

International Symposium on Mitigation Measures against Snow Avalanches and other Rapid Gravity Mass Flows – Siglufjörður 3–5 April 2019

Field excursion – hand-out

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Northern Iceland has two avalanche-prone towns, Siglufjörður and Ólafsfjörður, several power lines and important roads through avalanche terrain and many farmsteads threatened by avalanches. The Tröllaskagi highland is the most popular mountain skiing area in Iceland, requiring high awareness about snow avalanche danger in the mountains. On the following pages, you will find snow avalanche hazard maps and maps of registered avalanches for Siglufjörður and Ólafsfjörður, and Svarfaðardalur, overview information about avalanche protection measures that have been constructed for the two towns, and some information about the design of the protection measures and avalanche management for the road between the towns of Ólafsfjörður and Dalvík south of Siglufjörður.

Almost exactly 100 years ago to the day, on April 12th, 1919, several avalanches struck Siglufjörður and neighbouring rural areas, killing eighteen people and destroying the Evanger herring processing plant on the east side of the fjord. The avalanches caused enormous material damage at several locations, including damage to boats and the harbour of Siglufjörður by a tsunami wave triggered by the catastrophic snow avalanche from Skollaskál Mountain east of the fjord. It is fitting to organise a symposium in Siglufjörður on the centenary of these tragic events, to discuss methodologies and technologies for avalanche protection and see the progress in avalanche safety that has been made in the town of Siglufjörður in recent years.



Figure1: The tongue of a wet-snow avalanche in Skeggjabrekkudalur in Ólafsfjörður on 30 April 2013. The tongue on the valley bottom was ca. 350 m wide and ca. 450 m long in the flow direction, and ca. 6.5 ha in area. The undulating wet-snow “fingers” in the avalanche tongue were several metres high with towers of piled-up snow up to 8–10 metres high. Photograph: © Ingimar Eydal.



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Highlights from the Avalanche Chronicles

Siglufjörður and neighbouring districts

Siglufjörður, 23.12.1839: An avalanche was released from Skollaskál Mountain, on the east side of Siglufjörður, terminating in the sea. It triggered a tsunami wave, damaging seven boats on the coast on the west side of the fjord where the town of Siglufjörður is now located.

Siglufjörður, 12.4.1919: A catastrophic avalanche from Skollaskál destroyed a herring processing plant on the east side of Siglufjörður and killed nine people in the plant and in a neighbouring building, Sæból. It triggered a tsunami that caused much damage at the west coast of the fjord.

Engidalur, 12.4.1919: An avalanche from Engidalur valley to the west of Siglufjörður hit the farm Engidalur, killing seven persons. This avalanche was most likely released from the east side of the valley and made a remarkable, more than 90° turn, before hitting the farm. Avalanches in Héðinsfjörður, east of Siglufjörður, killed two additional persons at the farms Ámá and Vík in this same avalanche cycle, bringing the total death toll in this avalanche cycle to eighteen persons.

Ytra-Strengsgil/Jörundarskál, Siglufjörður, 1900–1960: At least five snow avalanches reached the currently settled area in the southern part of the town of Siglufjörður, the longest ones in 1919, 1936–1938 and 1938/1939, some of which terminated in the sea. More recently, avalanches hit houses below Ytra-Strengsgil and Jörundarskál in 1968, 1973, 1974 and 1994.

Hafnarhryna/Fífladalir/Fífladalagil, Siglufjörður, 1938, 1971 and 1988: Avalanches have reached the uppermost houses, fences or roads in the main part of Siglufjörður town on several occasions, causing some damage but no fatalities. This part of the town was faced with the largest potential for a catastrophic accident before the construction of protection measures in recent years.

Gróuskarðshnjúkur, 26.12.1963: An avalanche was released from the area where supporting structures have been installed in the mountain above the northern part of the town of Siglufjörður. It reached far into the settlement and caused substantial damage.

Héðinsfjörður

Vatnsendi, Héðinsfjörður, 9.5.1725: An avalanche destroyed the farm Vatnsendi and killed six people. The farm was relocated 100 metres to the north after the avalanche to a more sheltered location below a large bowl in the mountainside, Vatnsendaskál. An avalanche shortly before 1900 came very close to the relocated farm and may have damaged it a little. The farm was relocated a second time in 1936, ca. 100 metres farther to the north, to an apparently safer location directly below the bowl. The currently uninhabited Héðinsfjörður valley had up to nine farms in former times, almost all heavily threatened by snow avalanches.

