

Interagency Technical Operations Plan for Landslide and Tsunami Hazards at the Barry Arm Landslide Prince William Sound, Alaska, USA



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Cover: Barry Arm Landslide on June 17th, 2021. Photo courtesy of Dennis Staley.

Table of Contents

| | |
|---|----|
| Table of Contents | 3 |
| Executive Summary | 5 |
| Introduction and Scope | 6 |
| Version Notes | 7 |
| Acronyms | 9 |
| Agency Roles and Responsibilities..... | 11 |
| Multiagency team..... | 11 |
| U.S. Geological Survey (USGS) | 12 |
| Alaska Division of Geological & Geophysical Surveys | 13 |
| Alaska Earthquake Center | 14 |
| Collaborators | 15 |
| National Tsunami Warning Center | 15 |
| National Weather Service Anchorage Weather Forecast Office | 16 |
| U.S. Forest Service – Chugach National Forest | 16 |
| U.S. Coast Guard..... | 17 |
| Alaska Department of Homeland Security and Emergency Management | 17 |
| Stakeholders | 17 |
| Operational Framework | 18 |
| Surveillance..... | 19 |
| Periodic Surveillance | 21 |
| Continuous Surveillance..... | 22 |
| Seasonal Considerations | 23 |
| Landslide Activity Levels | 23 |
| Background..... | 23 |
| Activity Level 1 | 26 |
| Activity Level 2 | 27 |
| Activity Level 3 | 27 |
| Activity Level 4 | 28 |
| Significant Regional Earthquakes | 33 |

| | |
|---|----|
| Post-Failure Scientific Response..... | 33 |
| Technical Communications..... | 35 |
| Interagency Communications | 36 |
| Public and Media Communications..... | 38 |
| Protocols for Updating this Plan | 40 |
| Related and Referenced Literature..... | 40 |
| Appendix I: Landslide-Generated Tsunami Calldown Protocols | 42 |
| Phase I: NTWC Initial Calldown Protocol..... | 42 |
| Phase II: USGS Coordinating Scientist Calldown Protocol..... | 42 |
| Phase III: DGGS and AEC Coordinating Scientist Calldown Protocol..... | 43 |
| Appendix II: Structures and Kinematic Elements of the Barry Arm Landslide | 45 |
| Appendix III: Frequently Asked Questions | 46 |

Executive Summary

This plan summarizes protocols and tools to be used in preparation for a failure of the Barry Arm landslide in Prince William Sound (PWS), Alaska. Although this plan is written specifically for the Barry Arm landslide, protocols, plans, and contacts listed within may be applicable to other landslides in the State of Alaska.

- This Multiagency team is composed of scientists and technical staff from the U.S. Geological Survey (USGS), Alaska Division of Geological & Geophysical Surveys (DGGs), and Alaska Earthquake Center (AEC).
- Collaborators include the National Tsunami Warning Center (NTWC), U.S. Forest Service (USFS), U.S. Coast Guard (USCG) and Alaska Department of Homeland Security and Emergency Management (DHSEM).
- Interagency communication protocols and operational activities are defined through a series of four Landslide Activity Levels.
- Interagency communication methods include regular coordination meetings, ad hoc briefings, and calldown lists.
- This plan is dynamic and subject to periodic review, revision, and possible suspension or cancellation.
- The Multiagency team will informally discuss the plan each year, and:
 - Identify areas where adjustments and revisions are needed. An internal document will be circulated that includes these revisions. Similarly, the calldown list and group and team members list will be kept up to date on the internal systems and will be updated yearly.
 - Decide whether to pursue another year of continuous or period monitoring, or to decrease the current monitoring protocol.
- The publicly released plan will be formally reviewed by all participating agencies (Coordinating Scientist from each agency) once every three years. Any revisions will be noted in an appendix.
- Decreases in the frequency or outright suspension of all monitoring activities may occur as budgets, resources, and staffing levels evolve, or as more insight into the stability and likelihood of failure of the Barry Arm landslide is acquired. In consultation with appropriate organizational leadership, the interagency group will meet to reach consensus on when or if the operational activities described in plan need to be revised, suspended, or canceled.

Revisions may occur more frequently to account for changes in environmental conditions, collaborators, landslide risk, and operational monitoring efficacy. In addition, execution of this plan is dependent upon sufficient resources and personnel at each agency. If resources are not sufficient to implement the protocols established within this document, the technical operations may be reduced or suspended, with updates communicated via website updates, regular meetings, and email.

Introduction and Scope

Coastal Alaska has been impacted by tsunami waves generated by both earthquakes and landslides multiple times in recent history. During the 1964 $M_w 9.2$ earthquake, 106 fatalities were a direct result of coseismic tsunami waves, of which 85 were attributed to tsunamis generated by submarine and subaerial landslides. Waves generated during the earthquake and concurrent landslides were estimated to have heights of approximately 12 meters (39 feet) in Whittier, Alaska, resulting in extensive damage and 13 fatalities. The total volume of each slide generated during the 1964 earthquake is uncertain, but several of these slides had estimated volumes of at least an order of magnitude less than the Barry Arm landslide, which is the largest (active) landslide recently identified in Prince William Sound (Haeussler et al., 2014). In 1958, an earthquake-triggered landslide 30-60 million (M) m^3 impacted Lituya Bay, producing a wave with runup height exceeding 500 meters (1640 feet) in height and resulting in two fatalities (Miller, 1960; Dai et al., 2020). In 2015, a 70 – 80 $M m^3$ landslide triggered a tsunami in Taan fjord in Glacier Bay, with runup height on the shore in excess of 190 meters (620 feet) (George et al., 2017). Extensive shoreline modifications resulted, but fortunately there were no fatalities. In 2025, a 100 $M m^3$ landslide triggered a tsunami in Tracy Arm just past the toe of South Sawyer Glacier, causing a runup wave height of 470-500 meters (1540-1640 feet) across from the landslide (Read et al., 2025). Fortunately, there were no fatalities, though a group of kayakers camping on Harbor Island more than 50 kilometers (30 miles) away were nearly swept away by a 6-meter (20 foot) wave runup. The time of day, ebbing tide, poor weather for recreation, and lack of cruise ships in the fjord were all lucky factors in preventing fatalities.

Identified as a potential hazard in 2019, the Barry Arm landslide has an estimated volume of $\sim 500 M m^3$, significantly larger than the Lituya Bay, Taan Fjord, or Tracy Arm landslides or any recorded subaerial landslide during the 1964 $M_w 9.2$ earthquake. This currently slow-moving landslide is in a fjord exhibiting glacial retreat in Prince William Sound (PWS), Alaska (**Figure 1**). Although this landslide is identifiable in imagery dating to at least the 1930s, the rapid retreat of the Barry Glacier has increased the tsunamigenic potential and corresponding risk in recent years. Prior to 2010, failure of the landslide would have resulted in runout onto the glacier. Since the retreat of the glacier terminus, any partial or catastrophic failure of the landslide has the potential to directly enter the fjord and generate a tsunami that may have devastating consequences for nearby communities, marine traffic, infrastructure, and natural and cultural resources in PWS. To address these potential hazards, the U.S. Geological Survey (USGS) began coordinating with federal, state, and local partners to communicate the potential risk of the Barry Arm and other active landslides in PWS, and to develop an experimental warning system to alert of an impending tsunami generated by landslide failure.

Starting in 2021, the United States Congress provided the USGS with additional funding to coordinate with federal, state, and local agencies, communities, and partners to develop a framework for early warning of an impending landslide and tsunami. A critical first step in

achieving this objective is the development of this Interagency Technical Operations Plan that dictates the roles, responsibilities and communication protocols preceding, during, and immediately following a tsunamigenic landslide crisis.

Given the immediate threat posed by the Barry Arm landslide and its considerable risk to communities, infrastructure, and all marine traffic, it is imperative that the USGS and partner agencies develop protocols for communication and a scientific response to varying degrees of landslide activity. To that end, we present the following plan in order to:

1. Define the roles, responsibilities, and primary points of contact for each of the partner agencies at all phases of landslide activity.
2. Define Landslide Activity Levels based on monitoring data.
3. Describe operational actions and public messaging at each Landslide Activity Level.
4. Define the type, manner, and frequency by which monitoring data are checked
5. Define how updates are delivered to Collaborators and Stakeholders based on Landslide Activity Level.
6. Formalize the communication process between agencies, local officials, and the public at different Landslide Activity Levels.
7. Describe the process for revising or terminating this plan.

This document constitutes a technical operations plan rather than an emergency response plan. Its primary purpose is to provide a framework for interagency coordination, information sharing, and technical data gathering prior to catastrophic landslide failure. Post-failure emergency response operations will be conducted under the authority of state and/or federal agencies and be managed within the framework of existing plans and protocols. The technical operations plan presented here defines the monitoring, communication, and technical operation protocols to enhance situational awareness of evolving hazard conditions and provide decision-support tools to partner agencies responsible for hazard messaging, warning, and emergency response. While specific to the Barry Arm landslide, this plan could be used to provide guidance for interagency coordination, communications, and scientific activities for other landslides in the region given similar resources, personnel, and surveillance technologies.

Version Notes

This is the first edition of the plan, version 1.0, dated April 2026. The plan has been reviewed by USGS, DGGS, AEC, NTWC and was distributed to all Collaborators and many Stakeholders.



Figure 1. Overview map of Barry Arm Landslide (red polygon) in Barry Arm fjord within Prince William Sound, Alaska. Barry Arm Landslide is situated between Cascade and Barry glaciers, approximately 30 miles (50 kilometers) from the city of Whittier.

Acronyms

| Acronym | Full Name | Role in Barry Arm Landslide Work |
|----------------|---|--|
| AEC | Alaska Earthquake Center (University of Alaska Fairbanks) | Monitors seismic activity, detects landslides, provides seismic hazard guidance |
| AIS | Automatic Identification System | Marine transponder system that broadcasts navigational data over VHF radio |
| ANSS | Advanced National Seismic System | A nationwide network that delivers real-time earthquake data |
| AVO | Alaska Volcano Observatory | USGS program to monitor volcano hazards that works alongside the Landslides Hazards Program |
| BNM | Broadcast Notice to Mariners | A communication issued by the U.S. Coast Guard to alert mariners of hazards |
| CNF | Chugach National Forest (U.S. Forest Service) | Land manager for Barry Arm region; grants access for scientific work |
| CS | Coordinating Scientist | Oversees science coordination, preparedness, and response within each participating agency |
| DGGS | Alaska Division of Geological & Geophysical Surveys | State agency for geologic hazard assessment; conducts field studies and monitoring |
| DHSEM | Alaska Division of Homeland Security and Emergency Management | Directs State Emergency Operations Center (SEOC); disaster preparedness and tsunami siren maintenance |
| DOI | U.S. Department of the Interior | Department overseeing the USGS; directs landslide preparedness programs |
| GBSAR | Ground-Based Synthetic Aperture Radar | Remote sensing method for detecting landslide deformation |
| LASER | Landslide Assessments, Situational Awareness, and Event Response Research | USGS project of the Landslide Hazards Program that may aid rapid landslide assessment in the event of a catastrophic landslide |
| LIDAR | Light Detection and Ranging | Remote sensing tool for high-resolution topographic monitoring |
| NOAA | National Oceanic and Atmospheric Administration | Federal agency overseeing NTWC and NWS |
| NTHMP | National Tsunami Hazard Mitigation Program (NOAA) | A coordinated U.S. national effort to mitigate the impact of tsunamis through public education, community response planning, hazard assessment, and warning coordination |

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| NTWC | National Tsunami Warning Center (NOAA) | Detects earthquakes, issues tsunami warnings, maintains coastal sensors |
| NWS | National Weather Service (NOAA) | Provides weather forecasts and hazard messaging support |
| OPS | Operational Specialists | Maintain monitoring systems, analyze data, prepare reports |
| PI | Principal Investigator | Subject matter experts advancing scientific understanding of landslide hazards |
| PL | Project Lead | Leads the multiagency effort (also the USGS Coordinating Scientist, by default) |
| PWS | Prince William Sound | Geographic region impacted by Barry Arm landslide hazards |
| RCAC | Regional Citizens' Advisory Council (Prince William Sound) | Stakeholder group representing local communities and interests |
| RSS | Really Simple Syndication | Web feed format used for distributing updates |
| SAR | Synthetic Aperture Radar | Remote sensing method for detecting landslide deformation |
| SEOC | State Emergency Operations Center | State of Alaska coordination hub at DHSEM for disaster response |
| UAV | Unmanned Aerial Vehicle | Tool, commonly referred to as a "drone", used to conduct landslide surveys in hazardous or inaccessible areas |
| USCG | United States Coast Guard | Ensures maritime safety; issues advisories and responds to hazards |
| USFS | United States Forest Service | Manages Chugach National Forest lands |
| USGS | United States Geological Survey | Federal lead agency for landslide hazards; conducts monitoring and hazard assessment |
| WFO | Weather Forecasting Office | Monitors local weather conditions; issues forecasts, warning, and advisories |

Agency Roles and Responsibilities

Here we define the roles and responsibilities of all agencies focused on landslide and tsunami hazards associated with the Barry Arm landslide. Because of the multi-hazard and multi-agency nature of this work, we divide those involved in tsunamigenic landslides in Barry Arm into three groups:

1. **Multiagency team** of scientists and engineers responsible for advancing the understanding of landslide processes, field-based and remote sensing analysis for scientific and operational monitoring and improving situational awareness of landslide hazards. Team members collaborate with professional and citizen scientists outside of the partnership to deepen their understanding of landslide hazards.
2. **Collaborators** are related agencies and local officials who have a mandate to address hazards that directly impact their primary mission, including protecting life and property, managing natural and cultural resources, managing infrastructure and waterways, and responding to natural disasters. These include federal, state, and local agencies and community officials.
3. **Stakeholders** are members of the public who live in potentially impacted communities, those who work or recreate in areas at risk to landslide and tsunami hazards, other scientists or academic collaborators who have professional interests in these hazards or this region, and members of the media.

