Tsunami Hazards Guidance for Vessel Operators: Workshop Summary

AUGUST 2024

NUKA RESEARCH AND PLANNING GROUP, LLC

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Opinions expressed in this workshop summary are not necessarily those of the Prince William Sound Regional Citizens' Advisory Council, the City of Valdez, or any of the participants or the organizations they represent.

1 Introduction

On June 3-4, 2024, the Prince William Sound Regional Citizens' Advisory Council (PWSRCAC) and City of Valdez hosted a workshop to better understand the risks to vessels posed by geological hazards and tsunamis, and review vessel operator guidance. A Steering Group (see Table 1) guided the development of the agenda and invitees.

Table 1. Workshop steering group

Name	Affiliation
Robert Archibald	Board President, PWSRCAC
Aaron Baczuk	Emergency Manager, City of Valdez
Bretwood (Hig) Higman	Ground Truth Alaska
Barrett Salisbury	Division of Geological & Geophysical Surveys (ADNR)
Paul Twardock	Alaska Pacific University

The workshop agenda included presentations, panels, and a breakout session on the first day. The second day was spent underway on a tour boat, with sites of interest, a hypothetical scenario discussion, "show and tell" opportunity, and additional brainstorming. The agenda is provided in Appendix A.

Workshop participants included experts in landslides; tsunami modeling; how tsunamis impact vessels and harbors; operation of different types of vessels; and other areas. Participants represented local, state, and federal agencies from the U.S.; private vessel operators; and academic institutions. Most participants came from within Alaska, including many from the Prince William Sound (PWS) region, though there were also experts from universities in Washington, California, and British Columbia. See Appendix B for a final list of participants.

This workshop summary attempts to synthesize information and ideas shared during the workshop. The summary is organized thematically and does not provide a record of every presentation or discussion. The summary was shared with all participants for an opportunity to comment prior to completion. Provided comments were resolved to the best of the author's ability and with the goal of minimizing the use of technical or scientific jargon. Note, however, that this document does not necessarily represent the views of all participants or the organizations, companies, or agencies they represent.

2 Current understanding of tsunami hazard to vessels

The current understanding of how tsunamis may impact vessels is based on both different kinds of modeling (numeric and analog) and eyewitness accounts of historical events. Because landslide-generated tsunamis have been rare in places frequented by people or vessels, most sources of information – both modeled and real world – are from tsunamis caused by earthquakes. When considering landslide-generated tsunamis, understanding landslides is also critical. This understanding also comes from both modeled and real-world observations or instrument recordings. This section attempts to describe the tsunami hazards with a focus on landslide-generated tsunamis and how they may impact vessels. The information is based on presentations[1] as well as information shared in other parts of the workshop.

Landslides

Landslides occur when terrain releases downhill, which can happen slowly or suddenly. Landslides may impact land, glaciers, or oceans/lakes. Landslides also happen under water (submarine landslides). Recent examples of shallow landslides impacting communities in Alaska include events in Sitka (2015), Haines (2020), and Wrangell (2023). The Lamplugh Glacier area has had multiple landslide events including in 2016 and 2022. None of these landslides caused tsunamis; others that did are mentioned below.

Earthquakes are a common cause of landslides. Great (magnitude (M) 8+) earthquakes like the 1964 Great Alaska Earthquake (M9.2) can trigger thousands of ground failures in the span of a few minutes: in 1964, more than a dozen submarine landslides occurred in Resurrection Bay alone. Submarine landslides were later determined to be the cause of much of the damage to communities and infrastructure resulting from that earthquake. Small or moderate earthquakes can also trigger local ground failures (as well as tsunamis).

Landslides may also be caused by permafrost thawing, glacial retreat, or heavy rains/snow melt, all of which are becoming more common in recent years. While places with recent glacial retreat are the primary concern, slides can also occur in areas where glaciers retreated long ago. It is also possible for past landslides to reactivate.

In addition to causing tsunamis, landslides can also dam rivers or streams. This can lead to flooding if these dams are breached, potentially impacting people or infrastructure over a much wider area than the landslide itself. This can also mean that hazards associated with the landslide are felt many years later.