Vatnsendi, Héðinsfjörður, 17.1.2004: An avalanche from Vatnsendaskál, the bowl high in the mountainside east of Héðinsfjörður, destroyed a summerhouse at the old Vatnsendi farmstead from 1936 and carried the ruins of the house far onto the ice-covered lake. The story of the farm at Vatnsendi is a remarkable testimony to the struggle of people in Héðinsfjörður and Siglufjörður with natural hazards through the ages. The 2004 Vatnsendaskál snow avalanche is one of the most remarkable long-run-out avalanches in Iceland, reaching a run-out angle of $\alpha = 16.5\text{--}17^\circ$ at the edge of the bowl at 220 m a.s.l.

Ólafsfjörður

Skeggjabrekkudalur, 28.3.1953, 5.12.1992: The valley Skeggjabrekkudalur on the west side of Ólafsfjörður is severely threatened by snow avalanches. The pipes of the municipal heating facility for the town of Ólafsfjörður have repeatedly been damaged by snow avalanches from the north side of the valley, in some cases transporting pieces of hot-water pipes hundreds of metres up the opposing valley side. A photograph of a wet-snow avalanche in Skeggjabrekkudalur is shown on the previous page.

Tindaöxl, Ólafsfjörður, 28.8.1988: Two debris flows were released from Tindaöxl above the town of Ólafsfjörður and caused widespread damage in the town. Large areas within the town were covered with debris.

Bakki, Ólafsfjörður, 13.1.2004: An avalanche from a hanging valley on the north side of Ólafsfjörður killed the farmer at Bakki, the innermost farm in Ólafsfjörður valley. Avalanches in the rural part of Ólafsfjörður district have killed at least eight persons in recent centuries.

Svarfaðardalur

The outer west side of Svarfaðardalur valley, 21.4.1919: A widespread slushflow cycle resulted in damaged farm buildings and killed livestock at several farms but people escaped. At least eighteen large slushflows are reported in this cycle and many more small and medium-sized.

Auðnir, Svarfaðardalur, 3.4.1953: The farm Auðnir was destroyed by a snow avalanche and two persons were killed. Two other people on the farm were miraculously saved. These are the only reported fatal accidents involving people in their homes in Svarfaðardalur but there are several cases where people narrowly escaped when avalanches hit farms. A total of ten fatal accidents involving people travelling, hunting or gathering sheep in Svarfaðardalur are reported, the last time two accidents in 1955. Extensive geomorphological evidence of high activity of large avalanches is found in many of the uninhabited tributary valleys of Svarfaðardalur.

Hazard zoning and protection measures for Siglufjörður

A large part of the town of Siglufjörður is within hazard zones according to the hazard zoning from 2002. Both the southern part of the town, below Ytra-Strengsgil/Jörundarskál, and the central part of the town, below Fífladalir and Gimbraklettur, are potentially endangered by catastrophic avalanches with run-out far into the settlement. Protection measures for Siglufjörður were highly prioritized in the planning of protection measures in Iceland after 1995 and the planned protection measures for Siglufjörður have largely been implemented. The hazard zoning, a map of recorded avalanches and information about the protection measures are shown on the following pages.