Multiagency team

The Multiagency team includes the 1) USGS, 2) Alaska Division of Geological & Geophysical Surveys (DGGS), and 3) University of Alaska Fairbanks, Alaska Earthquake Center (AEC) (**Figure 2**). The objective of this team is to characterize landslide processes and hazards throughout the State of Alaska and better understand the risk they pose to nearby communities, infrastructure, and irreplaceable natural and cultural resources. The **Project Lead (PL)** for this multi-agency effort is housed at the USGS. The USGS will also staff two Associate Project Leads as a backup for the PL.

Within the core team, each agency has:

1. **Coordinating Scientist (CS)** – Responsible for coordination of science, surveillance, scientific communications, preparedness, and response activities within the team and amongst Collaborators and Stakeholders. The USGS PL (or Associate PL) will also serve as the CS for this agency.

2. **Principal Investigators (PI)** - Subject matter experts that are responsible for advancing our scientific understanding of landslide processes and corresponding hazards through operational surveillance and interpretation of these data and assisting in the communication of these interpretations to CSs, Collaborators, and Stakeholders.
3. **Operational Specialists (OPS)** - Responsible for maintaining operational systems, analyzing critical datasets, and preparing and internally presenting status reports and helping create informational products for public dissemination.

The USGS, DGGS, and AEC team members work together to monitor the Barry Arm Landslide and define **Landslide Activity Levels** and execute all response actions therein. Monitoring checks will vary depending on Landslide Activity Levels and health status of existing equipment and season. Collectively, each agency’s monitoring capabilities and expertise allow them to offer actionable science and the support necessary for timely warning to communities at risk and for partners to prepare for and respond to a landslide emergency at Barry Arm.

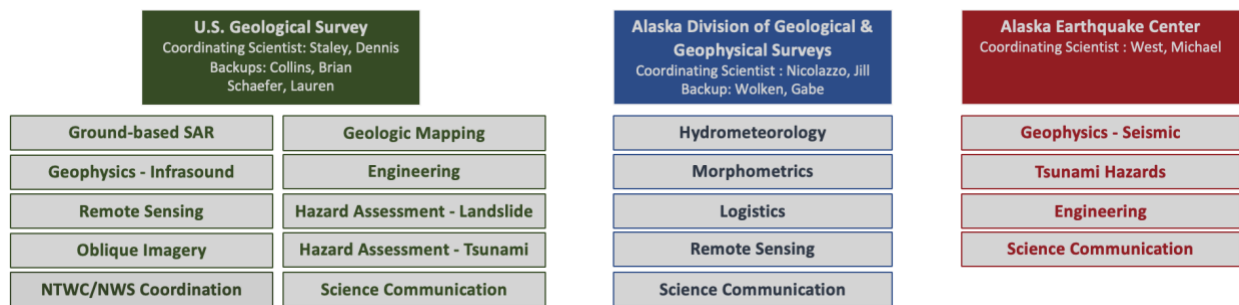


Figure 2. The Barry Arm Landslide Multiagency team consisting of the USGS, DGGS, and AEC. Each group is composed of a lead Coordinating Scientist and back-up(s), as well as Principal Investigators and Operational Specialists for each sub-task.

U.S. Geological Survey (USGS)

The Department of the Interior (DOI) directs the USGS through the Landslide Preparedness Act (Public Law 116–323) to establish a program that will work with State, Federal, Tribal, and local governments as well as with academia, the private sector, community-based groups, and nonprofit organizations to identify landslide hazards and risk and improve communication, coordination, and emergency preparedness, with the objective of reducing landslide losses.

The USGS is the point agency for landslide hazards in PWS, Alaska, with responsibilities including (a) local and regional characterization of controls on the spatial and temporal distribution of landslide processes, (b) surveillance and operational monitoring of landslides, and (c) hazard assessment, early warning support, and outreach. Points of contact for each project component are shown in **Figure 2** and described in **Appendix I**.

The USGS will:

1. Serve as the Project Lead (PL) for the entire Multiagency team. Under normal circumstances, the same person will also fill the USGS CS role. In addition to the CS, PL, PI, and OPS roles, the USGS Landslides group also has a Duty Scientist, a role that rotates between members of the team every week to maintain operational awareness of all landslide monitoring activity.
2. Conduct field-based and remote sensing studies to better understand regional and local controls on landslide distribution, size, mobility, and potential failure mechanism.
3. Be responsible for overseeing a plan for operational monitoring during all phases of landslide activity.
4. Leverage established and experimental methods of surveillance and operational monitoring to assess increases in landslide activity, potential precursors of slope failure, and coordinate within the team to detect landslide events as they occur using a combination of geospatial, geophysical, and mechanical techniques.
5. Collaborate with the NOAA National Tsunami Warning Center (NTWC) to support early warning efforts. This includes sharing preliminary information on landslide activity, providing equipment, logistical support for instrumentation, and providing scientific guidance and support during and after a landslide emergency.
6. Coordinate intra-agency landslide response activities at USGS, including integration with the Landslide Situational Awareness and Emergency Response (LASER) team based in Golden, Colorado, which has the capacity to engage the expertise of a nationwide team of USGS landslide scientists, rapidly deploy monitoring equipment, collect and analyze remote sensing data, and produce preliminary models of slope stability, landslide runout, and tsunami hazard.
7. Lead the coordination effort with all Collaborators, including quarterly meetings, ad hoc briefings, and written informational statements.
8. Provide landslide-related updates and briefings to relevant departments, and officials within the USGS, DOI, and for other agencies and officials within the Federal Government.
9. Contribute to the interagency public communication effort.
10. Manage, revise, and update this Interagency Technical Operations Plan for the Barry Arm landslide.

Alaska Division of Geological & Geophysical Surveys

The Alaska State Legislature has directed that the Alaska Division of Geological & Geophysical Surveys (DGGS) conduct scientific investigations to assess geologic hazards to buildings and transportation facilities (AS 41.08.020). DGGS conducts State of Alaska science and hazard assessment regarding landslides and landslide event response. DGGS will coordinate closely

with the USGS for study and analysis of the landslide characteristics, motion, and potential for failure and wave initiation. Points of contact for each project component are shown in **Figure 2** and described in **Appendix I**.

DGGS will:

1. Conduct field-based studies of hydrometeorology, glacial processes, snow dynamics, and landslide materials to better inform slope stability modeling and hazard assessment.
2. Coordinate with USGS on local and regional hazard and risk scenario and hazard assessment.
3. Collect high-resolution multi-temporal topographic data such as light detection and ranging (lidar) and structure-from-motion as a part of a routine monitoring program and during an emergency response.
4. Contribute to the interagency public communication effort and to the development and revision of this Interagency Technical Operations Plan.
5. Have primary responsibility for maintaining a centralized web page repository for public information regarding Barry Arm, monthly updates of landslide status, and hosting a collection of Frequently Asked Questions.
6. Provide updates and briefings to relevant departments, division, and officials within the State of Alaska government.
7. Participate in and contribute to interagency meetings and briefings.

Alaska Earthquake Center

The University of Alaska Fairbanks, Alaska Earthquake Center (AEC) acts under the direction of the Alaska State Legislature to inform public officials, industry, and private citizens of significant seismic events and hazards (AS 14.40.075). This includes mandates to record and archive seismic data, conduct seismological studies, and evaluate related hazards. State statute calls out the importance of coordinating these activities with other organizations and agencies to avoid duplication of effort. It also creates a designated university role, State Seismologist, to serve as a liaison to state and federal agencies in the event of emergencies. In addition, the AEC is the partner for the Alaska region to the Advanced National Seismic System (ANSS). Within this USGS-led framework, AEC is considered the authoritative source of information for significant seismic events across mainland Alaska. Points of contact for each project component are shown in **Figure 2** and described in **Appendix I**.

AEC will:

1. Maintain existing and install new geophysical instrumentation for the purposes of detecting and locating landslides and regional earthquakes in Alaska.

2. Analyze seismic data to detect catastrophic landslides and seismic activity that may be related to potential precursors to catastrophic landslides, ongoing mass-wasting processes (e.g., slow deformation, rockfall, partial landslide failures) and report their occurrence to the Multiagency team members and Collaborators.
3. Provide guidance on regional seismicity to inform the team's decisions regarding coseismic landslide hazards.
4. Provide updates related to notable seismic events and activity to relevant departments, divisions and officials within the State of Alaska government.
5. Work to ensure that landslide impacts are incorporated into community-level tsunami mapping and guidance.
6. Participate in and contribute to interagency meetings and briefings.

Collaborators

National Tsunami Warning Center

The National Oceanic and Atmospheric Administration (NOAA) National Tsunami Warning Center (NTWC) mission is to provide timely, reliable, and accurate tsunami forecasts and warnings, and to promote community resilience. NTWC is a 24/7 operational facility that detects and analyzes earthquakes and other potential tsunami sources and issues alert products related to tsunamis. NTWC jurisdiction includes oceans and low-lying coastal areas in all the United States except for Hawaii. NTWC is also responsible for warning in coastal Canada through a Memorandum of Understanding. Operational activities include global earthquake detection and magnitude estimation, analysis of sea level data and tsunami detection, issuance of tsunami alert products, tsunami forecasting, and dissemination of tsunami information to emergency management officials and the public.

As a critical component of this partnership, NTWC will:

1. Be solely responsible for tsunami detection and warning, via installation and monitoring of coastal or open water pressure sensors paired with seismometers.
2. Collaborate with Multiagency team to operationalize improvements to multidisciplinary data analysis and alerting procedures.
3. Communicate current Landslide Activity Level and any level changes to the United States Coast Guard (USCG).
4. Activate the landslide calldown protocols upon landslide event detection by calling the USGS PL or backup (**Appendix I**).
5. Conduct public outreach regarding the ongoing hazard and efforts to improve hazard awareness and mitigate risk.
6. Leverage existing communication protocols and contacts to improve landslide-generated tsunami awareness and preparedness.

7. In partnership with the National Weather Service (NWS) Anchorage Weather Forecast Office (WFO) and National Tsunami Hazard Mitigation Program (NTHMP), work with communities to enhance tsunami preparedness and emergency response plans and outreach.
8. Review public information and scientific products developed by the Multiagency team for consistency and clarity.
9. Participate in and contribute to interagency meetings and briefings.

National Weather Service Anchorage Weather Forecast Office

NWS Anchorage WFO, at the discretion of the Secretary of Commerce, has statutory authority for weather forecasting and issuing storm warnings for the region containing the Barry Arm landslide. NWS provides weather, water, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas, per 15 U.S.C. §313. This authority includes forecasting of weather and issuing storm warnings, including marine weather, operating flood forecasts for rivers, issuing frost advisories and freeze warnings, establishing long-term climate records and climate monitoring, and distributing meteorological information in the interests of agriculture, commerce, and public safety.

Specific to monitoring and warning at the Barry Arm landslide, NWS will:

1. Assist in the dissemination of hazard messaging in advance of a landslide disaster and with the conveyance of warning products in response to a landslide-generated tsunami.
2. In partnership with the NTWC and NTHMP, work with communities to enhance tsunami preparedness and emergency response plans and outreach.

U.S. Forest Service – Chugach National Forest

The U.S. Forest Service (USFS) is the land manager for the Chugach National Forest (CNF) region that includes the Barry Arm landslide. The USFS is responsible for managing terrestrial access in most of PWS, and the granting of permission for scientific work and instrumentation that requires access to USFS managed lands.

Regarding the monitoring of the Barry Arm landslide, the USFS will:

1. Assist in the permitting required to monitor the Barry Arm landslide.
2. Facilitate hazard messaging to USFS staff and forest users.
3. Close recreational facilities (e.g. recreation cabins) and limit other forest activities as allowed and as appropriate during times of elevated hazard or after catastrophic landslide failure.

U.S. Coast Guard

The U.S Coast Guard (USCG) is responsible for ensuring our Nation’s maritime safety, security and stewardship on all U.S. waterways, including PWS.

As a part of the Barry Arm landslide effort, USCG will:

1. Communicate with the science team on how their efforts can be used to inform their planning and operations.
2. Participate in interagency meetings and briefings.
3. Ensure proper messaging from the Multiagency team and Collaborators as it relates to maritime safety.
4. Issue Advisories, Local Notices to Mariners, and broadcast Bulletins on hazardous areas related to elevated landslide activity and/or threat via the Automatic Identification System (AIS) and Broadcast Notice to Mariners (BNM).
5. Respond to landslide disasters as dictated by protocols and mandates.

Alaska Department of Homeland Security and Emergency Management

The Alaska Department of Homeland Security and Emergency Management (DHSEM) is the state agency responsible for directing activities at the State Emergency Operations Center (SEOC) and for ensuring disaster preparedness in Alaska communities, facilitating community level planning and mitigation activities, maintenance of tsunami sirens in Prince William Sound, and coordinating state agency response to hazard events.

In event of Barry Arm landslide impacts, the DHSEM will:

1. Direct emergency response at the SEOC and coordinate the response to landslide and landslide-generated tsunami disasters.

Stakeholders

A primary objective of the multiagency effort is to provide credible, accurate, and actionable information about the Barry Arm landslide and potential tsunami hazards. We use “stakeholder” as an umbrella term for the diverse group of end users of the outputs and findings of the monitoring data, hazard assessment, and warning products and information that are compiled, analyzed, and synthesized by the Multiagency team and its Collaborators. This group of Stakeholders includes, but is not limited to:

1. Local officials and community members such as the Cities of Whittier and Valdez, Alaska,

2. Special interest groups, such as the PWS Regional Citizens Advisory Council (RCAC) and PWS Stewardship Foundation,
3. Commercial interests, such as fishing companies and vessels, shipping companies, and cruise lines, and
4. Other academic and non-profit science and research organizations, such as the Prince William Sound Science Center.