[1] Presenters on these topics included Bretwood Higman (Ground Truth Alaska), Dennis Staley (U.S. Geological Survey), Pat Lynett (University of Southern California), and Marten Geertsema (British Columbia Ministry of Forests).

Monitoring slopes

Scientists are using remote sensing to identify landslides or potential landslides in the PWS region, including those near water that could result in a tsunami.[2] Remote sensing monitoring can be done with both satellite or other aerial imagery allowing for comparisons of the area over time to detect movement or cracking that may be signs of slope instability. Lidar (light detection and ranging) provides more detailed mapping of changes in surface elevation indicating slope movement. Seismic measurements can also detect significant movements in real-time. Other types of instrumentation like infrasound, differential global positioning systems (dGPS), or radar systems can be used to monitor instabilities.

Landslides often occur without warning or an obvious trigger.

Barry Arm landslide and tsunami potential

State and federal agencies and universities are working together to monitor a large landslide above Barry Arm in Prince William Sound. The unstable slope is 1.5 miles wide and 3,000 feet high. While the slide has been moving for decades, significant movement was observed between 2009 and 2015 and has somewhat slowed more recently.

There is the potential for a significant and massive failure to occur and cause a large tsunami that would reach Whittier. Instrumentation is in place on the slope with updates provided on a webpage. Current efforts cost $3 to 4 million per year.

For more information and updates, see:
https://dggs.alaska.gov/hazards/barry-arm-landslide.html

Tsunamis

If a subaerial landslide reaches water (or if a landslide occurs under water) it may cause a tsunami. When this occurs, tsunami characteristics will depend on many factors:

- Volume, type, and mechanical nature of slope material (the landslide itself) and the mechanism of failure (partial vs. complete failure)
- Impact velocity
- Whether slope failure occurs above or below the water (or both)

[2] See Schaefer et al., 2024 at https://pubs.usgs.gov/publication/ofr20231099.

- Depth and shape of receiving waterway (this bathymetric data has been traditionally used for navigational charts, but is also key to modeling tsunamis)
    - Presence and extent of sea ice
    - Tide state at the time (or presence of storm surge or other drivers of water depth)
- Presence and type of debris from the slide itself or picked up from the shoreline (this may include natural features like rocks, trees, or ice, etc., but also manmade features such as buildings, containers, and other vessels)

The actual tsunami may consist of multiple waves, which may or may not break depending on their height and the water depth (wave breaking is more likely in shallower waters). Strong currents are also likely, possibly with significant eddies near breakwaters and constrictions. This effect has been observed in studies of seismic tsunamis in California. The wave height and wave shape, the speed and direction of currents, and extent and severity a tsunami's impact will all depend on the factors above.

Tsunami impacts to ports/harbors

Tsunamis can inundate ports and harbors along with other vulnerable coastal areas. Real world events provide insights into impacts to this infrastructure such as:

- Damage to docks, wharves, containers, and vessels (particularly docked vessels which end up on shore)
- Containers, vessels, or other equipment being picked up and circulated in the water, causing further hazard to people or infrastructure (e.g., containers can float in as little as one foot of water)
- A bollard pulled from a dock

Even modest waves can generate strong currents. As one example, currents associated with the 2011 Tohoku earthquake and tsunami in Japan damaged the harbor in Crescent City, California, causing significant damage (and cost) even though it did not actually inundate the land due to the low tide at the time. Even "small" tsunamis (1-meter (m) /3-foot (ft) waves) can produce currents greater than 10 knots. Currents may change rapidly over short distances and may produce large eddies. Eddies pose a particularly important hazard because they create strong currents with high shear along their margins and/or create erratic forces that interact with port infrastructure. Eddies can drift away from the location where they initially form, impacting areas that otherwise would have been relatively safe. These hazards are also difficult to map.

Tsunami impacts to vessels

Observed tsunami impacts to vessels (regardless of cause) include:

- Vessels sunk or partially sunk
- Vessels washed onto shore

- Groundings when the water withdraws significantly due to a tsunami (even of lashed ships)
- Damage to hull/equipment from contact with docks/piers
- Vessels broken free from moorings

Recent research has used analog models of tsunamis in wave tanks to understand the way currents form and dissipate in harbors, which can inform how they will impact vessels.