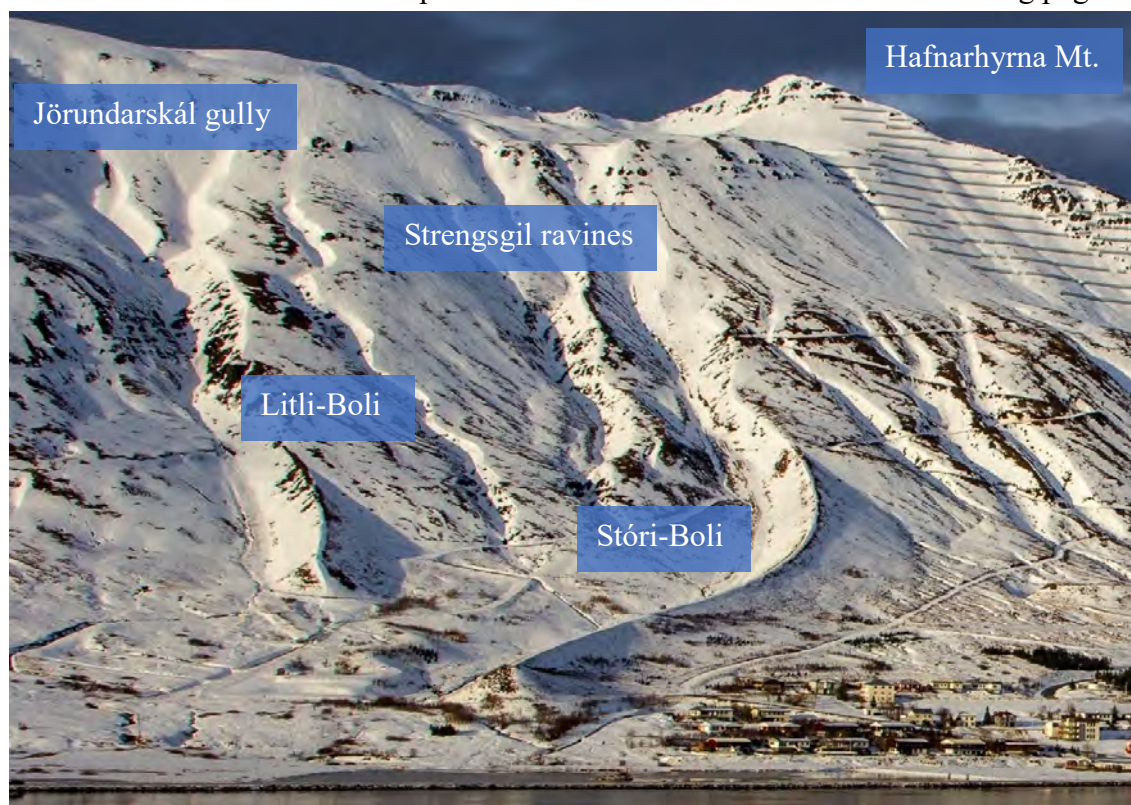


Figure 2: The deflecting dams Litli-Boli (left) and Stóri-Boli (right) mitigate the avalanche danger from the Jörundarskál gully and the Strengsgil ravines. Photo: © Árni Jónsson, 2018.

Many avalanche experts and institutes have been involved in the planning and design of the avalanche protection measures for Siglufjörður. Josef Hopf, former head of the WLV in Tirol, made the first sketch of deflecting dams below Jörundarskál and Ytra-Strengsgil in 1996. He also designed the structures in a pilot study of supporting structures for Icelandic conditions that took place in Grindagil, near the top of the mountain above Siglufjörður, in 1996. A more detailed, technical appraisal of the deflecting dams was made in 1997 by the civil engineer Þorsteinn Jóhannesson, from Siglufjörður, in collaboration with NGI in Norway, and the geotechnical design and landscaping of the dams was carried out by Hnit hf. and Landslag hf. in 1997. Stefan Margreth from the SLF made an appraisal of catching dams and supporting structures as protection measures for the town of Siglufjörður, north of the Ytra-Strengsgil gully, in 2000. He and Þorsteinn Jóhannesson developed the protections measures further over the following years in a series of studies involving geotechnical design of the dams and the determination the detailed location of the rows of supporting structures. VSO and Verkís Ltd. have in recent years been responsible for the technical design of the dams and supporting structures. The supporting structures have been produced by the Austrian company Josef Martin GmbH and the Italian company Mair Wilfried GmbH and installed by Icelandic contractors. Several Austrian consultants have been involved in the installation of the structures.

Hazard zoning and protection measures for Ólafsfjörður

A substantial part of the town of Ólafsfjörður is within hazard zones according to the hazard zoning from 2005, but only one building is in hazard zone C. The frequency of snow avalanches from the hillside above the town appears low but loose materials on the hillside are the source of debris flows that have cause widespread damage in the upper part of the town. Although few snow avalanches are reported, the danger of snow avalanches cannot be ruled out. The community health clinic and old people's home at Hornbrekka, in the easternmost part of the town, is considered particularly threatened and has been protected by a 13 m high deflecting dam. The hazard zoning, a map of recorded avalanches and information about the protection measures are shown on the following pages.

The technical appraisal of the deflecting dam above the clinic and old people's home at Hornbrekka was carried out by civil engineer Þorsteinn Jóhannesson, from Siglufjörður, and the geotechnical design by Verkfræðistofa Austurlands, from Egilsstaðir, E-Iceland.