While there is no pre-defined role or responsibility for the Stakeholders, this plan encourages two-way coordination between the Multiagency team and its Collaborators with the Stakeholder group, and recommends the follow actions by Stakeholders:

1. Annual attendance by a representative at a local PWS meeting, such as the annual PWS Stewardship Foundation Natural History Symposium in Whittier, and/or one of the PWS Regional Citizens' Advisory Council meetings, in order to facilitate direct exchange with Stakeholders.
2. Signing up for the Barry Arm landslide email distribution list managed DGGS.
3. Participation in other public briefings and meetings.
4. Direct communication between Stakeholders and Coordinating Scientists at USGS, DGGS, and AEC on an as-needed basis.

Operational Framework

The technical operations related to Barry Arm and conducted by the Multiagency team and Collaborators include four primary components:

1. Operation surveillance activities, including direct observations of landslide movement from ground-based, airborne, and satellite sensors, observations of geophysical activity associated with mass movements, regional earthquakes, hydrometeorological conditions, or tsunamis, and observations of water level at select locations in PWS.
2. The establishment of landslide activity levels and seismic events that define the intensity and frequency of monitoring observations, interagency coordination, and public messaging.
3. Scientific operations after a significant landslide event.
4. Technical communication activities leading up to, during, and after a landslide event.

In the following sections, we define these components and describe how they guide the operational activities of the Multiagency team.

Surveillance

Operational surveillance of landslide activity serves as the foundation of the interagency effort aimed at understanding landslide and tsunami hazards from the Barry Arm landslide and reducing public exposure to this hazard. Operational surveillance methods include:

1. **Ground-based sensors** that measure water surface level, land surface movement associated with landslide deformation, hydrometeorological conditions, and geophysical signals generated by landslide movement or seismic events.
2. **Remote sensing methods**, such as oblique imagery acquired by ground-based cameras, aerial or satellite imagery.

At present, all monitoring sensors in PWS are located in the vicinity of the Barry Arm landslide (**Figure 3**) (however, the Alaska Geophysical Network seismic stations, which our surveillance also depends on, are more broadly distributed). Aerial and satellite imagery and remote sensing data are also available for the Barry Arm landslide. Monitoring methods and corresponding data frequency, latency, and availability are described **Table 1**.

The Multiagency team and Collaborators conduct periodic and continuous surveillance of the Barry Arm landslide. This combination of satellite and ground-based imagery, geophysical monitoring, radar, and meteorological measurements improves the team's ability to detect landslide activity that may be a precursor to a larger failure. Information yielded from these data, particularly observations of increased velocity, seismicity, or other evidence of potential landslide failure, is relayed to NTWC for situational awareness. Not every method is guaranteed to be available year-round (i.e., snow cover in winter obscures some detection methods), and the operational approach will vary depending on monitoring state of health, hazard, risk, accessibility, time of year (season), and availability of staffing and resources. Here we discuss two types of monitoring data and instrumentation – periodic and continuous – and provide a brief overview of the different methods within each type. Specific information on the nature of observations, their frequencies, and the method in which they are logged are shown in **Table 1**.

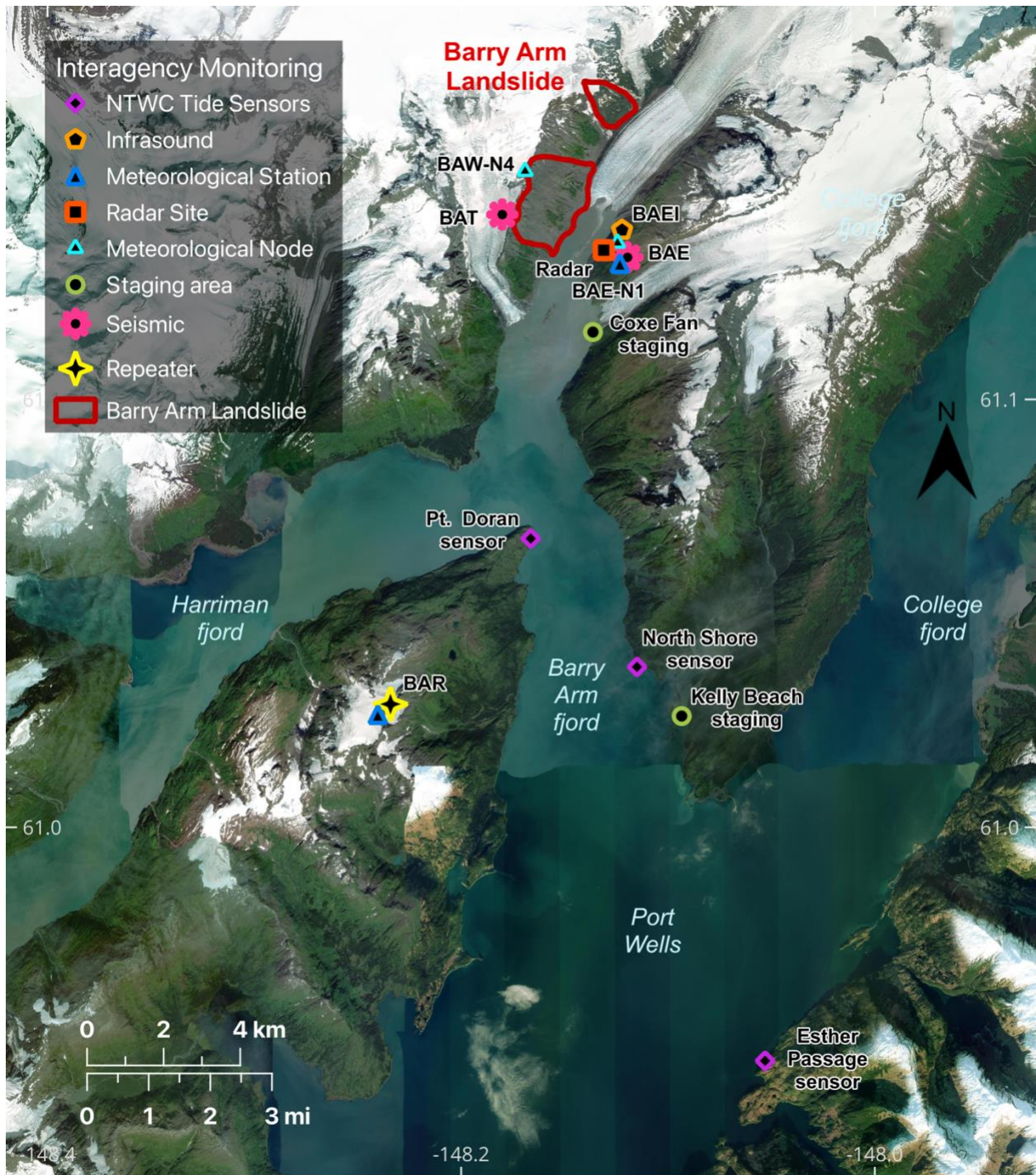













Figure 3. Map of Barry Arm Landslide (red outline) in Barry Arm fjord. The Barry Arm Landslide is situated between Cascade and Barry glaciers. The symbols indicate locations of various types of monitoring equipment used in this multiagency effort.

Table 1. Shows all surveillance methods used for the Barry Arm Landslide by various team members, along with the approximate frequency of repeat data collection and data latency (how long it takes for the data to be sent, processed, and be available to the team). The availability of the data (public or team-only) is also highlighted.

| Agency | Method | Data Frequency | Data Latency | Publicly available |
|---|----------------------------------|------------------|--------------------|--------------------|
|  | Ground-based SAR | Up to 10 minutes | 24 hours | No |
|    | Oblique imagery | Up to 15 minutes | 15 minutes - Daily | No |
|  | Infrasound | 50 hz | Seconds | Yes |
|  | Seismic | 50 hz | Seconds | Yes |
|  | Water Level | 10 seconds | Seconds | Yes |
|  | Hydrometeorology | 15 minutes | Hourly | Yes |
|  | Satellite InSAR | Biweekly | 1-2 days | Yes |
|   | Other Remote Sensing and Imagery | Variable | Variable | Yes |

Periodic Surveillance

Periodic surveillance data include all instruments, sensors, imagery, and geospatial products that are *not* transmitted in real-time or near real-time (i.e., every few seconds).

Remote sensing data have the lowest frequency and highest latency of all data sources in our current monitoring program. Aerial and spaceborne remote sensing include **satellite imagery**, spaceborne repeat **Synthetic Aperture Radar (SAR)**, and **light detection and ranging (lidar)** surveys. Satellite imagery is useful for tracking landscape changes that may be indicative of landslide activity or deformation. Spaceborne Interferometric Synthetic Aperture Radar (InSAR) provide measurements of deformation when atmospheric and ground conditions permit. Repeat fixed-wing or helicopter-based lidar surveys are frequently flown by DGGS and used to quantify decimeter-scale changes in topography.

Oblique imagery collected from cameras installed at monitoring sites capture and transfer images at a much higher frequency than those from aerial or spaceborne sources. These data are used to provide situational awareness of changes in landslide appearance and/or the occurrence of a landslide failure, the environmental conditions of a site, and the state of health of different sensors. While these data are transmitted at daily and hourly frequencies, they are not transmitted at a frequency that can be useful for direct inclusion in a warning system. These image sources are only able to confirm that an event has occurred within tens of minutes, to hours, to possibly days after the event.

In addition to remote sensing data, DGGs and USGS operate numerous **meteorological stations** throughout southeast and southcentral Alaska, including two stations and three smaller nodes in the vicinity of the Barry Arm landslide. These stations collect some or all the following data: rainfall, air temperature, snow depth, wind speed/direction, soil temperature, and soil moisture. Depending on the study area, additional or new meteorological stations may be installed. Given the somewhat low frequency rate of 15-minutes, these data are primarily used to develop historical datasets, inform models, and further our understanding of landslides in PWS.

The USGS maintains a **Ground-Based Synthetic Aperture Radar (GBSAR)**, commonly referred to as a ground-based radar) that scans the Barry Arm landslide at a frequency up to every 10 minutes. Scanning frequency can vary throughout the season depending on atmospheric conditions, power considerations, and continuity of telemetry. GBSAR measures the offset of the radio wave as it reflects from a moving object over multiple time periods, allowing scientists to calculate a landslide's motion with millimeter accuracy. While some analyses are conducted internally, the USGS relies on software run by the GBSAR manufacturer IDS GeoRadar and GeoPrevent, both USGS contractors, for much of the data ingestion and operational analysis. Radar data are transmitted and analyzed at a daily frequency and therefore cannot be used for real-time or near real-time monitoring of a landslide. The GBSAR data are a tool for situational awareness and not early warning.

Continuous Surveillance

Continuous surveillance represents the suite of instruments that provide real-time 24/7/365 data to the Multiagency team and NTWC for the purposes of the detection of landslide precursors, landslide failure, or the generation of a tsunami. Of primary importance for warning operations are the three **coastal water pressure sensors** that were installed in July 2021 and are maintained and monitored by NTWC. Additional pressure sensors may be installed in the future. These three sensors serve as the foundation of an experimental early warning system and can detect the passage of a tsunami as small as 10 cm. Operationally, if a detected signal from a sensor exceeds a certain threshold, or if two or more sensors fail in the correct order and timing, then an internal alarm is triggered at the NTWC to alert a scientist to review the data. Data are acquired and transmitted every five seconds to NTWC.

Geophysical monitoring methods, such as **seismometers** and **infrasound** sensors also provide continuous measurements in the study area. With the already existing Alaska Geophysical Network of seismic stations maintained by AEC, the infrastructure is in place for capturing large seismic events in the region. Additional seismic stations and infrasound arrays have been installed in the vicinity of the Barry Arm landslide to obtain higher resolution seismic and acoustic data that correspond to local landslide activity.

Seasonal Considerations

Prince William Sound is subject to severe weather conditions throughout the year, yet potential impacts to monitoring operations are most common during the winter. Heavy snowfall, deep snowpack, high winds, and limited solar insolation can damage equipment, reduce sensor capabilities, or limit solar charging of power supplies. Despite careful design, the monitoring equipment in and around Barry Arm can, and will, be damaged and go offline. During winter, limited daylight hours, flat lighting, heavy precipitation, and strong winds often preclude access to monitoring sites for needed repairs. Even if sites can be physically accessed by helicopter, deep snow combined with the short daylight hours may not allow sufficient time to dig out sites and execute repairs. While every effort will be made to quickly repair sensors as they are damaged, it may not be possible to visit or access sensors for days, weeks, or even months at a time. In some cases, repairs are not possible until snowmelt in late July. At a minimum, outages are reported in a monthly information statement publicly released by DGGs.

Landslide Activity Levels

Background

Large landslide complexes such as the Barry Arm Landslide are characterized by steep slopes, weak or damaged rock, and morphologies that are subject to rapid weathering, shallow deformation, and rapid episodic transport (**Appendix II**; Coe et al., 2021). As such, it is expected that there will be visual evidence of frequent surficial processes common on steep, easily eroded slopes, such as rockfall, debris flows, and shallow landslides. In addition, areas where rockfall accumulate, such as talus deposits at the base of the headscarp, may exhibit evidence of surficial creep detectable using our surveillance methods. In the winter, widespread avalanche activity, or the presence of localized glide avalanches, will be present.