Historical landslide-generated tsunamis in Alaska
Presenters shared the following select examples of landslide-generated tsunamis in Alaska:

Taan Fjord (2015): A landslide in an area with rapid glacial retreat caused a tsunami. Waves reached 193 m (633 feet). There were no known casualties or infrastructure damage in this remote region.

Beluga Bay/Hubbard Glacier (2012): Only the tip of a much bigger landslide reached water in this case, causing a 2 m high tsunami.

Lituya Bay (1958): A M7.8 earthquake triggered a landslide that generated a giant tsunami in Lituya Bay, Alaska. The highest recorded runup on shore was 524 m (1719 ft). This is also the highest recorded runup of any tsunami worldwide. Of the three vessels in the bay at that time, one was lost, resulting in two fatalities. Another was heavily damaged, forcing two people to abandon ship.

Historical landslide-generated tsunamis elsewhere
Examples of landslide-generated tsunamis from British Columbia, Greenland, and Norway were shared with photos and video.

3 Agency responsibilities

Agency representatives from the local, State of Alaska, and federal levels shared an overview of what they do – or would do – as related to landslide-generated tsunami events.[3] This ranges from identifying and monitoring potential landslides to conducting search and rescue or

[3] The panelists were: Dave Snider (National Tsunami Warning Center); Commander Sarah Rousseau (U.S. Coast Guard); Barrett Salisbury and Jill Nicolazzo (Alaska Department of Natural Resources); Anna Carey (Alaska Department of Environmental Conservation); and Aaron Baczuk (City of Valdez).

recovery operations after a tsunami. The table below was developed from their remarks as well as information shared in other sessions.

Table 2. Government mandates and activities related to landslide generated tsunami vessel hazard

Agency/department	Relevant activities
Federal	
National Oceanic and Atmospheric Administration (NOAA)	
National Tsunami Warning Center (NTWC)	Within National Weather Service (NWS), issues both guidance and warnings when a tsunami occurs
NOAA Office of Coast Survey	Collect bathymetry data (currently 63% of Alaska does not have bathymetry up to modern standards)
	Publish "Coast Pilot" which includes information about coastal hazards (currently the Barry Arm instability is described)
U.S. Coast Guard (USCG)	
Captain of the Port	Operate PWS Vessel Traffic System (VTS)
	Communicate to mariners via Channel 16 (tsunami alerts are received from the NTWC in about one minute)
	Ensure continuity of operations
	Close port if appropriate
	Respond to oil/hazardous substance spills
	Coordinate recovery effort, as needed (including salvage)
Sector Western Alaska and the U.S. Arctic	Direct search and rescue as needed, including with Valdez-based vessels/assets
U.S. Geological Survey (USGS)	Study landslides and tsunamis to inform risk mitigation
	Organize multi-agency landslide research effort in PWS
State of Alaska	
Alaska Department of Natural Resources (ADNR) Division of Geological & Geophysical Surveys (DGGS)	Identify and communicate flooding, landslide, earthquake, and tsunami hazards in Alaska (and other geologic hazards)
	Respond to geohazard events at the behest of the State Emergency Operations Center
	Currently identifying landslide "hot spots" in Alaska
	Developing a landslide-reporting app for public use (forthcoming)

Agency/department	Relevant activities
Alaska Department of Environmental Conservation (ADEC)	Oversee industry contingency plans Oversee response to oil/hazardous substance spills Participate in state Emergency Operations Center
Local	
City of Valdez	Local emergency response plan Hosted statewide tsunami exercise this year Educate residents about hazards and what to do in event of a tsunami

The **National Tsunami Hazard Mitigation Program (NTHMP)** is a federal funding source to support the collaboration of the State of Alaska's DGGS, the University of Alaska Fairbanks, the Division of Homeland Security and Emergency Management, and the Alaska Earthquake Center to assess tsunami hazards and issue guidance. NTHMP produces informational products showing potential tsunami impacts for different communities and waterways in Alaska. These are available at earthquake.alaska.edu. The National Tsunami Warning Center leads warning centers and aids in state mitigation/education efforts.