Hazard management on the road between Ólafsfjörður and Dalvík

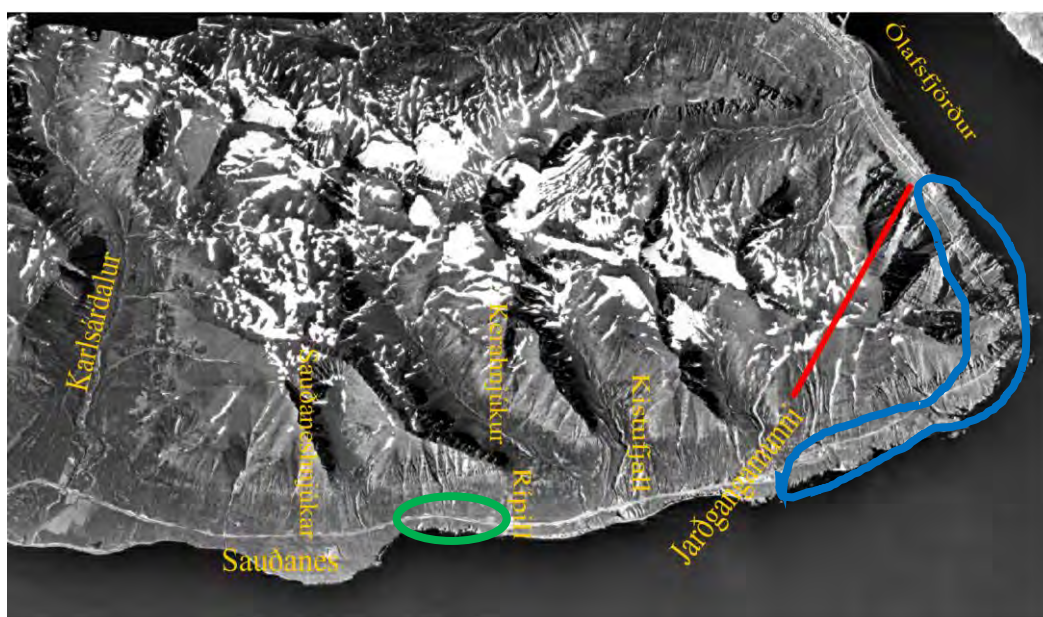


Figure 3. The mountain range between Sauðanes/Dalvík and Ólafsfjörður. The red line depicts the tunnel opened in 1991. The blue shape depicts the location of the old road used before the tunnel was opened. The green ellipse depicts the location of steel sheet piles. Aerial photo: LMI.

The road 82 from Dalvík to Ólafsfjörður (Figure 3) passes through several active avalanche paths, some of them running almost every year. The Icelandic Road and Coastal Administration (IRCA) started registration of avalanche activity in 1976 and until 2001, 2123 avalanches were registered. After the opening of the tunnel in 1991, a dramatic decrease is in the number of avalanches reaching the road can be clearly seen, Figure 4.

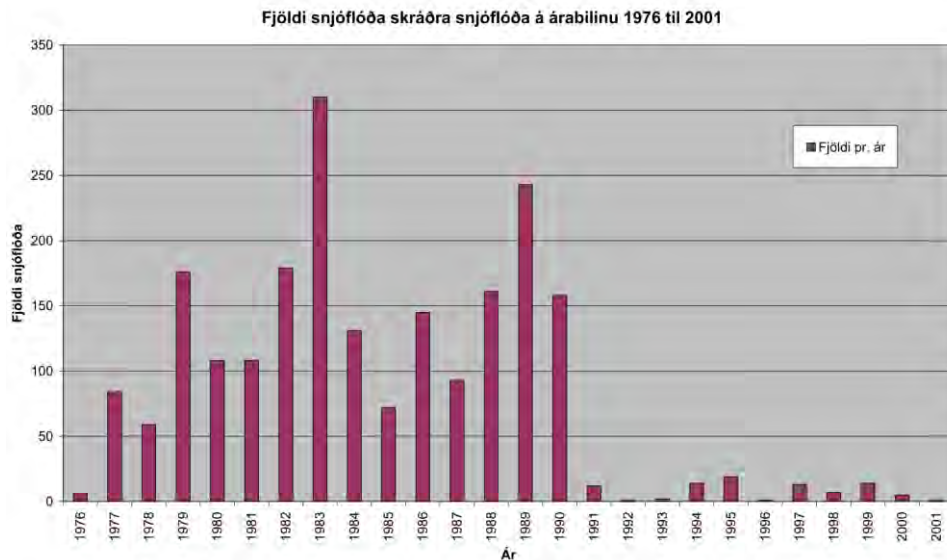


Figure 4. Number of registered avalanches from 1976 to 2001. A dramatic change in number of avalanches is seen when the Ólafsfjarðarmúli tunnel opened in 1991.

The tunnel eliminated some of the most severe avalanche paths but the green ellipse in Figure 3 shows an area where avalanches run almost every year in three main paths.

When IRCA considered improvement of road-users safety on the road between Dalvík and Ólafsfjörður, steel sheet piles were considered to be the best way to improve the safety against snow avalanches and rock fall at that time.