The Barry Arm landslide routinely experiences episodes of slow deformation that do not result in catastrophic failure. Photographic evidence of the landslide exists going back to the 1930s, and perhaps as early as 1905 (Grant and Higgins, 1913; Bradford Washburn Photograph Collection, 1937; Dai et al., 2020; Schaefer et al., 2023). There have been frequent episodes of slow and moderate rates of landslide deformation throughout the known history of the landslide, with rates as high as 26 m y^{-1} during a period of rapid glacial recession spanning the years of 2010 – 2013

(Dai et al, 2020). More recently, annual rates have decreased to around 3 m y^{-1} since 2017, with most of the deformation occurring between the months of July and November (Schaefer et al., 2023). Under present conditions, measurements obtained through continuous or periodic monitoring will likely detect frequent but slow landslide-wide movement.

It is important to note that small increases in the extent or rate of movement *does not necessarily imply imminent failure*. There are numerous examples of landslides accelerating and decelerating without failure, including two periods of deformation at the Barry Arm landslide in the late summer and fall of 2022 and 2023. As such, the precise likelihood of catastrophic failure is very difficult, if not impossible, to estimate from our surveillance alone. Landslide failure is possible with no precursory deformation, and therefore could occur without precursory signals, such as acceleration or increases in the frequency of rockfall or smaller shallow landslides. However, in general, landslide failure becomes increasingly likely as deformation rates increase and the area that is moving grows.

Even in the absence of precursory deformation, a moderate local or strong regional earthquake has the potential to trigger widespread subaerial and submarine landslides, including the failure of the Barry Arm landslide. The magnitude of the earthquake, regional geology, and distance from the epicenter to the landslide exert influence on the potential for coseismic failure. Although these linkages are complex, a simple distance-magnitude method adopted from Keefer (1984) is used to set activity levels in response to a local or regional earthquake (**Figure 4**). While catastrophic landslide failure is of primary concern during an earthquake, a strong seismic event also has the potential to damage or destroy monitoring equipment. In that case, a thorough assessment of equipment status and health is required, followed by repair missions as soon as safely possible.

We establish the following Landslide Activity Levels based on observations of landslide deformation and in the context of experience and present observations at Barry Arm and other large, slow-moving landslides with the potential for rapid and catastrophic failure. These Landslide Activity Levels include technical and communication protocols for each level. We provide the a) criteria to establish each Landslide Activity Level and to move between levels, b) operational monitoring protocols, and c) scientific communication responsibilities of each team member.

Monitoring data and surveillance described in the previous section are synthesized to establish Landslide Activity Levels ranging from Level 1 to Level 4 (**Figure 5**). These four levels describe the rate, magnitude, and spatial extent of landslide deformation and corresponding geomorphic activity. *It is important to recognize that lower activity Levels 1 and 2 do not directly relate to landslide hazard or probability of catastrophic failure and should not be interpreted in that manner.*

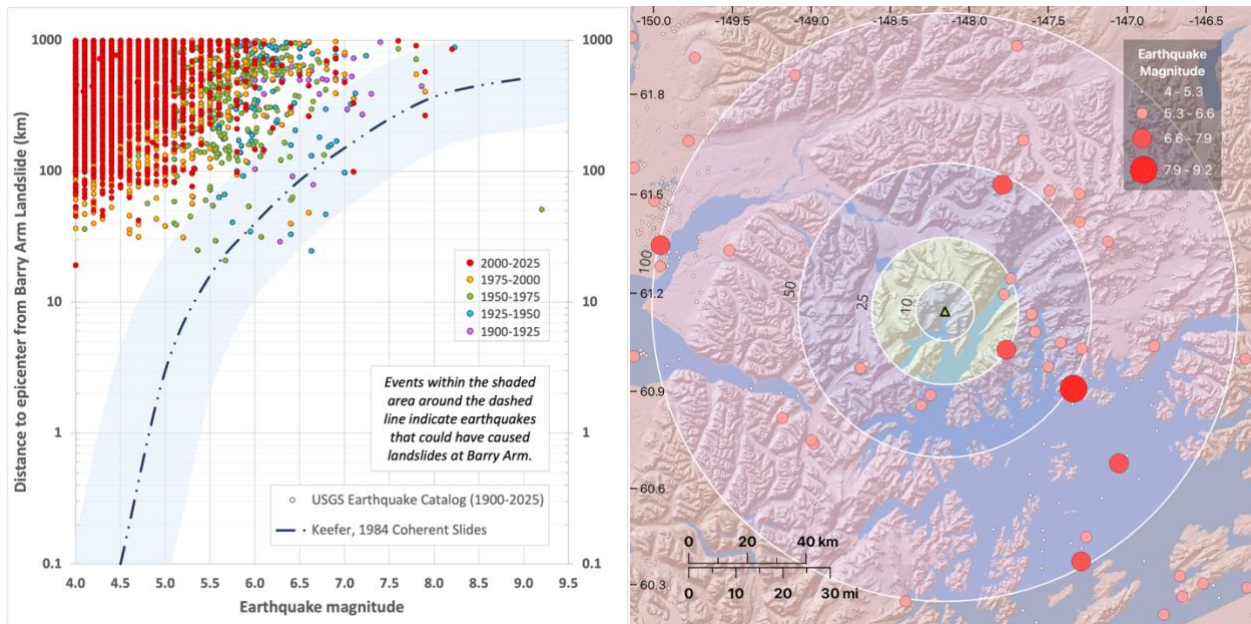


Figure 4. a) Distance of Barry Arm Landslide from the epicenter of nearby earthquakes (1900-2025, split into 25-year periods by color), showing a landslide failure threshold as it relates to earthquake magnitude (modified from Keefer, 1984). b) Map of all USGS earthquakes (1900-2025) in relation to distance from Barry Arm (yellow triangle) with concentric circles at 10, 25, 50, and 100 km distances.

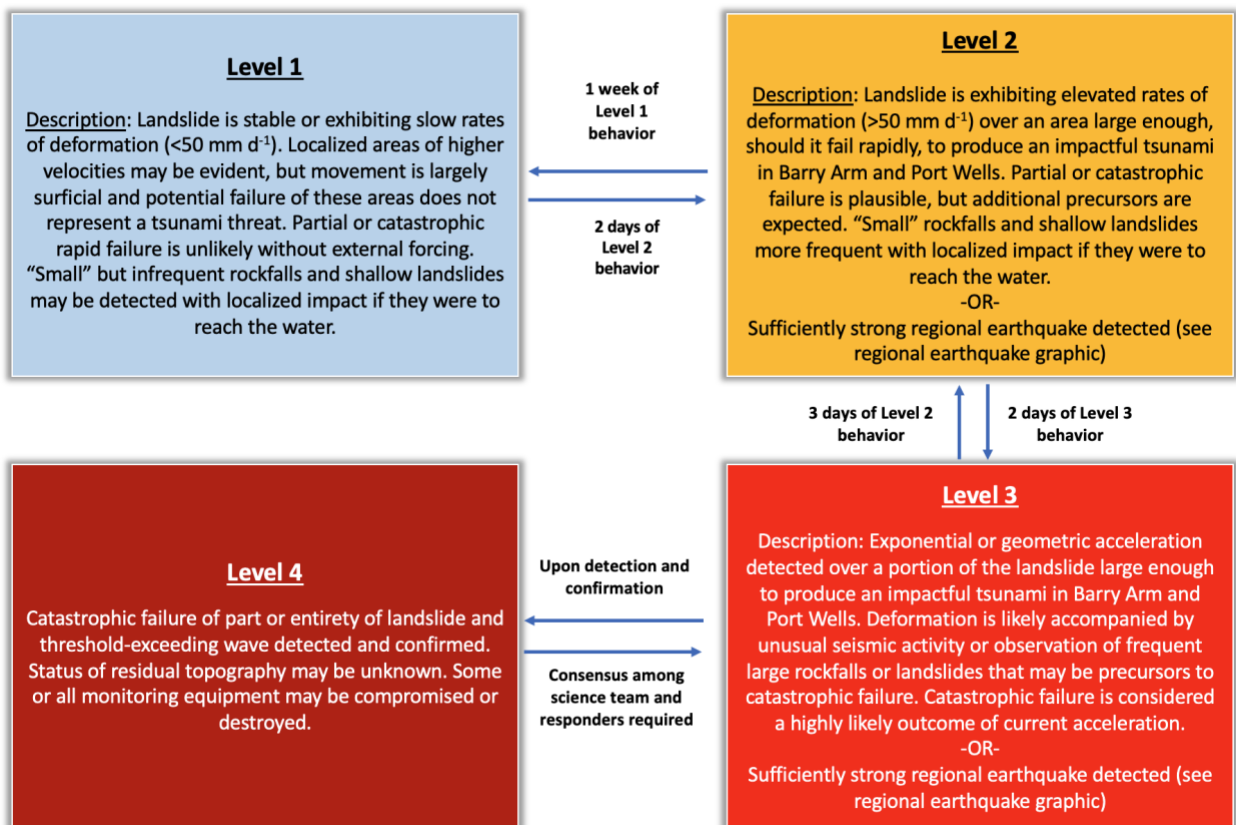


Figure 5. Landslide Activity Levels 1 through 4, with a description of the corresponding geomorphic activity that defines each level, as well as what landslide behaviors are required to move up or down a level.

We recognize that any change in detected landslide movement may demand flexibility in approach and response protocol. However, the framework presented here should serve as a useful guide that can be adapted to specific event circumstances. In addition, the specific metrics used to establish Landslide Activity Level (e.g., rates of movement, extent of movement, earthquake magnitudes and distance from epicenter, etc.) may be refined as we learn more about landslide stability conditions, material properties, and potential triggering events.

Activity Level 1

Description

At this activity level, measurements obtained through continuous or periodic monitoring may detect localized acceleration of surficial materials or slow broad-scale movement. In addition, small, infrequent rockfall and shallow landslides may be evident, especially during periods of prolonged rainfall or rapid changes in temperature.

Given an established and well-documented history of slow deformation at the Barry Arm landslide, we consider this type of behavior to be normal, expected, and not necessarily indicative of an imminent failure or elevated hazard potential. As such, we include episodes of widespread slow deformation that do not exceed 50 mm d^{-1} , and show no rapid increases in rates, as measured by ground-based radar, to be within the range of behavior characterized by Activity Level 1. In addition, localized areas of higher velocities may be evident, but movement is largely surficial (e.g., talus creep) and potential failure of these areas does not represent a significant widespread tsunami threat with only local impact (i.e., in the splash zone) if they were to reach the water.

Actions at Level 1

Activity Level 1 is the base operating level. Operational checks are conducted according to **Table 1**. Interagency communications include quarterly coordination meetings by Multiagency team members and Collaborators, which provide updates on the DGGs Barry Arm webpage related to landslide status and relevant operational or scientific events or products (**Table 2**). Each group is responsible for adhering to internal reporting requirements. Specific information on communication products can be found in **Table 3**. In brief, Activity Level 1 will be characterized by regular quarterly meetings and informational products.

Public Messaging at Level 1

At this level, messages on hazards in PI statements and at briefings should focus on consistent reminders of background hazards at Barry Arm, including the potential for failure without any precursory signal and/or during a regional seismic event. In coordination with the Collaborators, we suggest messaging for Activity Level 1 seen in **Table 4**.

Activity Level 2

Description

At Activity Level 2, the Barry Arm landslide is exhibiting elevated rates of deformation (>50 mm d⁻¹) over an area large enough, should it fail rapidly, to produce an impactful tsunami in Barry Arm and Port Wells. Partial or catastrophic failure is plausible, but additional precursors would be expected prior to failure. “Small” rockfalls and shallow landslides are more frequent with localized impact should they enter the water. A strong regional earthquake ($>M_w7$, > 60 miles away) or local earthquake ($>M_w5$, < 60 miles away) may elevate the landslide status to this level.

Actions at Level 2

Operational checks at Activity Level 2 are conducted according **Table 1**. Interagency communications include weekly coordination meetings by the Multiagency team and Collaborators, which provide monthly updates on the DGGs Barry Arm webpage related to landslide status and relevant operational or scientific events or products **Table 2**. Each group is responsible for adhering to internal reporting requirements. Specific information on communication products can be found in **Table 3**.

Public Messaging at Level 2

At this level, message on hazard in PI statements and at briefings should focus on increasing the awareness of elevated hazards in and near Barry Arm. We suggest messaging for Activity Level 2 seen in **Table 4**.

Activity Level 3

Description

At Activity Level 3, rapid movement of the Barry Arm landslide indicates landslide failure and tsunami may be imminent. An exponential or geometric acceleration has been detected and confirmed over a portion of the landslide large enough to produce an impactful tsunami in Barry Arm and Port Wells. Landslide movement is likely to be accompanied by unusual seismic activity or observation of frequent large rockfalls or landslides that may be precursors to catastrophic failure. Catastrophic failure is considered a highly likely outcome of current acceleration. Alternatively, we may classify the landslide at this level should there be a strong regional or local earthquake at or greater than M_w7 .

Actions at Level 3

Operational checks are conducted according to **Table 1**. At least twice per week, the Multiagency team leads will directly engage with leadership at potentially impacted communities and with local emergency managers and responders. Emergency Management offices at the state

and federal level are directly notified of updated landslide levels and potential increase in failure potential. Interagency communications include coordination meetings and briefings that include the Multiagency team and Collaborators and weekly updates on the DGGs Barry Arm webpage related to landslide status and relevant operational or scientific events or products **Table 2**. Each group is responsible for adhering to internal reporting requirements. Specific information on communication products can be found in **Table 3**.

Public Messaging at Level 3

At this level, message on hazard in PI statements and at briefings should focus on increasing the awareness of elevated hazards in and near Barry Arm through active outreach to nearby communities. We suggest messaging for Activity Level 3 seen in **Table 4**.