4 Guidance for mariners

The NTHMP developed guidance for mariners in California based on lessons learned from recent tsunamis. That guidance was developed based on input from the maritime community focused on when/whether to move boats out of an area, how to reach boat owners, and how to prepare for long-term recovery and improve resilience. Guidance for mariners has been developed for Alaska as well, considering both local and distant earthquakes. The current guidance, which focuses on earthquake-generated tsunamis, is shown below. [4]

"General Guidance on Distance Source Tsunamis

1. If mariners have limited options, are experienced boat handlers, and are prepared to remain at sea for up to a 24-hour period, they may attempt to take their vessel out of harbor and transit offshore. Personal considerations include:

- estimates of weather
- size of the tsunami
- seaworthiness of the boat

[4] Text from workshop presentation by Elena Suleimani

- personal supplies already on board, including fuel
- the time and inconvenience of moving the boat
- the relative safety the berth provides the boat

2. Most recent recommendation: travel beyond 30 fathom (180 foot) depth. Stay 1/2 mile away from the shore to avoid coastal currents.

General Guidance on Response to Local Tsunamis (originating in the Gulf of Alaska)

– If you are on land or tied up at the dock: Leave your boat and go to high ground on foot as soon as possible. NO attempt should be made to move a boat for locally generated tsunamis.

– If you are on the water but near shore: Use your best judgment to decide between the two options: safely beach/dock the vessel and evacuate to high grounds or get to minimum offshore safe depth. If you can safely beach or dock your boat and get to high ground before the tsunami, then this is your best chance. If that is not possible, head to deep water as quickly as possible.

– If you are at sea, do not return to port if a tsunami warning has been issued. A boat located where large currents may form may be better off in deeper water, i.e. 100 fathoms or greater. Stay at least 1/2 mile from shore."

A panel of vessel operators[5] shared some of the procedures they have in place in the event of a tsunami and their experiences with tsunami warnings (e.g., scrambling to higher ground from nearshore campsites). In Portage Lake, where there is a known unstable slope, there has been winter damage to the tour boat and dock from the boat being picked up and slammed into pilings (the boat remains in the frozen lake for the winter).

Paddlers and small boat operators may have a "go-bag" of essentials in case they need to quickly evacuate an area, including a communications device like VHF radio to both listen to updates and communicate with others. They should always know the best route to higher land from a camp site, though steep and/or forested slopes can make it difficult to get higher quickly. Currents of 1-2 knots become challenging for kayaks, and debris can be dangerous. The tanker operators in Prince William Sound get tsunami alerts via satellite communications to the ships. The ships are capable of handling large waves in deep water. If they were at the dock, they would shut down

[5] Paul Twardock (kayaker and guide); Joy Briggs (Holland America tour boat); Dave Janka (Auklet); Andrea West (Polar Tankers)

cargo operations and depart the berth to go to deep waters. They would coordinate with ADEC and USCG to determine the best course of action, including whether any of the speed restrictions in the Sound would be lifted to get the ship to more open water faster.

Workshop participants discussed several considerations related to the best course of action for a vessel in the event of a landslide-generated tsunami. While communications are key, it is entirely possible that waves would arrive too quickly for the alert system to be activated, at least not in time to inform vessels nearby. The considerations discussed reflect the type of information that vessel operators will need to understand in advance to make safer decisions quickly in the event of an incident. The following considerations were discussed:

- **Greater awareness of the "natural warning signs" is needed because it is unlikely there will be time for an alert.** These include signs of increased instability of slopes (e.g., rockfalls, dust rising), loud noises indicating a landslide is underway, or unexpected wave breaking indicating a tsunami is occurring.
- **Vessel operators who frequent an area may notice changes such as dust rising or cracking of the slope that would not otherwise be identified.** It is necessary to advise vessel operators of the importance of these observations and how they can share this information with scientists.
- **Waters protected from winds or wind-generated waves may be less safe than open water in a tsunami.** While seeking shelter from wind-driven waves behind land (an island, headland, etc.) is very familiar to vessel operators, currents or eddies from a tsunami may be *worse* there. Tsunami waves may also surge over the land.
- **Increase awareness of areas with unstable slopes so vessel operators can make informed decisions about whether to avoid them**. This includes understanding that the nicest anchorages at the heads of bays may not be the safest in terms of tsunamis. This information may also change over time as slopes change or new information becomes available.
- **Beware of debris in the water after an incident.** This may include rocks/boulders where they had not existed before, floating and semi-submerged trees or ice, or damaged coastal infrastructure, vessels, or cargo.
- **Vessels should be prepared to stay on the water for several days (with a "mariner survivor kit").** It may not be possible to return to harbor that has been damaged by waves/currents or debris right away. A specific list of items was not developed, but fuel, water, and provisions were suggested.
- **If a vessel is in an inlet or fjord, it may be better to aim for the deepest water *there* rather than risk crossing shallower waters (such as a glacial moraine) trying to reach any certain water depth.** This will depend in part on how fast the vessel can move, but if the landslide occurs in that inlet/fjord, most vessels would not be able to beat