Little is known about the forces that avalanches or rock falls exert on cantilever steel sheet piles and how the latter react to these loads. For this reason, the Icelandic Road and Coastal Administration (IRCA) and the Norwegian Geotechnical Institute (NGI) decided to instrument one such wall in north Iceland in 2014 (Figure 5).

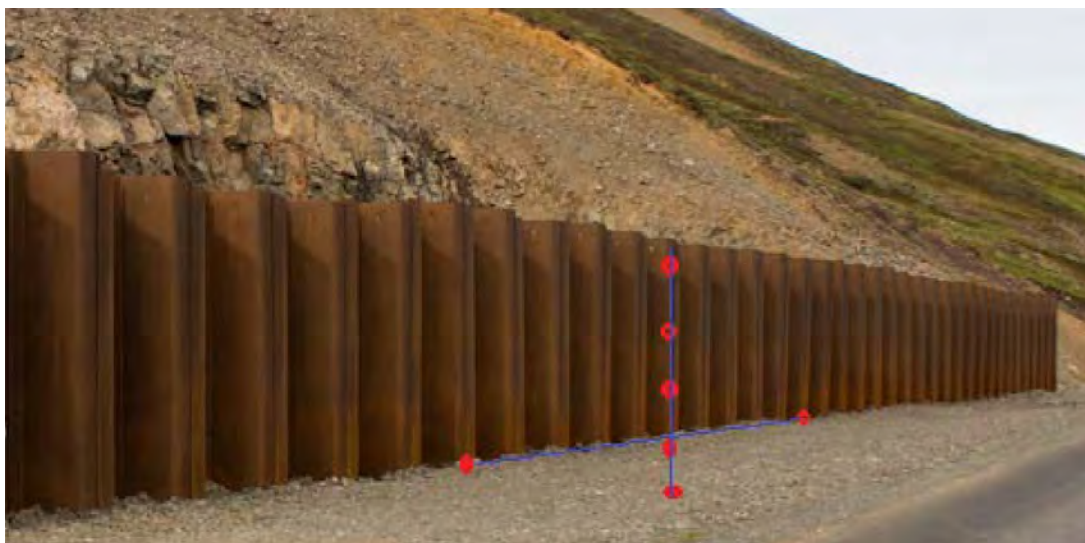


Figure 5. Red dots indicate the location of the strain gauges. The four dots seen on the ground indicate strain gauges below the ground. Photo: © Árni Jónsson

There have been many obstacles on the way in this research project such as power supply problems, false signals (triggering of the gauges) due to thermal expansion and data transmission errors but some results will be described during the excursion.

Accompanying maps and documents

1. Photographs from the installation of supporting structures in Siglufjörður.
2. Hazard map for Siglufjörður, attested by the Minister for the Environment on 22 March 2002.
3. Except from an information sign from Siglufjörður: Recorded avalanches, hazard zoning and overview of protection measures.
4. Except from an information sign from Siglufjörður: Overview map of dams and supporting structures, summary technical information about the protection measures.
5. Supporting structures in Hafnarhryna and Gróuskarðshnjúkur above the town of Siglufjörður.
6. Hazard map for Ólafsfjörður, attested by the Minister for the Environment on 13 May 2005.
7. Except from an information sign from Ólafsfjörður: recorded avalanches and landslides, deflecting dam at Hornbrekka.
8. Except from an information sign from Ólafsfjörður: Overview map of town and its surroundings with skiing and hiking trails near the deflecting dam at Hornbrekka.
9. A map of registered snow avalanche outlines in Skútudalur and Héðinsfjörður.
10. A map of registered snow avalanche outlines in Svarfaðardalur.