Activity Level 4

Description

Catastrophic failure of part or entirety of landslide and threshold-exceeding wave has been detected and confirmed. The status of residual topography at the Barry Arm landslide and in adjacent areas may be unknown. Some or all monitoring equipment may be compromised or destroyed. Significant additional landslide and landslide-generated hazard may still exist. Life-threatening water conditions are present in Barry Arm, College Fiord, Port Wells Passage Canal, and other fiords and passages in western PWS and are possible throughout PWS.

Actions at Level 4

Detection of a partial or catastrophic failure at Barry Arm warrants the initiation of the NTWC and Multiagency team calldown protocols. Prior to any other actions, emergency response protocols are initiated and include the following:

1. Upon geophysical detection of failure and confirmation of a threshold-exceeding wave:
 - a. Warning products are issued and standard calldown procedures implemented at NTWC and NWS.
 - b. NTWC contacts USGS Coordinating Scientist (or backup) to provide notification of failure, wave detection, and warning.
2. Upon notification of an event and warning from NTWC:
 - a. Emergency response plans will be activated by those charged with disaster response, rescue and recovery operations, and emergency management, including DHSEM and USCG.
 - b. USGS Coordinating Scientist (or backup) initiates calldown protocols (see **Figure 6** procedure).

3. Upon notification by USGS Coordinating Scientist (or backup):
 - a. All groups implement agency-specific response and calldown plans (**Appendix I**).
 - b. The Multiagency team coordinates daily briefings, media events, and community outreach, with guidance from agency communication offices.

The Multiagency team coordinates with emergency responders to schedule scientific activities needed to better understand the geographic extent of impact, size and stability of new slope configuration, and other critical ephemeral datasets. These data are important but *should not delay or interfere with any emergency response activities at partner agencies*.

Operational checks are conducted according to **Table 1**. Interagency communications include coordination meetings and briefings that include the Multiagency team and Collaborators and daily updates on the DGGs Barry Arm webpage related to landslide status and relevant operational or scientific events or products **Table 2**. Each group is responsible for adhering to internal reporting requirements. Specific information on communication products can be found in **Table 3**.

Public Messaging at Level 4

At this level, message on hazard in PI statements and at briefings should focus on active outreach regarding hazard warnings in and near Barry Arm. We suggest messaging for Activity Level 4 seen in **Table 4**.

Table 2. Coordination and communication activities conducted at Landslide Activity Levels 1 through 4.

| Activity Level | Minimum Frequency | USGS | DGGS | AEC |
|----------------|-------------------|--|--|--|
| 1 | Quarterly | <ul style="list-style-type: none"> Coordinate and host Quarterly Coordination Meeting. Summarize activities and observations at Quarterly Coordination Meeting. Satisfy internal reporting and logging requirements. Summary statement to USGS Leadership. Promote DGGS social media posts. Weekly participation in NTWC coordination meetings. | <ul style="list-style-type: none"> Summarize landslide-related activities at Quarterly Coordination Meeting. Participate in monthly science team meeting. Monthly website update. Social media posts. Satisfy internal reporting and logging requirements. Summary statement to DGGS and State of Alaska Leadership. | <ul style="list-style-type: none"> Summarize activities and observations at Quarterly Coordination Meeting. Participate in monthly science team meeting. Satisfy internal reporting and logging requirements. Promote DGGS social media posts. |
| 2 | Weekly | <ul style="list-style-type: none"> Arrive at consensus with DGGS and AEC confirming status level changes (when possible). Notify NTWC of change in status level. NTWC notifies Coast Guard. Draft Public Information Statement with adherence to FSP. With DGGS and AEC, initiate direct communication with leadership at potentially impacted communities. (Optional) Coordinate Ad Hoc Briefing. Increase monitoring frequency per protocol. Participate in DGGS communications group meeting. Satisfy Level 1 responsibilities at elevated frequency. | <ul style="list-style-type: none"> Contribute to decision on status level. Internal review of Public Information Statement and web update(s). Increase monitoring frequency per protocol. Organize communications group meeting when circumstances warrant. Satisfy Level 1 responsibilities at elevated frequency. Backup for USGS. | <ul style="list-style-type: none"> Contribute to decision on status level. Internal review of Public Information Statements and website update(s). Participate in DGGS communications group meeting. Satisfy Level 1 responsibilities at elevated frequency. |
| 3 | 3x per week | <ul style="list-style-type: none"> Set level in consultation with DGGS and AEC. Daily coordination with DGGS, AEC, and NTWC regarding landslide activity. Coordinate Ad Hoc Briefing. With DGGS and AEC, initiate direct communication with leadership at potentially impacted communities. (Optional) Coordinate media outreach and press briefings. Satisfy Level 2 responsibilities at elevated frequency. | <ul style="list-style-type: none"> Coordinate with USGS and AEC to set level. Daily coordination with USGS, AEC, and NTWC regarding landslide activity. With USGS, participate in direct communication with leadership at potentially impacted communities. (Optional) Coordinate media outreach and press briefings. Satisfy Level 2 responsibilities at elevated frequency. | <ul style="list-style-type: none"> Contribute to decision on changing status level. Satisfy Level 2 responsibilities at elevated frequency. |
| 4 | Daily | <ul style="list-style-type: none"> Receive notification from NTWC that failure has occurred, initiate Multiagency team landslide call down. Coordinate Ad Hoc Briefing. Daily communication with NTWC and SEOC, staff embedded as requested. Daily communication with leadership at potentially impacted communities. Daily communications with State officials. Staff embedded at NTWC or SEOC as requested. Satisfy Level 3 responsibilities at elevated frequency. | <ul style="list-style-type: none"> Receive notification from USGS that failure has occurred, initiate internal landslide call down. Daily communication with NTWC and SEOC, staff embedded as requested. Daily communication with leadership at potentially impacted communities. Daily communications with State officials. Staff embedded at NTWC or SEOC as needed. Satisfy Level 3 responsibilities at elevated frequency. | <ul style="list-style-type: none"> Receive notification from USGS that failure has occurred, initiate internal landslide call down. Satisfy Level 3 responsibilities at elevated frequency. |

Table 3. Communication products produced by the Multiagency team and NTWC Collaborator for Landslide Activity Levels 1 through 4.

| Activity Level | Minimum Frequency | USGS | DGGS | AEC | NTWC |
|----------------|-------------------|--|--|---|---|
| 1 | Monthly | <ul style="list-style-type: none"> Monthly Communication Products Check-in. Science team meeting. Summary statement to USGS and DOI Leadership. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Webpage update with AEC and NTWC. Summary statement to DGGS and State of Alaska Leadership. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Satisfy internal reporting and logging requirements. |
| | | <ul style="list-style-type: none"> Public Information Statement. Direct communication with leadership at potentially impacted communities (with DGGS, AEC, NTWC). (Optional) Coordinate Ad Hoc Briefing. | <ul style="list-style-type: none"> Internal review of Public Information Statement and web update(s). Direct communication with leadership at potentially impacted communities (with USGS, AEC, NTWC). | <ul style="list-style-type: none"> Internal review of Public Information Statement. Direct communication with leadership at potentially impacted communities (with USGS, DGGS, NTWC). | <ul style="list-style-type: none"> Internal review of Public Information Statement. Direct communication with leadership at potentially impacted communities (with USGS, DGGS, AEC). |
| 3 | 3x per week | <ul style="list-style-type: none"> Coordination meeting with DGGS, AEC, NTWC. Ad Hoc Briefing. Direct communication with leadership at potentially impacted communities (with DGGS, AEC, NTWC). (Optional) Media outreach and press briefings. Social Media. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Coordination meeting with USGS, AEC, NTWC. Direct communication with leadership at potentially impacted communities (with USGS, AEC, NTWC). Social Media. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Coordination meeting with USGS, DGGS, and NTWC. Direct communication with leadership at potentially impacted communities (with USGS, DGGS, NTWC). Social Media. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Coordination meeting with USGS, DGGS, and AEC. Direct communication with leadership at potentially impacted communities (with USGS, DGGS, AEC). Social Media. Satisfy internal reporting and logging requirements. |
| | | <ul style="list-style-type: none"> Coordination meeting with DGGS, AEC, NTWC. Ad Hoc Briefing. Direct communication with leadership at potentially impacted communities (with DGGS, AEC, NTWC). Coordination with responders (with DGGS, AEC, NTWC). Media outreach and press briefings. Social Media. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Coordination meeting with USGS, AEC, NTWC. Direct communication with leadership at potentially impacted communities (with USGS, AEC, NTWC). Coordination with responders (with USGS, AEC, NTWC). Media outreach and press briefings. Social Media. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Coordination meeting with USGS, DGGS, NTWC. Direct communication with leadership at potentially impacted communities (with USGS, DGGS, NTWC). Coordination with responders (with USGS, DGGS, NTWC). Media outreach and press briefings. Social Media. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Warning Products Coordination meeting with USGS, DGGS, AEC. Coordination with responders (with USGS, DGGS, AEC). Direct communication with leadership at potentially impacted communities (with USGS, DGGS, AEC). Social Media. Media outreach and press briefings |
| 4 | Daily | <ul style="list-style-type: none"> Coordination meeting with DGGS, AEC, NTWC. Ad Hoc Briefing. Direct communication with leadership at potentially impacted communities (with DGGS, AEC, NTWC). Coordination with responders (with DGGS, AEC, NTWC). Media outreach and press briefings. Social Media. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Coordination meeting with USGS, AEC, NTWC. Direct communication with leadership at potentially impacted communities (with USGS, AEC, NTWC). Coordination with responders (with USGS, AEC, NTWC). Media outreach and press briefings. Social Media. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Coordination meeting with USGS, DGGS, NTWC. Direct communication with leadership at potentially impacted communities (with USGS, DGGS, NTWC). Coordination with responders (with USGS, DGGS, NTWC). Media outreach and press briefings. Social Media. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Warning Products Coordination meeting with USGS, DGGS, AEC. Coordination with responders (with USGS, DGGS, AEC). Direct communication with leadership at potentially impacted communities (with USGS, DGGS, AEC). Social Media. Media outreach and press briefings |
| | | <ul style="list-style-type: none"> Coordination meeting with DGGS, AEC, NTWC. Ad Hoc Briefing. Direct communication with leadership at potentially impacted communities (with DGGS, AEC, NTWC). Coordination with responders (with DGGS, AEC, NTWC). Media outreach and press briefings. Social Media. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Coordination meeting with USGS, AEC, NTWC. Direct communication with leadership at potentially impacted communities (with USGS, AEC, NTWC). Coordination with responders (with USGS, AEC, NTWC). Media outreach and press briefings. Social Media. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Coordination meeting with USGS, DGGS, NTWC. Direct communication with leadership at potentially impacted communities (with USGS, DGGS, NTWC). Coordination with responders (with USGS, DGGS, NTWC). Media outreach and press briefings. Social Media. Satisfy internal reporting and logging requirements. | <ul style="list-style-type: none"> Warning Products Coordination meeting with USGS, DGGS, AEC. Coordination with responders (with USGS, DGGS, AEC). Direct communication with leadership at potentially impacted communities (with USGS, DGGS, AEC). Social Media. Media outreach and press briefings |

Table 4. Hazard messaging examples during Landslide Activity Levels 1 through 4, including notices issued by the U.S. Coast Guard (USCG).