the waves out and could be caught from behind or caught by a breaking wave, eddy, or strong current if they move to shallower or narrower areas.

- **It may be better *not* to go to shore, given the increased likelihood of breaking waves in shallower waters.** Depending on the vessel and the shoreline, it may also be difficult or impossible to safely disembark crew and, if any, passengers and move away from breaking waves in time.
- **Prepare captain, crew, and passengers for going over/through a breaking wave if it cannot be avoided.** Waves are more likely to break the shallower the water. One cubic yard of saltwater breaking weighs one ton.
- **Do not turn your back after the first wave, as a tsunami will likely include multiple waves.** In a landslide-generated tsunami event, the duration of the waves and strong currents is hard to predict, but do not assume it is over after one wave.
- **Eddies and strong currents may extend well away from the waves caused by a tsunami**. Currents or strong eddies could still impact a vessel, particularly in steep or narrow areas, even if tsunami waves do not reach it (or are not large enough to impact it if they do). Strong currents may persist long after the sea surface disturbance has passed.
- **If you are onshore, seek higher ground**. In a community where inundation mapping has been conducted, follow the directions provided. Do not try to observe the tsunami near the harbor or shore. If in a remote area, go higher. There is not a specific height at which safety is guaranteed, as the height of landslide-generated tsunami waves is unpredictable. It was recognized that climbing steep and/or densely forested shorelines is difficult and may be slow.

Additionally, there could be designated muster stations away from shore where vessels can gather after an event if it is not yet safe or possible to reach a harbor. This is partially guidance for vessel operators but would ultimately need to be coordinated by the USCG.

5 Research needs

Tsunami inundation has long been modeled to inform emergency response planners and the public of how to avoid potential flooding on shore. A panel session and subsequent discussions considered the current status and gaps related to research to inform understanding of different types of vessels' exposure, sensitivity, and adaptive capacity to tsunami hazards.[6] Numerical

[6] Panelists in this session were: Pat Lynett (University of Southern California); Katy Barnart (U.S. Geological Survey); Elena Suleimani (National Tsunami Hazard Mitigation Program); Randy LeVeque (University of Washington); Vasily Titov and Yong Wei (NOAA).

modeling results are being used to inform vessel operators and harbor development in Washington and California, with maps of potential currents and waves resulting from earthquake-generated tsunamis.

Modeling what a landslide-generated tsunami could look like requires location-specific information about all the factors described in the previous section, from the volume, mass, and velocity of the landslide to the bathymetry of the water body. Even with good information, it is not possible to predict specific outcomes. Future efforts should include:

1. Increased monitoring of unstable slopes to provide the best information possible regarding potentially unsafe anchorages, campsites, etc. The Barry Arm landslide is the best example of a multi-agency effort to instrument and monitor an actively deforming, potentially tsunamigenic slope.
2. Continue to refine models as used for Barry Arm and extend to other areas so vessel operators can have better information on locations where landslide-generated tsunamis may be the most likely to occur, the extent and characteristics of associated waves, and nature of associated currents.
3. Continue to use numerical and analog models to better understand how different sizes or types of vessels may be impacted (i.e., their sensitivity to different tsunami conditions) and how to best mitigate such impacts.
    a. Test maneuvers for different types of vessels, particularly for large vessels to be able to ride out waves or retain control during large currents.
    b. Consider vessel structural integrity and potential for failures of large vessels.
4. Continue to generate and share bathymetry data for areas where this is needed to inform tsunami modeling.
5. Continue to generate and share elevation data in the intertidal zone (that connects bathymetric and topographic datasets) for use in inundation modeling.
6. Identify potential locations and characteristics of submarine landslides.
7. Improve modeling of how a tsunami forms from the location where the landslide meets the water (for landslides from above the water).
8. Increase tsunami/tide sensors to improve monitoring of all types of sea-level disturbances.