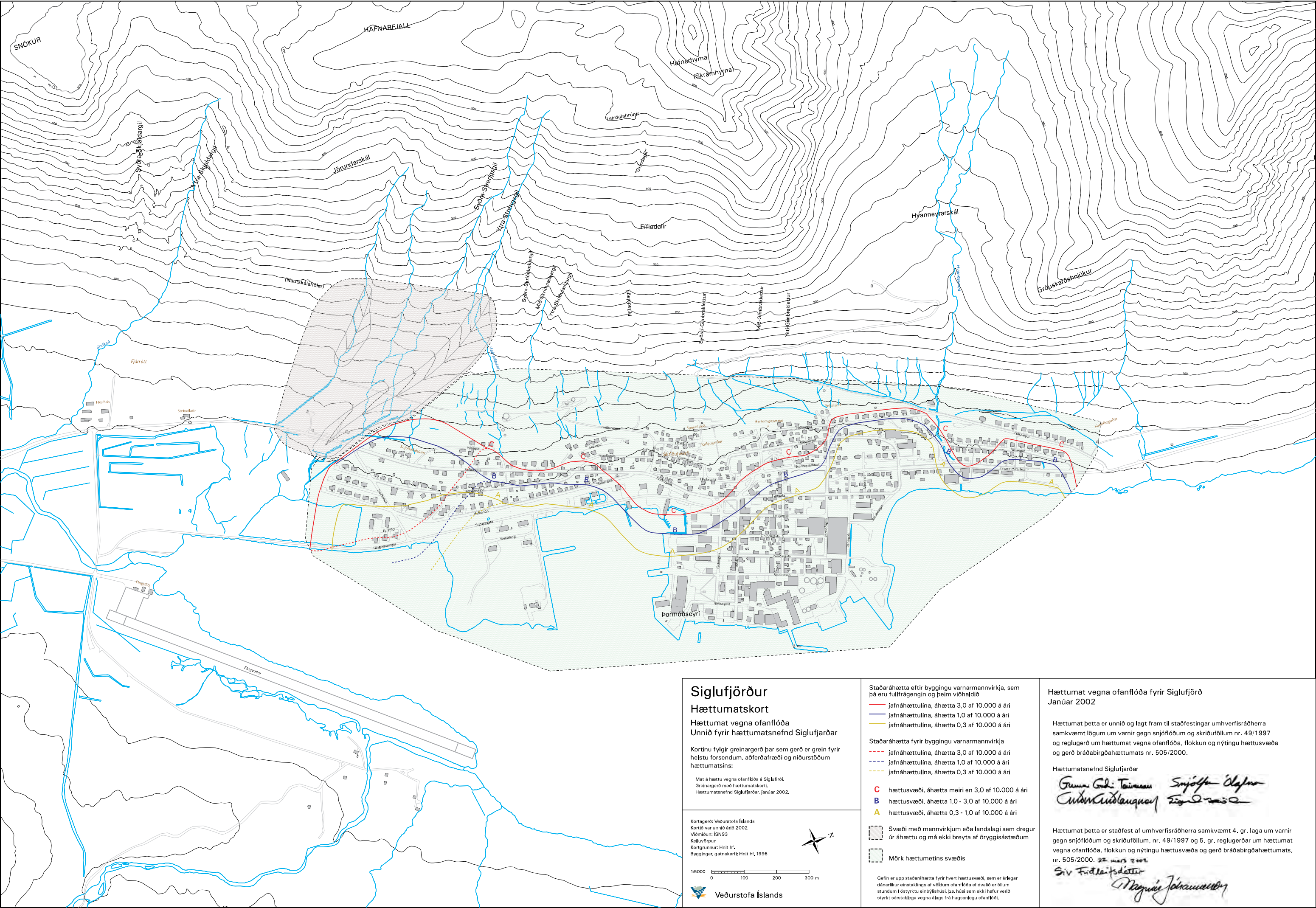


Digging through an avalanche on the road at Miðströnd north of Siglufjörður on 21 January 2012.
Photo: siglo.is.









Siglufjörður
Hættumatskort
Hættumat vegna ofanflóða
Unnið fyrir hættumatsnefnd Siglufjarðar

Kortinu fylgir greinargerð þar sem gerð er grein fyrir helstu forsendum, aðferðafræði og niðurstöðum hættumatsins:

Mat á hættu vegna ofanflóða á Siglufirði.
Greinargerð með hættumatskorti.
Hættumatsnefnd Siglufjarðar, janúar 2002.

Kortagerð: Veðurstofa Íslands
Kortið var unnið árið 2002
Viðmiðun: ISN93
Kelluvörpun
Kortgrunnur: Hnit hf.
Byggingar, gatnaakerfi: Hnit hf, 1996

1:5000
0 100 200 300 m
Veðurstofa Íslands

Staðaráhætta eftir byggingu varnarmannvirkja, sem þá eru fullfrágengin og þeim viðhaldið
— jafnáhættulína, áhætta 3,0 af 10.000 á ári
— jafnáhættulína, áhætta 1,0 af 10.000 á ári
— jafnáhættulína, áhætta 0,3 af 10.000 á ári

Staðaráhætta fyrir byggingu varnarmannvirkja
--- jafnáhættulína, áhætta 3,0 af 10.000 á ári
--- jafnáhættulína, áhætta 1,0 af 10.000 á ári
--- jafnáhættulína, áhætta 0,3 af 10.000 á ári

C hættusvæði, áhætta meiri en 3,0 af 10.000 á ári
B hættusvæði, áhætta 1,0 - 3,0 af 10.000 á ári
A hættusvæði, áhætta 0,3 - 1,0 af 10.000 á ári

□ Svæði með mannvirkjum eða landslagi sem dregur úr áhættu og má ekki breyta af öryggisástæðum

□ Mörk hættumetins svæðis

Gefin er upp staðaráhætta fyrir hvert hættusvæði, sem er árlegar dánarlíkur einstaklings af völdum ofanflóða ef dvalir er öllum stundum í östryktu einbýlishúsi, þ.e. húsi sem ekki hefur verið styrkt sérstaklega vegna álags frá hugsanlegu ofanflóði.