| Activity Level | DGGGS Web Statement | Local Notice to Mariners (USCG) | AIS (USCG) | BNM (USCG) |
|----------------|---|---|--|--|
| 1 | <p>An ongoing landslide and landslide-generated tsunami threat exists in Barry Arm, northwestern Prince William Sound, Alaska. Rapid failure of the landslide has the potential to create a tsunami that results in life-threatening waves and currents in Barry Arm, Harriman Fiord, Port Wells and adjacent fiords. Mariners should maintain vigilance when in the vicinity of Barry Arm or nearby waters. If any unusual rockfall activity is seen or heard, or if unusual waves, currents, or tides are observed, those who are ashore should immediately travel to higher ground. Those off-shore should transit to or remain in deep water.</p> | <p>An ongoing landslide and landslide-generated tsunami threat exists in Barry Arm, northwestern Prince William Sound, Alaska. Rapid failure of the landslide has the potential to create a tsunami that results in life-threatening waves and currents in Barry Arm, Harriman Fiord, Port Wells and adjacent fiords. Mariners should maintain vigilance when in the vicinity of Barry Arm or nearby waters and be prepared to depart the area if any unusual rockfall activity is seen or heard, or if unusual waves, currents, or tides are observed. Broadcast notices to mariners will be sent when hazard is elevated. For additional information, please visit the following website: https://dgggs.alaska.gov/hazards/barry-arm-landslide.html.</p> | | |
| 2 | <p>Escalating landslide and tsunami threat in Barry Arm, northwest Prince William Sound. Landslide may produce large, life-threatening waves with little notice. Mariners are encouraged to avoid the area. If any unusual rockfall activity is seen or heard, or if unusual waves, currents, or tides are observed, those who are ashore should immediately travel to higher ground. Those off-shore should transit to or remain in deep water.</p> | <p>Confirmed recent movement of the Barry Arm landslides indicates an escalating landslide and tsunami threat in Barry Arm, northwest Prince William Sound. Landslide may produce large, life-threatening waves with little notice. Mariners are encouraged to avoid the area. If any unusual rockfall activity is seen or heard, or if unusual waves, currents, or tides are observed, those who are ashore should immediately travel to higher ground. Those off-shore should transit to or remain in deep water. For additional information, please visit the following website: https://dgggs.alaska.gov/hazards/barry-arm-landslide.html.</p> | | |
| 3 | <p>Rapid movement of the Barry Arm landslide indicates landslide failure and tsunami may be imminent. Life threatening conditions likely in Port Wells and adjacent fiords. Unpredictable and dangerous waves, water levels, currents, and tide cycles possible throughout Prince William Sound. Mariners are advised to avoid northern Port Wells, Barry Arm, Harriman Fiord, and other adjacent fiords where topography and seafloor characteristics enhance tsunami energy. If on shore, be prepared to seek higher ground. If on water, be prepared to move to deeper water if rockfall or unusual tides, currents, or waves are observed.</p> | <p>Rapid movement of the Barry Arm landslide indicates landslide failure and tsunami may be imminent. Life threatening conditions likely in Port Wells and adjacent fiords. Unpredictable and dangerous waves, water levels, currents, and tide cycles possible throughout Prince William Sound. Mariners are advised to avoid northern Port Wells, Barry Arm, Harriman Fiord, and other adjacent fiords where topography and seafloor characteristics enhance tsunami energy. If on shore, be prepared to seek higher ground. If on water, be prepared to move to deeper water if rockfall or unusual tides, currents, or waves are observed. For additional information, please visit the following website: https://dgggs.alaska.gov/hazards/barry-arm-landslide.html.</p> | <p>Barry Arm Landslide posit 61-08, 148-09. Possible tsunami or other waves may be imminent.</p> | |
| 4 | <p>A catastrophic failure of the Barry Arm landslide has occurred and produced a tsunami. Life threatening conditions exist and may continue in Port Wells and adjacent fiords. Unpredictable and dangerous waves, water levels, currents, and tide cycles are confirmed in Port Wells and adjacent areas and may be present throughout Prince William Sound. Be prepared to move to deeper water if rockfall or unusual tides, currents, or waves are observed. Mariners are encouraged to avoid all of northwestern Prince William Sound and remain vigilant when transiting other parts of Prince William Sound.</p> | <p>A catastrophic failure of the Barry Arm landslide has occurred and produced a tsunami. Life threatening conditions exist and may continue in Port Wells and adjacent fiords. Unpredictable and dangerous waves, water levels, currents, and tide cycles are confirmed in Port Wells and adjacent areas and may be present throughout Prince William Sound. Be prepared to move to deeper water if rockfall or unusual tides, currents, or waves are observed. Mariners are encouraged to avoid all of northwestern Prince William Sound and remain vigilant when transiting other parts of Prince William Sound.</p> | <p>Barry Arm Landslide posit 61-08, 148-09. Possible tsunami or other waves generated.</p> | <p>A landslide occurred at 231623 UTC, which is 0823 Alaska time on October 23rd, 2023, in the Barry Arm located in approximate position 61-08N, 148-09W. This landslide is expected to create potentially dangerous wave activity within the Western Prince William Sound region. Mariners are advised to either move ashore and to high ground or to transit to deep open water where tsunami type waves would have lesser affect. Mariners are also requested to report any unusually dangerous wave or water level activity to the Coast Guard Sector Anchorage Command Center on VHF/FM channel 16 or by phone to 907-428-4100.</p> |

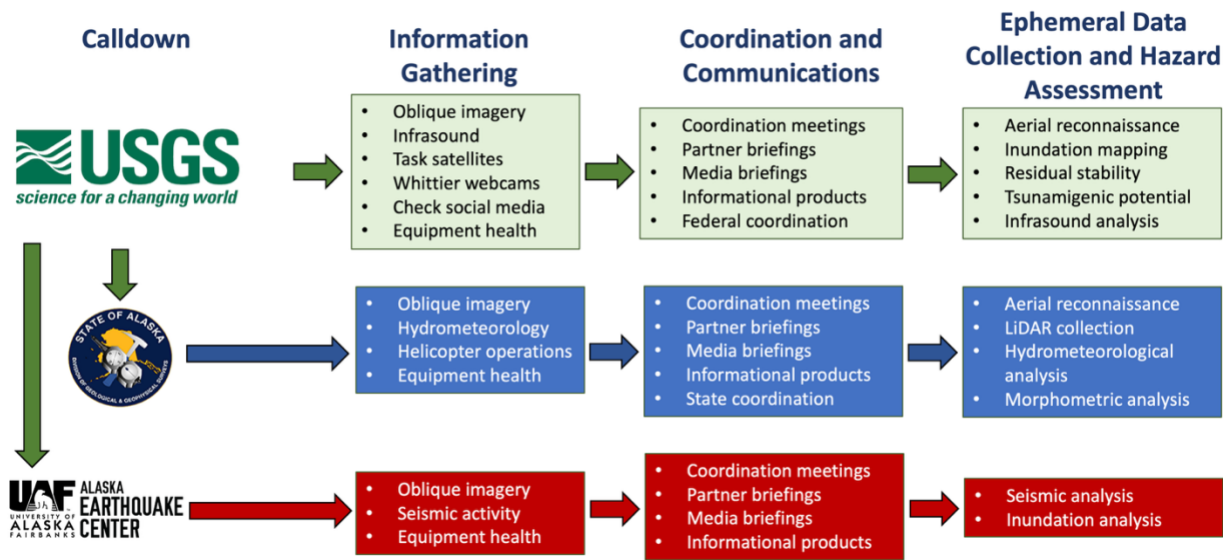


Figure 6. Calldown list after the USGS Coordinating Scientist has been contacted by NTWC that landslide failure has occurred (Landslide Activity Level 4).

Significant Regional Earthquakes

A moderate local or strong regional earthquake has the potential to trigger multiple widespread subaerial and submarine landslides, including the failure of the Barry Arm landslide. The magnitude of the earthquake, regional geology, and distance from the epicenter to the landslide exert influence on the potential for coseismic failure. Although these linkages are complex, the USGS has developed a near real-time tool for estimating the probability of ground failure in response to a regional earthquake. While we recognize that additional research is warranted to better understand how strong ground motion may influence the stability of the Barry Arm landslide, we adopt the approach in **Figure 4** and **Figure 5** as an initial framework for setting the landslide Activity Level after a regional earthquake.

In addition, a strong seismic event has the potential to damage or destroy monitoring equipment. In that case, a thorough assessment of equipment status and health is required, followed by repair missions as soon as safely possible.

Post-Failure Scientific Response

In the immediate aftermath of a partial or catastrophic failure, emergency protocols and response activities at NTWC, DHSEM, and USCG are of highest importance. Only those activities that directly support post-event operations and emergency response at NTWC, DHSEM, and USCG and other Collaborators will be prioritized, such as providing data about ongoing landslide and tsunami hazards that could impact the emergency response and site safety. *Scientific activities*

that do not directly support these objectives must be conducted in such a way that they do not interfere with post-event operational responsibilities or with the emergency response effort. However, once the initial response activities are completed, scientific activities that assess the impact of the event, health of monitoring equipment, and increased detail about potential for subsequent failure should then be prioritized (**Table 5**).

A partial or catastrophic failure may generate a sufficiently large wave to damage or destroy many of the sensors used for operational monitoring. In the immediate aftermath of an event, scientists must check the operational status of all proximal sensors to determine which ones have been damaged or destroyed, and to begin making plans to replace these instruments when environmental conditions permit, and with the safety of those performing the replacement of utmost priority.

It is expected that partial or catastrophic failure would also result in a new topographic configuration at the landslide that has a new stability condition not well-represented by pre-event topography. A large event may require substantial rescue and recovery operations and the repair or replacement of equipment in the area. It is therefore imperative that a thorough assessment of current landslide condition and tsunamigenic potential of future failures be conducted. In this case, we recommend the following actions occur as soon after failure as possible:

1. Conduct aerial reconnaissance, photographing, and mapping of the landslide and area impacted by the resultant tsunami.
2. Assess the status and health of surveillance equipment. Repair or replace critical monitoring systems that may have been damaged or destroyed in the event. Highest priority is given to the NTWC water level sensors, AEC seismometers, USGS infrasound arrays, and the supporting telemetry equipment. If able, bring online some form of optical surveillance.
3. Rapidly deploy airborne lidar instruments to survey the new topographic configuration of the landslide and splash zone.
4. Assess the regional impact of the event through remote sensing data analysis.
5. Model slope stability of residual topography and potential for further failure.
6. Model the tsunami that may be generated from plausible future failures as identified during the previous steps.

Scientists at USGS, DGGS, and AEC will coordinate to determine how these data are collected and how continuity of monitoring operations can be restored. Additionally, the LASER project at USGS may be recruited to aid with rapid deployment of field kits as well as data assessment and modeling efforts. Extended periods of elevated Landslide Activity Level will require staff rotation to manage fatigue, making it essential to train scientific personnel at all agencies in redundant skillsets. Once data are collected, the Multiagency team will use these data for

analyses needed to characterize the hazard associated with the new conditions at the Barry Arm landslide and provide actionable scientific products and guidance to Collaborators and Stakeholders to better inform emergency response operations, as requested by State or Federal emergency management. As such, we consider the collection of these datasets to be an integral part of an emergency response plan for a partial or catastrophic failure of the Barry Arm landslide.

Table 5. Post-event ephemeral data collection and hazard assessment plan

| Objective | Rationale | Data Needs | Analysis |
|--|--|--|--|
| Quantify residual topography | <ul style="list-style-type: none"> Evaluate stability of residual topography Estimate size of event Estimate local impacts Inputs for slope stability models Inputs for tsunami hazard assessment | <ul style="list-style-type: none"> Helicopter reconnaissance Airborne lidar Aerial photography Satellite imagery | <ul style="list-style-type: none"> Topographic change detection and volume calculation Structural mapping Longitudinal profiles and cross-sections Runout analysis Local runup Slope stability analysis Tsunami hazard assessment |
| Quantify regional impacts | <ul style="list-style-type: none"> Estimate environmental consequences Estimate damages to buildings and infrastructure Validate/verify original model estimates, recalibrate as needed | <ul style="list-style-type: none"> Helicopter reconnaissance Aerial photography Satellite remote sensing (optical, LandSat, Sentinel) | <ul style="list-style-type: none"> Regional runup Damage assessment Reflectivity change detection (dNDVI) |
| Quantify event seismology | <ul style="list-style-type: none"> Determine event duration and sequencing Identification of seismic triggering Identification of potential precursors | <ul style="list-style-type: none"> Seismic data | <ul style="list-style-type: none"> Event reconstruction Precursor seismicity Earthquake triggering |
| Quantify event infrasound characteristics | <ul style="list-style-type: none"> Determine event duration and sequencing Analysis of potential precursors | <ul style="list-style-type: none"> Infrasound data | <ul style="list-style-type: none"> Event reconstruction Precursor acoustics |
| Quantify hydrometeorologic conditions | <ul style="list-style-type: none"> Determine event duration and sequencing Validate/verify original model estimates and recalibrate as needed | <ul style="list-style-type: none"> Hydromet data (from DGGS) | <ul style="list-style-type: none"> Evaluation of pre-event conditions (temperature, precipitation accumulation, storm characteristics) for possible triggering and event reconstruction. |
| Field Mapping (when deemed safe) | <ul style="list-style-type: none"> Field measurements that support detailed analysis and modeling of tsunami runup, inundation, velocity, etc. | <ul style="list-style-type: none"> Onshore traces Sedimentological characteristics (particle size distributions, locations, sediment sampling, pits) Vegetation damage, location Building damage, location | <ul style="list-style-type: none"> Verification of aerial mapping and damage assessment Tsunami velocity, depth, and runup Tsunami damage and fragility assessment |

Technical Communications

Effective communication of landslide and tsunami hazards requires consistent, continued, and responsive messaging. In addition, as new information is learned and our understanding of hazard and risk evolve, it is imperative that partners, media, and the public are informed. The primary objectives of interagency communications are to (a) describe the mechanisms by which

the Multiagency team and Collaborators communicate hazard information to one another, (b) describe how the participating agencies interact with government officials at the federal, state, and local level, (c) describe how the participating agencies interact with the public and media. Primary points of contact within each agency are identified in **Appendix I**.

Interagency Communications

One of the primary objectives of the Interagency Technical Operations Plan is to define the mechanisms by which the Multiagency team and its Collaborators – NTWC, NWS, USFS, USCG, and DHSEM – communicate hazard information to one another, and to define pathways for interactive communication of hazard and risk information, plans, products, and response activities. These mechanisms include regularly scheduled coordination meetings and email communications, and ad-hoc briefings during periods of elevated landslide activity.

Quarterly Coordination Meeting

The USGS will organize and convene a quarterly virtual meeting for the purposes of interagency coordination. All Multiagency team members (USGS, DGGS, AEC) should attend, and all Collaborators (NTWC, NWS, USFS, USCG, DHSEM) are also invited to attend. Meetings will be scheduled for one hour and will take place on the last Wednesday of every third month at 2 PM Alaska Time. All attendees will be notified of changes in meeting schedule at least three days in advance of the meeting.

Each meeting will lead off with an update on the status of the Barry Arm landslide, monitoring equipment and results, and information related to any other landslide hazards in and around PWS. Following the update on landslide status, the Multiagency team should be prepared to convey the following information to the participating agencies:

- Are there ongoing activities (plans, events, etc.) that you want the team to be aware of related to landslide and tsunami hazards?
- What immediate needs do you have that would benefit from coordination with the Multiagency team or other Collaborators?
- How can we tailor our research and products to better serve your planning and operational needs?
- What can we do together to better inform the public of landslide and tsunami hazards and mitigate risk?
- Other items for general awareness or specific coordination needs?

Participating agencies are encouraged to provide updates or ask questions of the Multiagency team along the following themes:

- Are there ongoing activities (plans, events, etc.) that you want the science team and partners to be aware of related to landslide and tsunami hazards?
- What immediate needs do you have that would benefit from coordination with the Multiagency team or other Collaborators?
- How can we tailor our research and products to better serve your planning and operational needs?
- What can we do together to better inform the public of landslide and tsunami hazard and mitigate risk?
- What focus areas are critically lacking in current science activities?
- What other agencies and organizations need to be involved?