Item #1 provides an opportunity for vessel operators or other “citizen scientists” to contribute. Since installing and maintaining sensors in multiple locations would be expensive and could take years to complete, the public can assist by alerting agencies if they see signs of changes that indicate slope movement (DGGS and the City of Valdez are currently developing an app that the public can use to share these types of observations with scientists). Vessel operators can help,

especially those who travel repeatedly to the same locations and are therefore well-positioned to observe changes.

6 Communications mechanisms

In Alaska, tsunami-related messaging has typically focused on people on shore (in parallel to the focus on inundation maps, for example). Many suggestions were offered for ways to reach people who may be on the water. These will vary depending on the target audience.

Table 3, below, focuses on communications related to tsunami preparedness. These communications are not necessarily time sensitive but are instead intended to raise awareness about the tsunami hazard (generally or in a particular location such as Barry Arm, for example), heighten awareness of landslide-generated tsunamis (which are still new to some audiences), or educate vessel operators about how best to stay safe. Table 4 focuses on time sensitive communications in the event of an actual or potential tsunami. These communications may include notifying mariners of heightened reason for concern around a particular slope due to recent detection of rapid movement, alerting them to an actual or potentially imminent tsunami due to an earthquake or landslide somewhere, or providing information as part of response actions because a tsunami has occurred.

Some general challenges with communications in the PWS region were also mentioned: for example, additional VHF repeaters are needed (this is a work in progress and requires funding both for installation and maintenance). Communicating information to vessels via their Automated Identification Systems (AIS) is the only mechanism identified in both tables as it could be used both to raise awareness about locations with unstable slopes, for example (and link to broader guidance and information), *and* be used in the event of a tsunami incident and its aftermath. Though it was not a focus of the discussion, AIS could also be helpful more broadly during a response to a tsunami event as the location of vessels and their last known position are visible via the AIS system.

Table 3. Suggested options for communications mechanisms to reach professional mariners and recreational boaters for ***general awareness/education regarding tsunami preparedness***

Mechanism	Audience	Comments
Social media & traditional media	General public	Suggestions included local newspapers, television, and radio as well as various social media sites and applications
Signage at harbors	All harbor users	Basic awareness/messaging, such as “Kids Don’t Float” campaign

Mechanism	Audience	Comments
Events/outreach via harbors	All harbor users	Include water taxis, recreational boaters
Pamphlet/tri-fold brochure	General public/harbor users	Could be disseminated by harbormasters and USCG auxiliary
AIS	Vessels carrying AIS	AIS are required for most larger vessels and may be carried voluntarily by others (Marine Exchange of Alaska can send messages to AIS devices) Could send static notifications to vessels entering an area identified as having an unstable slope Getting AIS on more vessels would enhance this communication strategy
Trainings, targeted outreach	Professional mariners	Though not discussed as much in the workshop, the workshop itself and recent outreach to the Cook Inlet Harbor Safety Committee by the NTHMP and NTWC are examples of reaching out to vessel operators; this could also be done via fisheries organizations, etc. around Alaska
"Coast Pilot" (NOAA publication)	Available to public; used more by professional mariners	Updated periodically but updates may be hidden in large volume of text
Charts	Available to public, mariners, recreational boaters	Use to identify areas of known unstable slopes (discussed generally; role of electronic charts and virtual aids to navigation not explored)

*Table 4. Suggested communication mechanisms for **real-time, time sensitive information** targeting professional mariners and recreational boaters*

Mechanism	Audience	Comments
VHF Channel 16	Anyone using a VHF radio	USCG disseminates the message but does not develop it – that needs to come from NTWC Mariners can notify each other on Channel 16 as well (if people have it on)

