement is most commonly caused by fault movement during an earthquake, but can also be caused by a large submarine landslide, a volcanic eruption, or impact by a large meteorite. Large landslides into lakes have produced tsunami-like waves.

2. Using the accompanying wave diagram that can be reproduced on an overhead sheet, review the parts of a wave and explain how waves change as they move from deep water to shallow water.

   - wave height – vertical distance from lowest (trough) to highest (crest) part of a wave
   - amplitude – height of crest above still-water line (i.e. ½ wave height)
   - wavelength – distance between adjacent wave crests
   - period – time between 2 adjacent crests
   - travel time – time for a wave to travel from source to a specific location
   - Wave energy is proportional to both wavelength and wave amplitude squared.
   - In deep water, energy is transferred through the entire water column, resulting in long wavelengths and small amplitudes. With wavelengths of several kilometres and amplitudes in the order of centimetres to a few metres, the tsunami waves would be difficult to recognize in deep water.

- As the depth of water shallows, the wave energy is transferred through a much shorter water column. This causes wave speed to decrease, wavelength to decrease, and, since energy must remain the same, wave amplitude increases, forming the large destructive tsunami waves that crash onto the shore.

3. Introduce the formulas that the students will be using in their calculations:

**Velocity:** Tsunami velocity is controlled by the water depth, so velocity changes as a wave nears the shore.

$$V = \sqrt{gxD}$$

where D is water depth and

g is the acceleration due to gravity (9.81 m/s$^2$)

**Travel time:** Time = Distance / Velocity

**Amplitude**: If the amplitude in deep water is known, the amplitude in shallower water can be calculated.

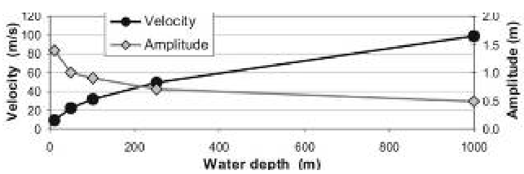
$$As/Ad = \sqrt{Vd/Vs}$$

$$As = Ad\ (\sqrt{Vd/Vs}\ )$$

where d is the value in deeper water and s is the value in shallower water

4. **Distribute the worksheets.** Part A involves the calculation of velocities and amplitude of a theoretical tsunami. Part B involves calculation of travel time for the 1929 tsunami that struck Newfoundland. (Note: other activities involving the 1929 tsunami are also available in this series.)
5. **Discuss in class the answers to the final questions**. Students may need 2 class periods to finish or may finish as homework.

<u>**Worksheet answers/comments**</u>:




velocities (99.0; 49.5; 31.3; 22.1; 9.9 m/s)

amplitudes (0.5; 0.7; 0.9; 1.0; 1.4 m)

Question 9. No. Although today we could go on alert and initiate evacuations, communications were very limited in 1929. Tsunamis were unknown on east coast.

Question 10. Warnings today - television and radio warning broadcasts, phone alerts to local officials, emergency vehicle loudspeakers, ship to shore radio, automated warning systems to alarm sirens (still uncommon).

Question 11. Reasons for inaccuracy?

