24 January 2025

Rannsóknasjóður Vegagerðarinnar: final report

Project	Future proglacial lake evolution and outburst flood hazard in Iceland
Project manager	Greta Hoe Wells (Institute of Earth Sciences, University of Iceland)
Project members	Þorsteinn Sæmundsson (Institute of Earth Sciences, University of Iceland) Snævarr Guðmundsson (South East Iceland Nature Research Center)
Project status	Completed. *Total awarded*: 1.2 million ISK *Total used*: 1.2 million ISK

This project investigates future proglacial lake development and outburst flood hazard in south Iceland. Icelandic glaciers have lost 20 percent of their ice volume since 1890 and are predicted to lose at least 20 percent more by 2100. Much of this meltwater accumulates in proglacial lakes in front of glaciers, which can drain suddenly in jökulhlaups if a rock avalanche or landslide enters the lake and generates a tsunami-like wave that overtops the lake dam. These mass movement events become a greater risk in a warming climate as retreating glaciers remove support from valley walls, destabilizing slopes. Though this process triggers glacial lake outburst floods (GLOFs) worldwide, only one such event has occurred in Iceland—a 1967 jökulhlaup at Steinsholtsjökull. However, it will likely become a greater likelihood in future under projected climate warming. This project investigates: 1) How will Icelandic proglacial lakes evolve in a warming climate? 2) How will lake development affect outburst flood risk? 3) How will this hazard impact downstream infrastructure and communities?

We study this emerging hazard at three sites in south Iceland: Sólheimajökull, Fjallsjökull, and the western part of Breiðamerkurjökull (Breiðárlón). Each site is experiencing rapid glacier retreat, proglacial lake expansion in a steep-walled valley that may be prone to slope failures, and a high potential societal impact if a flood occurs. Answering our research questions requires four steps: 1) stitch together datasets of lake bathymetry, subglacial topography, and subaerial terrain to create a continuous map of bedrock topography (what the landscape looks like if the ice and lake are removed); 2) combine this map with past glacial lake extents to measure lake volume change over time; 3) identify zones on the valley walls that are at higher risk of producing slope failures (based on steep slopes with large vertical relief); and 4) estimate future lake location and volume based on projected glacier retreat rates.

The Vegagerðin grant enabled us to complete field data collection for this project and purchase a sonar scanner to expand the project to map additional lakes in future. Though we initially applied for funds to pay a company to survey lake bathymetry at Sólheimajökull, we reallocated funding to cover other parts of the project instead:

1) Field campaign to survey subglacial topography at Sólheimajökull with radio-echo sounding. This involves hiking in transects across the glacier with equipment that sends radio signals through the ice that reflect off the bedrock, recording ice thickness and mapping bed topography (May 2023) (Figure 1). Costs included rental car and petrol for the field team.

2) Two field campaigns at Breiðárlón to map the proglacial area and conduct a bathymetric survey to measure lake depth (July and September 2024) (Figures 2 and 3). This involved sailing in transects across the lake with the sonar scanner, which emitted sound waves that reflected off the lake bottom to map lake floor topography. Costs included rental car, petrol, accommodation, and food for the field team.

3) Purchase of our own sonar scanner to survey lake bathymetry (Figure 3). Though the output data does not have as high a resolution as equipment used by many professional companies, it is accurate enough for our study and is much more cost effective, allowing us to survey more lakes independently without relying on repeatedly obtaining funding for surveys by external companies. We successfully used this sonar scanner to survey Breiðárlón, and we plan to use it to map bathymetry at additional proglacial lakes in future.

4) Purchase of necessary equipment to conduct the sonar scanner surveys (i.e. batteries, insulated flotation suit to wear in the boat; memory cards to record data…).

We have used these field data to create comprehensive topographic maps of Sólheimajökull (complete) and Breiðárlón (in process), which we are interpreting to estimate future lake extent, volume, and potential outburst flood hazard scenarios. We are currently writing up results in a manuscript that we plan to submit to a peer-reviewed scientific journal in Summer 2025. We also presented preliminary results at the annual Vegagerðin research conference in October 2023.

The next step is to communicate results to government agencies, local communities, and guiding companies to inform hazard assessments, identify key areas for monitoring (i.e. slopes with a higher risk of failing), and plan flood mitigation strategies such as levees or restricted zones for new construction. This is especially important since these lakes are only a few kilometers upstream of Hringvegur, and a flood could significantly damage the road and bridges, as well as deposit sediment that would need to be cleared. This information can also guide sustainable tourism development. As glacier and lake positions shift in future, new access and viewing points will be needed, and this emerging outburst flood hazard should be considered in future planning. This is especially important at Sólheimajökull, which is one of Iceland's most visited sites for glacier tours. We will also reach out to Vatnajökull National Park and Katla Geopark about the possibility of developing information signboards about climate change impacts and proglacial processes at Icelandic glaciers.

Beyond Iceland, lake bathymetry is an important dataset for understanding glacier–lake interactions. Glaciers tend to retreat more quickly when they terminate in lakes due to increased melting and calving, but field-derived datasets are relatively rare given the difficulty of directly measuring them. Thus, our results can inform proglacial lake studies in other regions worldwide, such as Greenland, the Himalayas, the Andes, and Alaska.

Figure 1. Conducting the radio-echo sounding survey to measure ice thickness on Sólheimajökull, May 2023. Photo by Greta Wells.

Figure 2. Bathymetric survey preparation at Breiðárlón, September 2024 (pictured: project members Greta Wells and Þorsteinn Sæmundsson). Photo by Steffen Mischke.

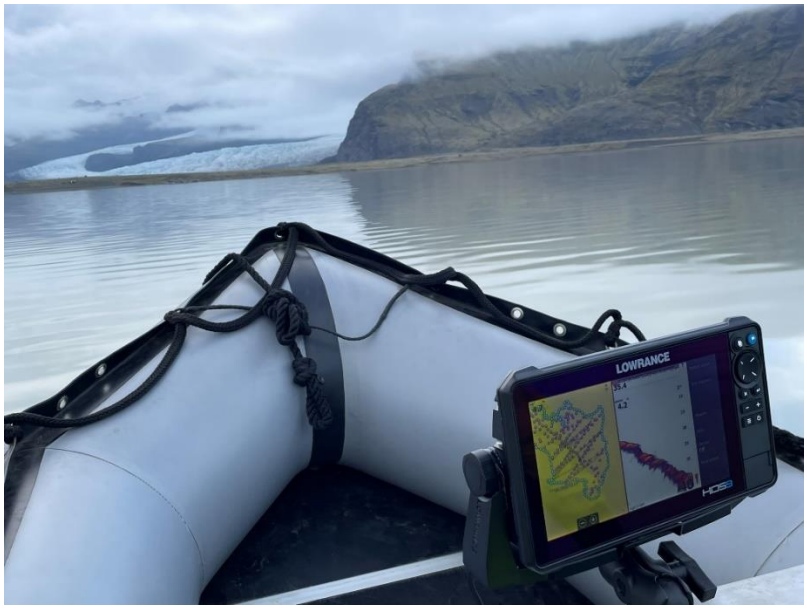

Figure 3. Bathymetric sonar scanner in action surveying Breiðárlón, September 2024. Photo by Greta Wells.