Mechanism	Audience	Comments
		Smaller vessels such as kayaks may not have a VHF, keep it on, or monitor Channel 16
Nixle app	Anyone in cell/internet range who has signed up for alerts	Intended for general population and wide range of emergencies
USGS Earthquake Notification service	Same as above	Earthquake alerts https://earthquake.usgs.gov/ens/
NTWC alerts	Same as above	Alerts of tsunamis or potential tsunamis https://tsunami.gov/?page=productRetrieval
InReach	Anyone carrying device; most common for paddlers/small vessels who do not carry other comms devices	Not always on (saving battery) Getting Nixle messages sent via InReach would be an improvement Messages may be delayed if connection is not reliable
Satellite communications on vessel	Vessels who carry these devices	Mentioned as key source of information for tanker operators
AIS	Vessels carrying AIS	AIS are required for most larger vessels and may be carried voluntarily by others (Marine Exchange of Alaska can send messages to AIS devices) Could be used to alert AIS-carrying vessels in potential impact area real-time if Marine Exchange is notified
"Coast Pilot" (NOAA publication)	Available to public; used more by professional mariners	Updated periodically but updates may be hidden in large volume of text

7 Conclusions

Landslide-generated tsunamis are a growing concern in Alaska as permafrost thaws and glaciers retreat, leaving unstable slopes in more parts of Alaska's mountainous waterways. Just over 40 experts in geologic hazards, tsunami modeling, different types of vessel operations, and on-water emergency response (including to pollution events) met to share perspectives, needs for further research or communications, and options for vessel operators to minimize risk to their

vessel, crew, and passengers in such an event. Tsunami experts emphasized that landslide-generated tsunamis may require very quick reaction, include multiple waves, and bring on fast currents and eddies that could impact vessels beyond the immediate area. Vessel operators may be safest going towards the deepest water nearby (not to shore or over shallows), facing into the wave, and doing their best to watch for debris. A tsunami may consist of a series of waves, so it is important to stay on station to the extent possible for an hour or more. After a tsunami, it is possible that a vessel will be unable to return to a harbor or shore if it has been damaged. Preparing for unexpected time on the water is important.

The need to expand education of both professional mariners and recreational boaters was highlighted, along with some potential avenues for both education and awareness of the issue and options and time-sensitive alerts. These mechanisms also apply to tsunamis from other sources, such as earthquakes. Education about landslide-generated tsunamis should also include what to watch for and how to share information with scientists if there are signs of significant changes in a mountainside. Additional research is needed to improve on the information and guidance for mariners, ranging from expanding instrumentation and monitoring (including by citizen scientists) of potentially unstable slope areas, to continuing to improve modeling related to landslide-generated tsunamis and how different types of vessels may be affected.

Appendix A – Workshop agenda

PWS Vessel Operator Tsunami Hazards Guidance

June 3-4, 2024 * WORKSHOP AGENDA

Valdez Convention and Civic Center*314 Clifton Ct., Valdez, Alaska

IMPORTANT NOTE: We will spend the **SECOND** day underway on a Stan Stephens Glacier & Wildlife Cruises vessel, the *Valdez Spirit*. All passengers must have registered for the workshop or notified Nelli Vanderburg in advance to board.

Monday, June 3 **Coffee and refreshments available at 8:30 am**

TIME	SESSION	SPEAKERS
9:00 – 9:10	Opening remarks & reflections on 1964 earthquake and tsunami	Robert Archibald (Board President, PWSRCAC)*; Dorothy Moore, (PWSRCAC Board)
9:10 – 9:25	Workshop purpose, scope, and intended outcome	Bretwood Higman (Ground Truth Alaska & Workshop Steering Committee)
9:25 – 9:40	Agenda, logistics, and who is in the room	Sierra Fletcher, Nuka Research
9:40 – 10:10	What's the problem? Unstable slopes/potential landslide-generated tsunamis in PWS region	Dennis Staley, US Geological Survey
10:10 – 10:20	**Break**	
10:20 – 10:50	In a landslide tsunami event, what might happen on the water in PWS and how might vessels be impacted?	Pat Lynett, University of Southern California
10:50 – 11:20	**PANEL:** Vessel operators – what and where do you generally operate, and what would you do if a tsunami occurred?	Paul Twardock (kayaker); Joy Briggs (tour boat); Dave Janka (Auklet); Andrea West (Polar Tankers)
11:20 – 12:15	**PANEL:** Agency roles before, during, and after an event	Dave Snider (National Tsunami Warning Center); Barrett Salisbury and Jill Nicolazzo (Alaska Department of Natural Resources); Anna Carey (Alaska Department of Environmental Conservation); Aaron Baczuk (City of Valdez); CDR Sarah Rousseau (U.S. Coast Guard)
12:15 – 1:15	**Lunch (provided)**	

* Archibald was unable to attend. Opening remarks given by Jim Herbert (PWSRCAC Board).