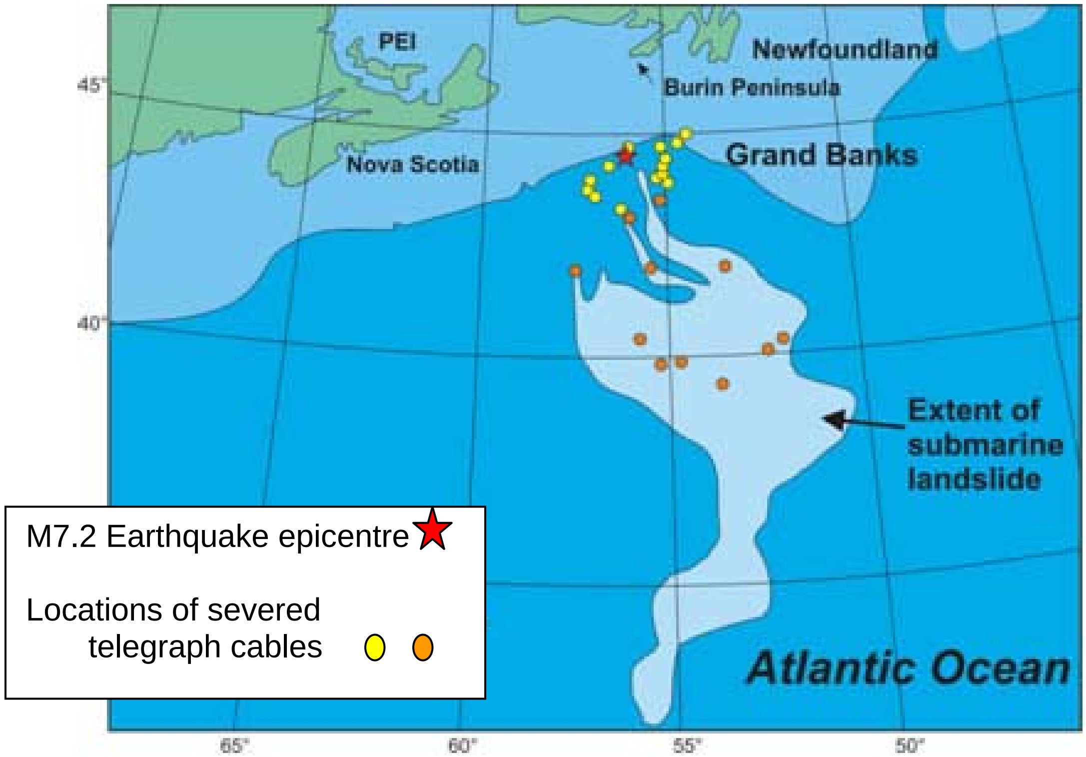
- Velocity of the waves will vary with changes in water depth but we used a constant velocity of 140 km/hr, which was true for much of the Grand Banks area. Reports state that the tsunami traveled at speeds up to about 500 km/hr through deep water, and about 140 km/hr over the continental shelf, but the tsunami waves slowed to about 40 km/hr near the coast.
- Map imprecision: The scale bar is not very precise, nor are ruler measurements, which result in inaccurate distance measurements.

Question 12. Fishing boats A and B.

- In deep water, energy is transferred through the entire water column, resulting in long wavelengths and small amplitudes, so that the tsunami waves have less impact on Boat B. As the depth of water shallows, the wave energy is transferred through a much shorter water column. This causes wave speed to decrease, wavelength to decrease, and, since energy must remain the same, wave amplitude increases, forming the large destructive tsunami waves that crash onto the shore. Boat A, near the shore in shallow water, would have had a much more dramatic ride.