Monthly Communication Products Check-in

The USGS will organize a monthly virtual check-in for the purposes of coordinating interagency and public communication needs, including DGGS website updates, media requests and needs, social media activities, and public outreach and engagement events. Regular participants will include representatives from the Multiagency team members, and Collaborators will be invited. Stakeholders will be invited as appropriate.

Ad Hoc Briefings

During periods of elevated landslide hazard, the USGS will organize and convene interagency briefings on landslide status open to all Multiagency team members and Collaborators. The purpose of these briefings is to provide situational awareness of detection and confirmation of signals associated with increased landslide activity (e.g. landslide movement, increases in the frequency or magnitude of seismic or acoustic emissions that may be indicative of movement or small failures) that may be precursors of partial or catastrophic failure. These meetings will be scheduled at frequencies defined by the Landslide Activity Levels and described in **Table 2**. The briefings will start with an update on landslide activity and status, followed by an open question-and-answer session. At the conclusion of the briefing, the organizer will discuss next steps, schedule the next briefing, and decide upon future communication needs, such as the scheduling of a briefing for other federal, state, and local officials, press conferences, or public meetings. Although the Ad Hoc Briefing is scheduled for 30 minutes, the Multiagency team members will remain available after the meeting wrap-up to answer any questions or go into greater detail on scientific interpretations and hazard implications related to the increased activity detected at the Barry Arm landslide.

Ad Hoc Press Conferences and Public Meetings

If consensus is reached that additional awareness is required by Stakeholders, other federal, state, or local officials, or if a press conference or public meeting is warranted, the participating agencies will work together to develop a plan for scheduling these events and decide on which agency and agency representative(s) will organize and execute these activities. These decisions will be made at the end of the Ad Hoc Briefings described above, or through other forms of written and verbal communication when safety concerns require an accelerated decision.

Public and Media Communications

The Multiagency team and its Collaborators are responsible for sharing actionable science and hazard information with Stakeholders, the public, and the media, in coordination with their internal agency communication teams. To this end, the framework presented within this plan should guide the strategy and tactics for preparing public messages, the protocols for delivering the message to the target audiences, and plans for how to engage with the target audience in advance, during, and after a landslide emergency. The audience for this communication includes, but is not limited to, the following groups:

- Communities and Census Designated Places in the PWS region, including Whittier, Cordova, and Valdez
- Tribal governments and related agencies, including the villages of Chenega and Tatitlek
- Recreationists and other maritime users in northern PWS
- Non-commercial and commercial services and related organizations; tourism, business, and commerce-related groups (e.g., cruise operators, railway, fisheries)
- Congressional delegations at the Federal and State government as coordinated by appropriate liaison offices at USGS, DGGS, AEC, and NOAA
- Local, regional, national, or possibly international media representatives and organizations
Environmental and conservation groups
- College and universities or academic collaborators in the region or with a known interest in Alaska landslide hazard issues

Objectives for these communication products and events include:

- Safety messaging, broad outreach, and communication to emergency managers, community leaders, and recreationalists to ensure they are aware of ongoing monitoring efforts, situational changes, evacuation routes, and appropriate safety measures to protect themselves and others.
- Increase understanding among interested and impacted Stakeholders (i.e., local communities, marine and navigation pathways, infrastructure like ports and harbors, oil

pipeline and rail line, etc.) about the risk associated with the landslide/tsunami hazard in terms of scientific information that will be gathered to help guide future observations and response.

- Provide timely and open information to the media; generate responsible press coverage regarding this situation.
- Strengthen relationships with Stakeholders and interested parties through transparent, open and proactive communication. Ensure state and local government officials have the information they need to prepare, mitigate, and act responsibly for their communities.

To achieve these objectives, specific responsibilities and activities include:

- DGGS will maintain a website (including Frequently Asked Questions, as featured in **Appendix III**) and Really Simple Syndication (RSS) web feed containing the latest scientific information about landslide activity. This website will be updated every month during periods of relative quiescence at the landslide, and more frequently if landslide activity increases to Levels 2-4.
- The USGS will attend an annual coordination meeting with local communities, media, local organizations and interest groups, academics, and the public. The purpose of this meeting is to inform partners and Stakeholders of landslide status, scientific results, ongoing or upcoming field campaigns, and products or activities that may be of interest to members of the audience. In addition, this will be an opportunity for audience members to ask questions of the participating agencies, provide updates on their group activities, and engage directly with individual scientists, emergency managers, and federal, state, and local officials who are in attendance. These meetings may be coincident with other events of regional interest, such as the annual PWS Natural History Symposium.

To better inform the media and public about landslide status and ongoing work, Multiagency team commits to producing and maintaining the following communication products:

- Monthly updates to the DGGS website that will include email notifications. Posts to social media by the Multiagency team, Collaborators, and Stakeholders that include updates on science, surveillance, warning and public engagement and outreach activities.

Protocols for Updating this Plan

This plan will be formally reviewed and modified by the Coordinating Scientist from all participating agencies once every three years to account for changes in organizational structures, and protocols. Internal updates to the plan (e.g., calldown list and named staff members) will be discussed via an informal review each year. A new version of the plan will be made available through the USGS website for viewing by the general public, with an appendix noting updates from previous versions. If there are no changes to be made, a new version will not be required.

Decreases in the frequency or outright suspension of all monitoring activities may occur as budgets, resources, and staffing levels evolve, or as more insight into the stability and likelihood of failure of the Barry Arm landslide is acquired. The Multiagency team and Collaborators will meet to reach consensus on when or if the operational activities described in the plan need to be revised, suspended, or canceled. Any changes to the technical operations plan that occur within the normal annual review cycle will be communicated within the Multiagency team and to all Collaborators and Stakeholders. These changes will also be made available to the general public via the DGGs Barry Arm Landslide website after consensus is reached and changes to the revised plan have been completed. Questions about the current plan can be directed to the USGS Project Lead, Dennis Staley: GS-AK_Landslides_Duty_Scientists@usgs.gov.

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Appendix I: Landslide-Generated Tsunami Calldown Protocols

Phase I: NTWC Initial Calldown Protocol

Upon detection of a significant landslide or landslide-generated tsunami that exceeds warning criteria, NTWC will prioritize their standard calldown protocols for tsunami warnings. Only when those priority notifications are completed will NTWC initiate Phase I of the calldown protocol outlined here.

NTWC will call the USGS Coordinating Scientist (CS) (or backup) to initiate the multiagency calldown protocols. Once a USGS CS (or backup) has been contacted, NTWC has no additional calldown responsibilities within these response protocols. The information for the USGS CS should include:

- Estimated wave height at sensor(s)
- Time and duration of event
- Known impacts (if any)

NTWC calldown list:

| Name | Agency | Role |
|---------------------------|---------------|--|
| Staley, Dennis | USGS | USGS Coordinating Scientist and Project Lead |
| Collins, Brian | USGS | Primary backup for Staley |
| Schaefer, Lauren | USGS | Secondary backup for Staley |
| AVO Duty Scientist | USGS | Tertiary backup for Staley |

Phase II: USGS Coordinating Scientist Calldown Protocol

Upon notification of a landslide emergency by NTWC, the USGS CS will call the DGGS and AEC CSs, as well as USGS team scientists. The message for all below will include:

- Estimated wave height at sensor(s)
- Time of event
- Known impact
- Immediate next steps
- A time/day to meet about future steps

The USGS CS will also further coordinate with the Alaska Volcano Observatory (AVO) Duty Scientist to initiate a USGS agency-wide response, which would include notifying the USGS Alaska Regional Office, the USGS Landslide Hazards Program, the Volcano Science Center, the USGS Emergency Management Program, and the DOI Office of Emergency Management.

USGS CS calldown list:

| Name | Agency | Role |
|---------------------------|---------------|---|
| Admin Duty Phone | DGGS | Emergency contact, rotating personnel |
| West, Michael | AEC | AEC Coordinating Scientist |
| Collins, Brian | USGS | USGS Associate Coordinating Scientist and Radar lead |
| Schaefer, Lauren | USGS | USGS Associate Coordinating Scientist and Remote Sensing lead |
| AVO Duty Scientist | USGS | General awareness and USGS support |
| Read, Cyrus | USGS | Engineering |

Phase III: DGGS and AEC Coordinating Scientist Calldown Protocol

Upon notification of a landslide emergency by the USGS Project Lead (or backup), the Coordinating Scientists at DGGS and AEC will call team scientists at their organization and relevant state officials. The message for all below will include:

- Estimated wave height at sensor(s)
- Time of event
- Known impact
- Immediate next steps
- A time/day to meet about future steps

Furthermore, the DGGS Coordinating Scientist will coordinate with State officials to coordinate State response activities. AEC will also coordinate with State officials as defined by existing seismology mandates.

DGGS CS calldown list:

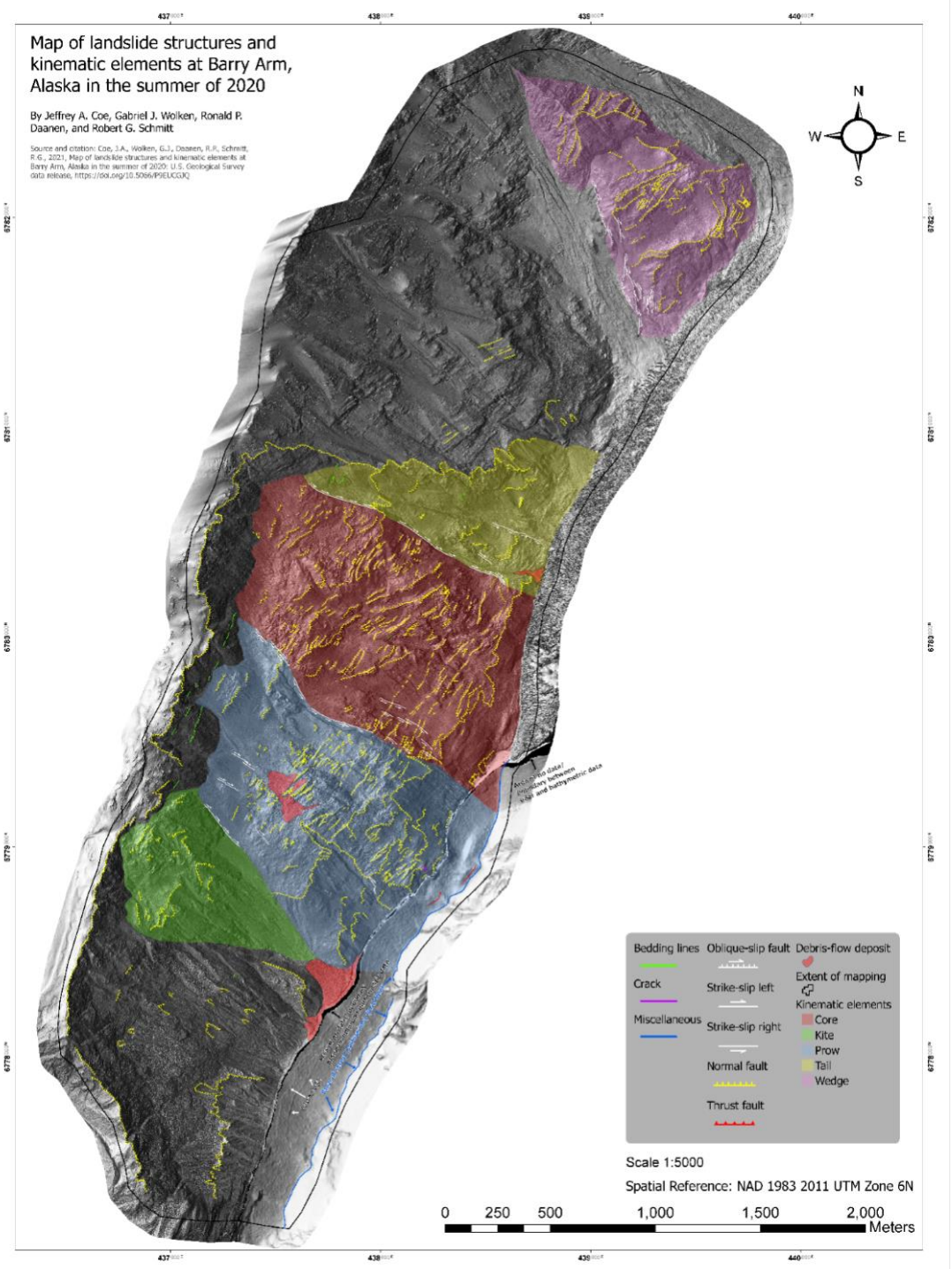
| Name | Agency | Role |
|------------------------------------|---------------|--|
| Nicolazzo, Jill | DGGS | Landslide Hazards Geologist |
| Cameron, Cheryl | DGGS | Geohazards Section Chief |
| Wolken, Gabe | DGGS | DGGS Science Lead |
| Salisbury, Barrett | DGGS | Geohazards and Science Communications |
| Zirnheld, Lee | DGGS | Logistics |
| Wikstrom-Jones, Katreen | DGGS | Snow Science, Hydrologist |

AEC CS calldown list:

| Name | Agency | Role |
|--------------------------|---------------|------------------------|
| Karasozen, Ezgi | AEC | Seismologist |
| Holland, Austin | AEC | Director of Operations |
| Duty Seismologist | AEC | Rotating personnel |

Appendix II: Structures and Kinematic Elements of the Barry Arm Landslide

Reproduced from: Coe, J.A., Wolken, G.J., Daanen, R.P., & Schmitt, R.G. (2021). *Map of landslide structures and kinematic elements at Barry Arm, Alaska in the summer of 2020: U.S. Geological Survey data release*. U.S. Geological Survey. <https://doi.org/10.5066/P9EUCGJQ>



Appendix III: Frequently Asked Questions

Where is Barry Arm, the glacier and potential landslide area?