Hættumat vegna ofanflóða fyrir Siglufjörð
Janúar 2002

Hættumat þetta er unnið og lagt fram til staðfestingar umhverfisráðherra samkvæmt lögum um varnir gegn snjóflóðum og skriðuföllum nr. 49/1997 og reglugerð um hættumat vegna ofanflóða, flokkun og nýtingu hættusvæða og gerð bráðabirgðahættumats nr. 505/2000.

Hættumatsnefnd Siglufjarðar
Guðni G. Tómasson *Sigríður Ólafsson*
Cúthinn Cúthinnsson *Sigríður*

Hættumat þetta er staðfest af umhverfisráðherra samkvæmt 4. gr. laga um varnir gegn snjóflóðum og skriðuföllum, nr. 49/1997 og 5. gr. reglugerðar um hættumat vegna ofanflóða, flokkun og nýtingu hættusvæða og gerð bráðabirgðahættumats, nr. 505/2000. 22. mars 2002.
Siv Fridelefsdóttir *Magnús Jónsson*

SNJÓFLÓÐAVARNARNIR VIÐ SIGLUFJÖRÐ

AVALANCHE DEFENSE AT SIGLUFJÖRÐUR

Stefna stjórnvalda og markmið

Á 20. öldinni létust 193 manns í snjóflóðum og skriðuföllum á Íslandi, þar af 166 í snjóflóðum. Flest þessara flóða féllu í sjávarbyggðum sem hafa byggst upp í þröngum fjörðum við brattar fjallshlíðar.

Í kjölfar mannskæðra snjóflóða sem féllu á Suðavík og Flateyri 1995 og urðu 34 manns að bana, mörkuðu stjórnvöld stefnu um skipulegt áhættumat á hættusvæðum viðsvegar um landið og í kjölfarið markvissa uppbyggingu snjóflóðavarna.

Samkvæmt nýju hættumati er snjóflóðahætta í nálega allri byggðinni norðan við Stóra-Bola á Siglufirði.

Markmiðið með byggingu varnarmannvirkjanna er að tryggja svo sem kostur er öryggi fólks gagnvart snjóflóðum sem og öðrum ofanflóðum.

Varnarmannvirkin á Siglufirði eru í aðalatriðum þrenns konar

1. Leiðgarðar sem hannaðir eru til þess að beina snjóflóðum framhjá byggð með því að breyta stefnu snjóflóðanna fremur en að stöðva þau.

2. Þvergarðar sem eru hannaðir til þess að stöðva flóð þar sem ekki er mögulegt að beina flóðunum framhjá byggðinni.

3. Uptakastoðvirki: Stálgrindur er kornið fyrir á upptakasvæðum snjóflóða til þess að koma í veg fyrir að snjóflóð fari af stað.

Framkvæmdasaga

Bygging leiðgarðanna tveggja Stóra-Bola og Litla-Bola, sunnan byggðarinnar, hófst í júní 1998 og markaði upphaf fyrsta hluta framkvæmdanna sem lauk september 1999.

Mannvirkin sönnuðu gildi sitt veturinn 1998-1999 þegar allstórt snjóflóð féll óvænt á Strengsgilsgarð ófullgerðan. Síðan hafa nokkur snjóflóð fallið á garðinn sem hefur reynst öðrum vörn.

Hönnun 1. hluta framkvæmdarinnar hlaut sérstaka viðurkenningu við veitingu evrópsku Rosa Barba verðlaunanna í landslagshönnun árið 2003.

Í seinni hluta framkvæmdarinnar, sem hófst 2003 og lauk árið 2008, voru byggðir fimm þvergarðar og einn leiðgarður í snarbratti fjallshlíðinni ofan við bæinn. Uptakastoðvirki voru sett upp í Gróuskarðshnjúki árið 2003.