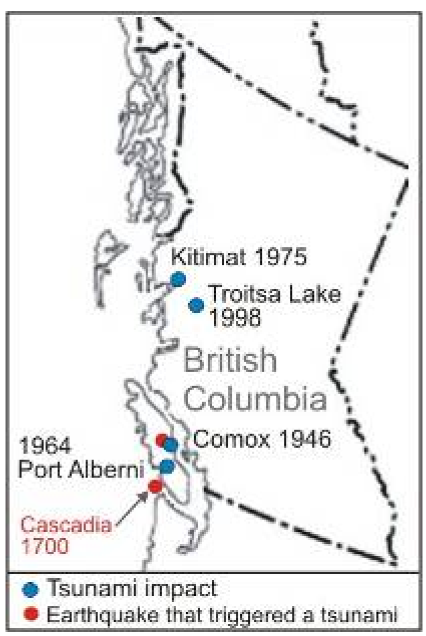
Overhead 1

## 1929 Grand Banks Tsunami



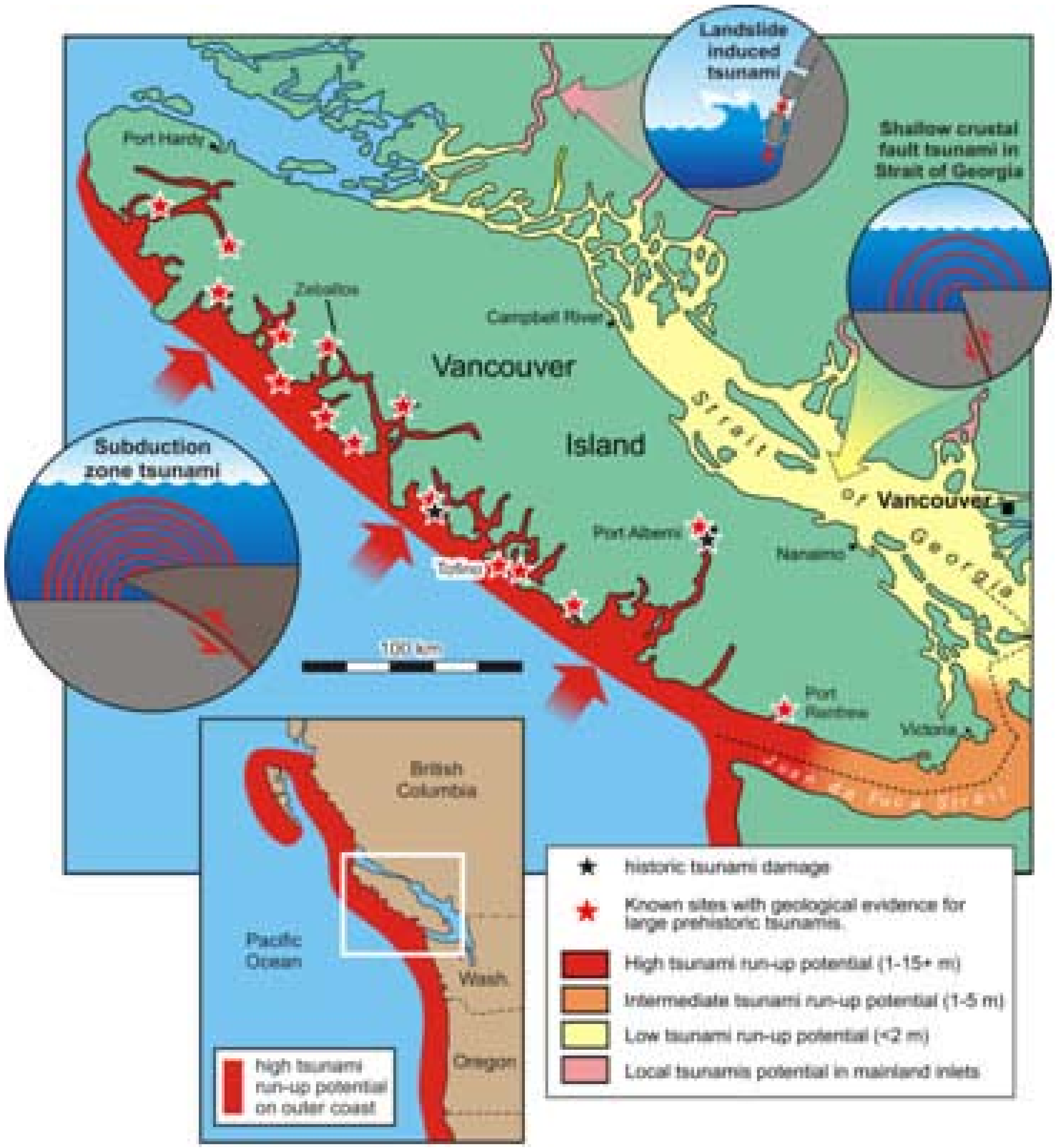

Source: EarthNet/Geonet Virtual Resource Centre for Earth Science Educators/Un centre virtuel de matériel pédagogique pour les enseignants en sciences de la Terre (http://www.earthnet-geonet.ca/)

## Map of Tsunami impacts in British Columbia



Overhead 2

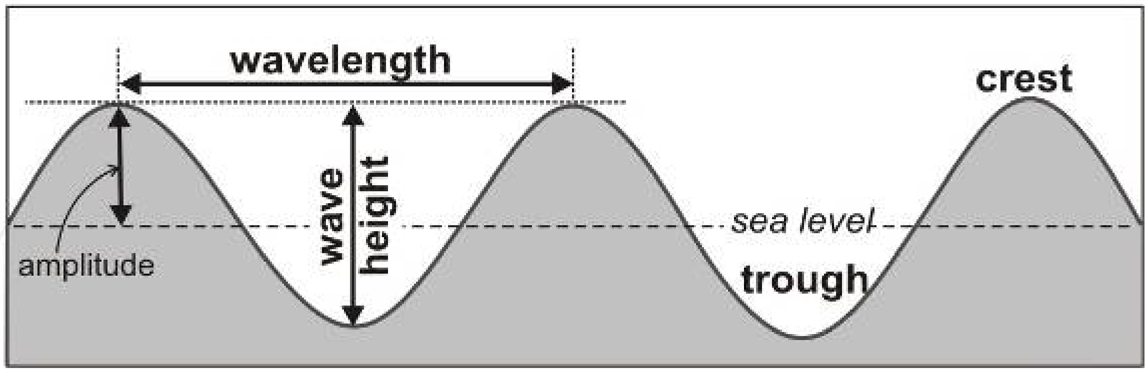
## Tsunamis hazard potential in Southern British Columbia