The unstable slope that could fail into the fjord is located on the west side of upper Barry Arm near the terminus of Barry Glacier, 28 miles northwest of Whittier in Prince William Sound, Alaska.

What are the chances there will be a massive landslide and tsunami in Barry Arm?

While geologists can clearly identify the region is at risk for a landslide, there is much they don't know about the situation. It is difficult, if not impossible, to predict with any degree of certainty when a failure could occur and what exactly it would look like. Scientists are working to gather what information they can, to help them better understand the risks, and to better guide any emergency communications and response.

How long have you known about this landslide-tsunami risk?

The general risk of landslides in glacial fjords throughout Prince William Sound is well known, although we are still gathering information about specific landslides and the large landslide on Barry Arm. Landslides in these areas can produce localized tsunamis. The best way to be prepared is to remember the warning signs: a long or strong earthquake, sea-level change, and in this case any unusual noises from the hillside or the water. If you notice any of these conditions, don't wait for a siren or an alert. Stop what you're doing and move to higher ground!

Is the unstable slope in Barry Arm moving now?

Analysis of airborne and satellite data reveal motion of the landslide beginning as early as 1957. Between 2009 and 2015, the landslide moved 600 feet (183 meters) toward the fjord at the same time as Barry Glacier was thinning and retreating below the landslide. Since 2016, the landslide rate has slowed; a 2020 [analysis](#) of satellite radar data shows landslide motion during the period June through September 2020 was less than a few inches, but between October 9 and October 24 eight inches (20 centimeters) of downslope motion was detected. We consider a normal background level of the Barry Arm landslide movement to be less than 2 inches (5 cm) a day. You can check the current activity and landslide status on the dedicated DGGS webpage [here](#).

When will a tsunami occur?

Currently, the National Tsunami Warning Center has no indication that the rapid failure of the landslide is imminent. Landslides can happen at any time and the community needs to remain vigilant. The National Tsunami Warning Center will continue to work with local, state, and federal partners to develop reliable, sustainable information that will give us critical awareness whenever we need it.

How bad would a landslide and tsunami be?

While we are preparing for the possibility that the entire unstable slope could fall into the water, there are other possibilities ranging from no future movement to rapid full failure of the entire unstable slope. The possibility of any amount of landslide movement producing a tsunami is real and could occur without warning. Recent modeling of a catastrophic failure of the Barry Arm landslide produces a wave with an estimated maximum height exceeding 500 feet (150 meters) in Barry Arm, and in excess of 6 feet (2 meters) in Passage Canal near Whittier, Alaska. Runup height of the tsunami wave depends on the specific bathymetry and topography of the shoreline in question. For comparison, the tsunami generated by landslides from the 1964 earthquake led to maximum wave heights around 11.5 feet (3.5 meters) and subsequently led to shoreline runup heights between 15 and 80 feet (5 and 25 meters) above mean sea level in Passage Canal around Whittier.

Is Whittier still at risk even though the wave is smaller than originally thought?

While the new estimates of 7 feet (2 meters) tsunami height are much lower than initially estimated, these waves still pose a risk. It only takes 1 foot (0.3 meters) of water to lift a car, so 7 feet (2 meters) can do some real damage to people and property in Whittier. The tidal conditions are also an important factor to keep in mind – tide heights typically vary by 18 feet (5.5 meters) in Whittier, which can either dampen or exaggerate the effect of a tsunami wave.

Could an earthquake trigger the landslide? What magnitude?

We don't know enough about the failure plane of the Barry Arm landslide to model the impacts of an earthquake, but we know that a large earthquake increases the risk of failure.

What is being done about the situation?

Scientists from multiple state and federal agencies are working together to expand our understanding of slope stability in Prince William Sound and evolve tsunami prediction and warning methods. Barry Arm is being actively monitored, and new landslide identification efforts are underway. These agencies are working with local and regional emergency managers to ensure timely dissemination of relevant and actionable updates to keep people safe while working to protect local infrastructure.

Why can't you stabilize the slope and keep it from moving? Can't you anchor it somehow?

The landslide is too large to prevent or mitigate its movement using structural means, and large landslides cannot be artificially triggered (e.g. using explosives) in a controlled manner.

Why don't you just blow it up / trigger the landslide in a controlled way so we can get it over with?

On a technical side, it would be impossible to pre-emptively trigger the landslide in a controlled way because the landslide's internal structure is not fully constrained and it would be highly hazardous to workers to access any of the landslide surface to implant any equipment directly. This might also result in new landslide failure planes or other unstable areas with future risk. On a practical side, the landslide and its ensuing tsunami wave would trigger hazardous conditions for a large area (tsunami wave, runup heights), as well as drastic ecological consequences (disturbance to marine life, stripping of vegetation from shorelines, erosion of nearby glaciers, for example) with implications for ecosystem health, and the vital fishing, recreation, and tourism industries around Whittier and Prince William Sound. These consequences would also create large legal liability issues.

Will Whittier have time to evacuate if a landslide-tsunami occurs in Barry Arm?

Whittier will have very little time to react and evacuate. Seconds matter! When a landslide occurs that causes a tsunami, the natural warning signs may be your best alert. When a long or strong earthquake occurs, an unusual sea-level change is noticed, or, in this case, unusual noises from the hillside or the water - people should not wait for a warning or siren. Stop what you're doing and move to higher ground immediately! If an event is detected, the National Tsunami Warning Center will send an alert message within 5 minutes, but that is if everything goes well. That may not leave enough time to take the necessary actions. Use your best judgment based on natural warning signs. The National Tsunami Warning Center will continue to work with our local, state, and federal partners to monitor this threat and give as much advance warning as possible.

What do I do if I can't take the tsunami evacuation route? Example: Train is blocking the route.

If you cannot safely or quickly leave via the designated tsunami evacuation route, you should try to move as far uphill and inland as possible. You can also look for sturdy structures and tall buildings and climb to the top floor or roof. Remember, seconds count! A tsunami wave triggered by a landslide at Barry Arm could reach Whittier in less than 15 minutes from the initial triggering event.

How will the National Tsunami Warning Center alert me if a tsunami occurs?

If a tsunami is detected, the National Tsunami Warning Center will issue an alert within 5 minutes. DO NOT rely on only one type of alert system to receive this important information. You may receive a tsunami warning over:

- NOAA Weather Radio and marine VHF channel 16
- Your cell phone and Wireless Emergency Alerts
- Radio / television / internet sites
- Tsunami siren

- Nixle alert subscriptions
- Official social media sites

Is Prince William Sound monitored for tsunamis?

NOAA's National Tsunami Warning Center has three sensors that are designed to detect a tsunami in Prince William Sound. While every effort is made to maintain these sensors in the harsh Alaskan coastal conditions, it is possible that these sensors will not be functional at all times. Reasons for inoperability include damage from weather or waves, damage from animals, burial in snow, and hardware or software failures. Upon identification of a failed sensor, scientists and technicians will attempt to fix the issues at the earliest opportunity. However, weather and landslide activity may delay maintenance trips, as team safety is the highest priority. Currently, the system to provide alerts of a tsunami generated by a failure of the Barry Arm landslide is in an experimental status. No fully established system for landslide-triggered tsunamis exists globally, though there are several other experimental systems like the one at Barry Arm.

Is Whittier prepared for a tsunami?

Whittier is a [Tsunami Ready](#) community. Being Tsunami Ready means the city of Whittier works with the National Tsunami Warning Center and the State of Alaska to prepare for and understand the community's Tsunami Risk. Whittier has alerting tools such as tsunami sirens and has established evacuation routes to help keep the people of Whittier safe. There are 13 Tsunami Ready communities in Alaska.

What precautions can I take when I go onto the water for work/recreation?

Make sure to have your radio channel communications turned on and listen for any alerts. If you are camping in Prince William Sound, tie down your gear and make sure to set up your camp well above the high tide line (kayakers were nearly swept away from their tent sites more 30 miles away from the Tracy Arm landslide that failed in 2025). Avoid transiting or stopping near the Barry Arm fjord, particularly if Landslide Activity Levels are elevated (check the DGGS [website](#) for updates). Keep an eye out for unusual rockfall activity, strong earthquakes, or unusual waves, currents or tides. Have a good communication plan set up and always let someone know about your planned route and expected return.

What is the geologic history of Barry Arm?

The Barry Arm fjord is in an area referred to as the "accretionary prism," where plate tectonics forced sedimentary rocks to collide and merge with the southern shore of the Alaska mainland long ago in geologic history. This process created numerous fractures and faults in the bedrock, and the subsequent, multiple glacial advances further fractured and eroded the landscape. As alpine permafrost thaws and glaciers thin and retreat, support of the

valley walls is degraded and removed, allowing rockfalls and landslides to occur; landslides entering the water have the potential to create tsunamis.

What is a fjord?

A fjord is a glacier-carved narrow inlet of the ocean between two steep slopes. In many parts of Southcentral and Southeast Alaska, a fjord leads to the toe of a glacier that reaches the ocean, called a tidewater glacier. Thanks to the numerous glaciers that once covered Southcentral and Southeast Alaska, the state is home to a great number of fjords.

What is the history of the Barry Arm slope movement?

- In 2020, a large rockfall event at Barry Arm was recorded by a nearby seismic station (the instrument thankfully remained intact). Comparison of two lidar-derived elevation models for the Barry Arm landslide mass revealed a significant rockfall (~850,000 cubic yards, or 650,000 cubic meters) on the main body of the landslide. Slow, widespread movement of the landslide mass identified using satellite radar was also confirmed by the repeat lidar scans conducted in late summer/early fall.
- The unstable slope in Barry Arm is in an area of steep, glacier-carved terrain where the glacier has recently thinned and retreated, and the bedrock is highly fractured. While the slope moved about 600 feet (180 meters) toward the fjord between 2009 and 2015, its motion has slowed in recent years. Data from scientific observations in June and July 2020 indicate the slope movement was less than a few inches during that period, suggesting that the risk from a potential landslide-generated tsunami is lower now than it was between 2009 and 2015.
- There are numerous examples of the landslide accelerating and decelerating without catastrophic failure, including two periods of deformation at the Barry Arm landslide in the late summer and fall of 2020, 2022, and 2023.
- Research continues and efforts to monitor this slope with satellite and airborne sensors, and with sensors attached to the surface and buried into the slope are ongoing. Satellite monitoring will continue until fall, when snow will cover the region around Barry Arm.

How will we know what is happening in Barry Arm?

- Multiple state and federal agencies and institutes are working together to collect baseline data that will help them understand how big the landslide area is, whether or how much it is moving, and how big a tsunami could result from a landslide.
- Currently, scientists are monitoring motion by comparing data on the site collected at different times using a variety of scientific techniques. These include ground- and satellite-based Synthetic Aperture Radar (SAR), airborne light detection and ranging (lidar), geophysical monitoring methods including seismometers and infrasound, cameras, and aerial photograph-based mapping.

- There are three tide gauge stations in the Barry Arm and Port Wells region to monitor for a tsunami should a landslide occur. Bathymetric surveys collected in 2021 help scientists better understand the underwater sea floor and how it would affect a tsunami should a landslide occur.
- Scientists are meeting routinely to discuss their observations, share information about any notable changes, and share this information with emergency management agencies.

Has Alaska seen landslide-generated tsunamis before?

- Many coastal areas in Southcentral and Southeast Alaska are susceptible to tsunamis generated by landslides, and history records several such events, including the 1958 Lituya Bay and the 2015 Taan Fjord tsunamis.
- The Lituya Bay tsunami was generated by a 39 million cubic yards (30 million cubic meters) landslide, triggered by a Magnitude 7.8 earthquake on the Fairweather Fault on the west side of Glacier Bay National Park. That tsunami contributed to the deaths of two people.
- The 2015 Taan Fjord tsunami was generated by a 99 million cubic yards (76 million cubic meters) landslide that occurred following retreat of the Tyndall Glacier. The wave affected the entire length of the fjord.
- In 2025, a 130 million cubic yards (100 million cubic meters) landslide triggered a tsunami in Tracy Arm just past the toe of South Sawyer Glacier, causing a runup wave height of 1540-1640 feet (470-500 meters) across from the landslide. Fortunately, there were no fatalities, though a group of kayakers camping on Harbor Island more than 30 miles (50 kilometers) away were nearly swept away by a 20-foot (6 meter) wave runup. The timing of day, falling tide, poor weather for recreation, and lack of cruise ships in the fjord were all lucky factors in preventing fatalities.
- Within Glacier Bay National Park, a slope on the north side of Tidal Inlet has been slowly moving since at least the early 1900s but has never catastrophically failed and entered the water.

How big could a Barry Arm landslide be?

The Barry Arm landslide is about 1.4 square miles (3.7 square kilometers), with an estimated total volume of approximately 650 million cubic yards (~0.5 cubic kilometers), or roughly 6.5 times larger than the landslide at Taan Fjord. It is not known how much of this landslide volume would enter the water during a potential rapid failure. (For a graphic depiction of the relative size of Alaska's largest tsunami-generating landslides, see this [letter](#).)

What does a Tsunami Warning mean?

A Tsunami Warning means you need to take action immediately! You must move quickly. Stop what you're doing and move inland (away from the coast) and head to higher ground.

You will not have time to reach deep water from the harbor. Dangerous coastal flooding and powerful currents will be possible for several hours.

Who is monitoring the landslide and tsunami risk?

- Alaska Department of Homeland Security & Emergency Management (DHSEM)
- Alaska Division of Geological & Geophysical Surveys (DGGS)
- Alaska Earthquake Center (AEC)
- National Tsunami Warning Center (NTWC)
- United States Forest Service (USFS)
- United States Coast Guard (USCG)
- United States Geological Survey (USGS)