TIME	SESSION	SPEAKERS
1:15 – 2:00	**PANEL:** Modeling tsunamis & impacts to vessels: what we know, what we don't know, what we wish we knew	Pat Lynett (University of Southern California); Katy Barnart (U.S. Geological Survey); Elena Suleimani (National Tsunami Hazard Mitigation Program); Randy LeVeque (University of Washington); Vasily Titov and Yong Wei (NOAA)
2:00 – 2:30	Current and anticipated analysis and information for mariners	Elena Suleimani (National Tsunami Hazard Mitigation Program)
2:30 – 2:45	Reflections from Canada: shared challenges or solutions?	Marten Geertsema (BC Ministry of Forests)
2:45 – 3:00	**Break**	
3:00 – 4:45	Breakout Groups & Report Back	Sierra Fletcher & Steering Committee
4:45 – 5:00	Wrap up Day 1	

5:30 – 7:00pm Fireside Chat at Magpie's on the Fly "Science, Slope Instability, and the City of Valdez" (hosted by City of Valdez and US Geological Survey)
*****Dinner on your own*****

Tuesday, June 4 *Onboard the* Valdez Spirit *(8:00 meet at dock, return by 3:00 pm)*

Come prepared to be on the water with a warm jacket (rain jacket depending on forecast), hat/sunglasses/sunscreen, and comfortable footwear.

TIME	SESSION	SPEAKERS
8:00 am	Meet at Stan Stephens Cruises ticket office	
8:30 am	Departure from dock; coffee and light breakfast onboard	
	Narration & explanations: • Sights of interest (Bretwood Higman, Dennis Staley) • View from the pilot house and decision-making under way (Amanda Bauer) • Barry Arm & reflections of a citizen scientist (Valisa Higman) Show & tell: • Participants share materials & other information Breakout stations: • Revisit our attempt to summarize the takeaways from yesterday's breakout groups – time for changing, adding, or underlining! Wrap-up & next steps (Sierra)	
2:30	Estimated return to dock (no later than 3:00 pm)	

Appendix B – Final participant list

Last Name	First Name	Affiliation
Adams	Loyce	University of WA
Baczuk	Aaron	City of Valdez
Barnhart	Katherine	USGS
Blancaflor	Mercedes	PWSRCAC
Braun	Chief Stephen	USCG
Briggs	Joy	Holland America
Carey-Eiman	Anna	ADEC
Dunkin	Mollie	ADEC
Fletcher	Sierra	Nuka Research
Geertsema	Marten	University of Northern BC
George	David	USGS
Herbert	James	Private boater
Higman	Bretwood	Groundtruth Alaska
Higman	Vasila	Artist
Hollingsworth	John	Marine Exchange of AK
Janka	David Phillip	Auklet Charters
Lally	Joseph	PWSRCAC
LeVeque	Randall	University of WA
Lydon	Barbara	USDA
Lynett	Patrick	University of S. CA
Mishmash	Sonja	ADEC
Mitchell	Max	Private boater
Nicolazzo	Jillian	AK DGGS
Payne	Dan	USCG
Predeger	Graham	USDA
Ray	Ellen	USDA
Robertson	Roy	PWSRCAC
Robida	Jeremy	PWSRCAC
Rousseau	CDR Sarah Kristine	USCG
Salisbury	Barrett	AK DGGS
Schantz	Donna	PWSRCAC
Snider	David	NOAA

Sorum	Alan	PWSRCAC
Staley	Dennis	USGS
Suleimani	Elena	University of AK
Talbott	Jeremy	City of Valdez
Titov	Vasily	NOAA
Twardock	Paul	Alaska Pacific University
Vanderburg	Nelli	PWSRCAC
Wei	Yong	NOAA
West	Andrea	Polar Tankers
Wilkinson	Caroline	NOAA