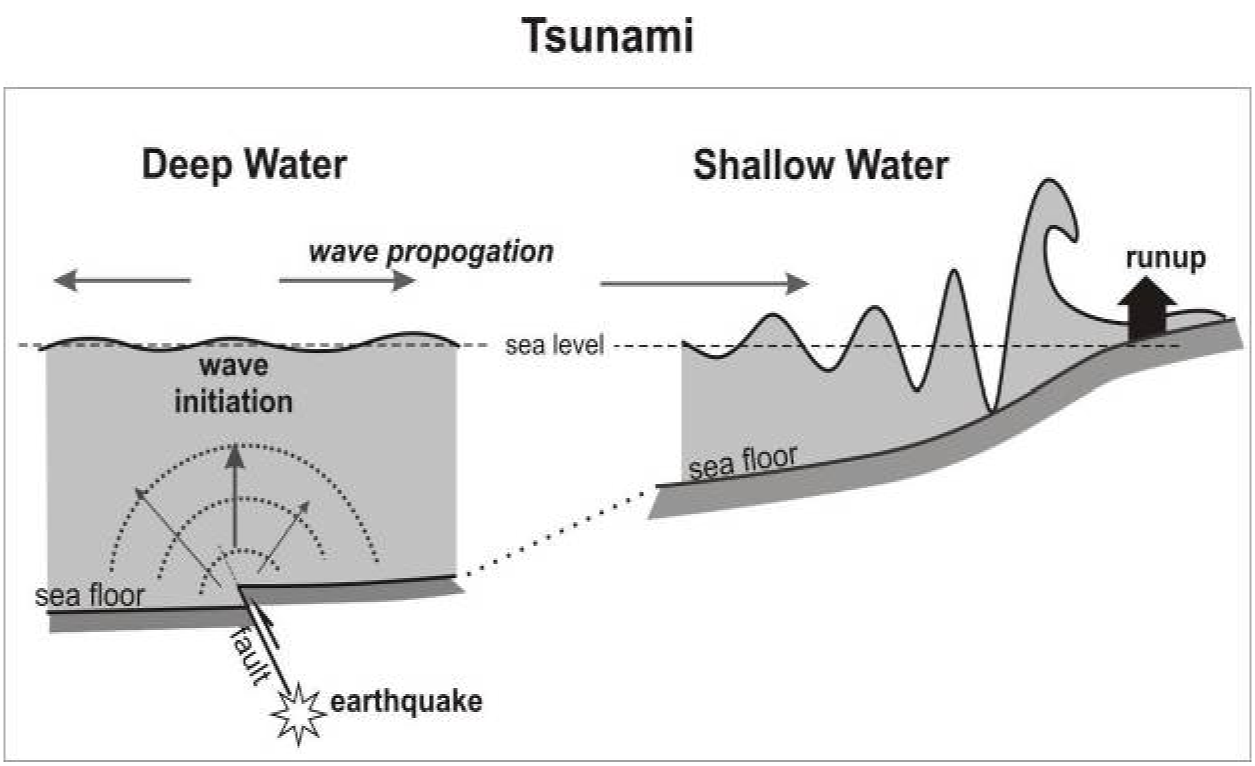



Source: Clague, J.J., Yorath, C.J.J., Franklin, R., and Turner, R.J.W. 2006. At Risk: Earthquakes and Tsunamis on the West Coast. Tricouni Press, Vancouver, 200 p.

Overhead 3

# Tsunami waves



Student worksheet 1 Name: ________________________________

## Part A: Calculating tsunami wave velocity and amplitude

1. A wave's velocity is dependent on the depth of water. A wave's amplitude is also controlled by the water depth. Using the formulas below, calculate the wave velocity and amplitude for these different water depths. Note that the amplitude in deepest water is given (0.5 m). (Hint: Calculate amplitude in steps, with Ad and Vd changing. i.e. The 'Ad' when calculating site B is site A; for site C it is site B, etc.)

   i. V = $\sqrt{gxD}$

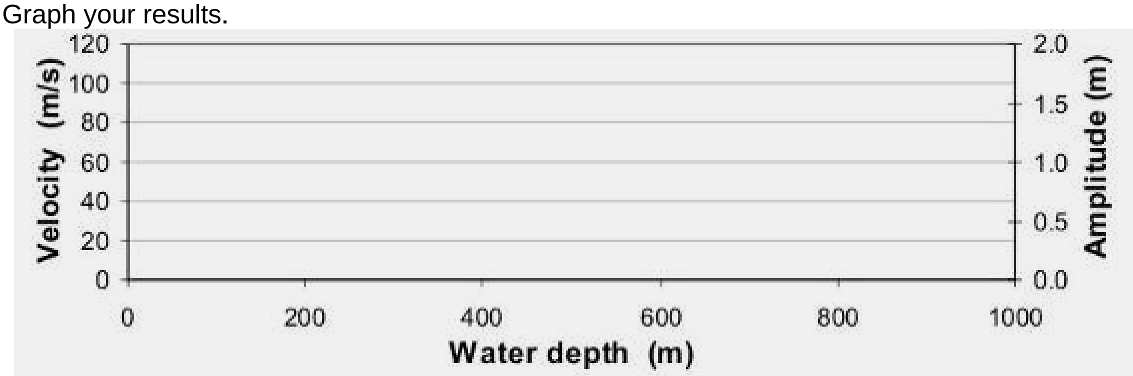
   where D is water depth and
   g is the acceleration due to gravity (9.81 $m/s^2$).

   ii. As = Ad ( $\sqrt{Vd / Vs}$ )

   where As is amplitude in shallower water
   Ad is amplitude in deeper water
   Vd is velocity in deeper water
   Vs is velocity in shallower water

| site | Water depth (m) | Acceleration due to gravity ($m/s^2$) | Velocity (m/s) | Amplitude (m) |
|---|---|---|---|---|
| A | 1000 | 9.81 | | 0.5 |
| B | 250 | 9.81 | | |
| C | 100 | 9.81 | | |
| D | 50 | 9.81 | | |
| E | 10 | 9.81 | | |

2. Graph your results.




3. Therefore, according to your calculations, wave velocity ________________________ as the wave approaches the shore. Wavelength also varies directly with water depth, so in shallower water, wavelength will ________________________. Because velocity ________________________in shallow water, to preserve wave energy (which remains approximately the same), amplitude of the waves must __________________________ .

 Name: ________________________________

# Part B: Calculating travel time of a tsunami

On November 18, 1929, a magnitude 7.2 earthquake, with an epicentre about 250 kilometres south of Newfoundland, generated an extremely large submarine landslide off the Continental Slope. The displacement of mass during this landslide caused a tsunami that struck the southern coast of Newfoundland. Tsunami waves travelled at a speed of 140 kilometres per hour across the Grand Banks.

1. Using the map scale and a ruler, measure the distance from the source (use the earthquake epicentre) to each station and landfall at Burin. Record the distances below.
2. Calculate the time travel of the tsunami to each station, using the formula below.

**Time = Distance / Velocity**

3. Assuming that the tsunami began at 5:00 pm at the epicentre, enter the actual time of arrival at each station.

| Station | Velocity (km/h) | Distance (km) | Travel Time (hr) | Actual time |
|---|---|---|---|---|
| Station 1 | 140 | | | |
| Station 2 | 140 | | | |
| Station 3 | 140 | | | |
| Station 4 | 140 | | | |
| Station 5 | 140 | | | |
| Burin, NFLD | 140 | | | |

4. On the map draw in travel time lines from the epicentre to Burin, NFLD. With a set of compasses, place the point on the epicentre and draw an arc through each of the stations. Indicate the time at which the tsunami would reach each station if it began at 5:00 pm at the epicentre.

Student Worksheet (page 2) Name: ________________________________

Answer the following questions.

5. Considering the travel time, _______, that you calculated, if the wave had been interpreted as a tsunami at station 1, would there have been enough time in 1929 to warn residents of the Burin Peninsula, NFLD, about the approaching tsunami? Explain.

6. If this event had happened today, what means could be taken to warn the shoreline communities of the approaching tsunami?

7. If a town needs to be evacuated, it is very important to know exactly how much evacuation time exists. The tsunami struck Newfoundland approximately 2.5 hours after the earthquake. Compare to your travel time calculations. If there is a difference, what are some reasons for your inaccuracy?

8. Examine the locations of fishing boats A and B on the map. Which of the boats will be more affected by the waves of the tsunami? Explain in detail why one boat experiences the full effects of the tsunami while the other only experiences a small wave.

Student worksheet 3

# Grand Banks Tsunami