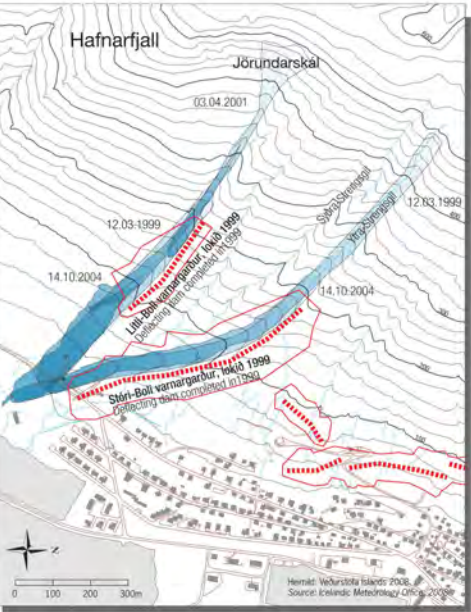
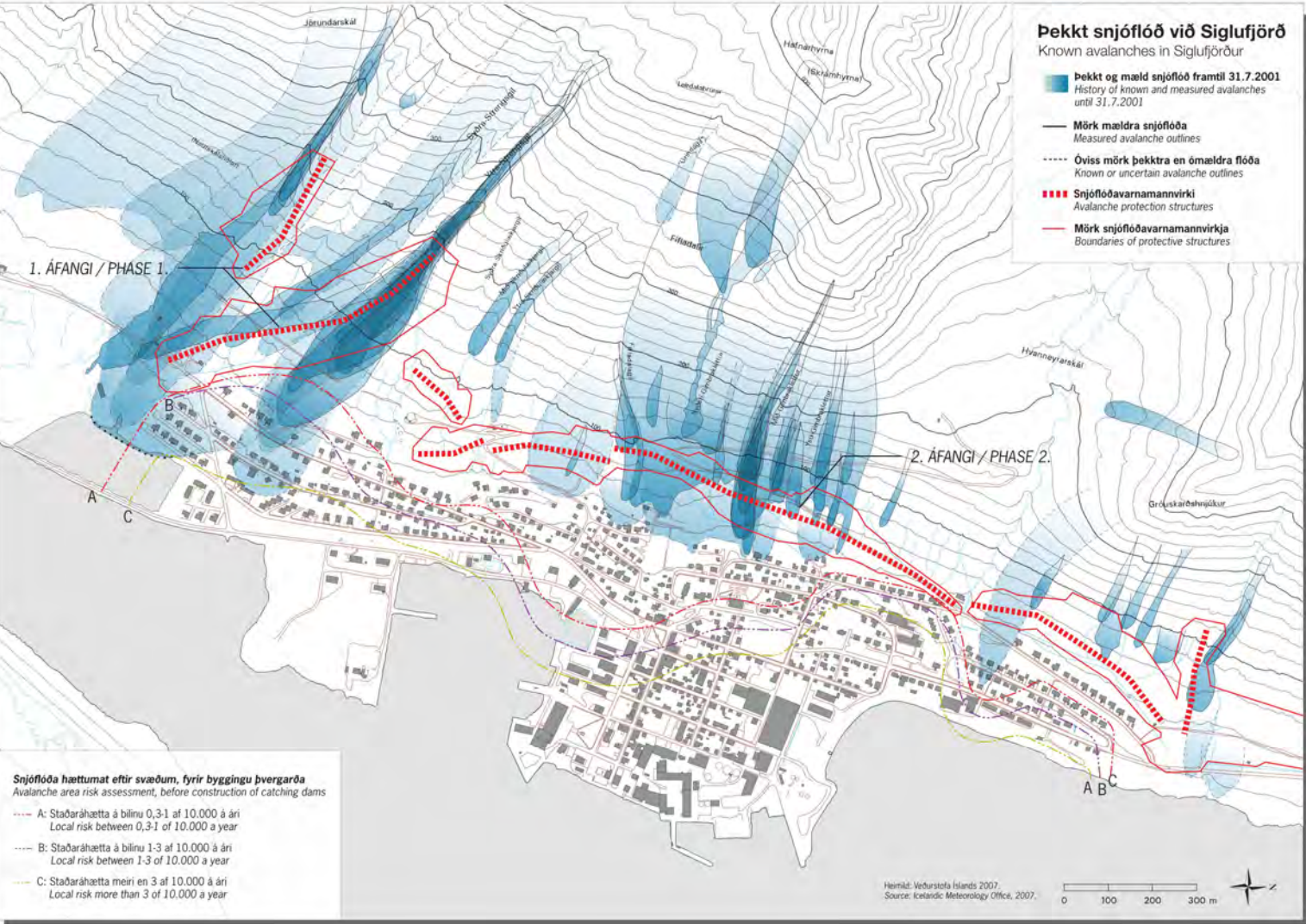
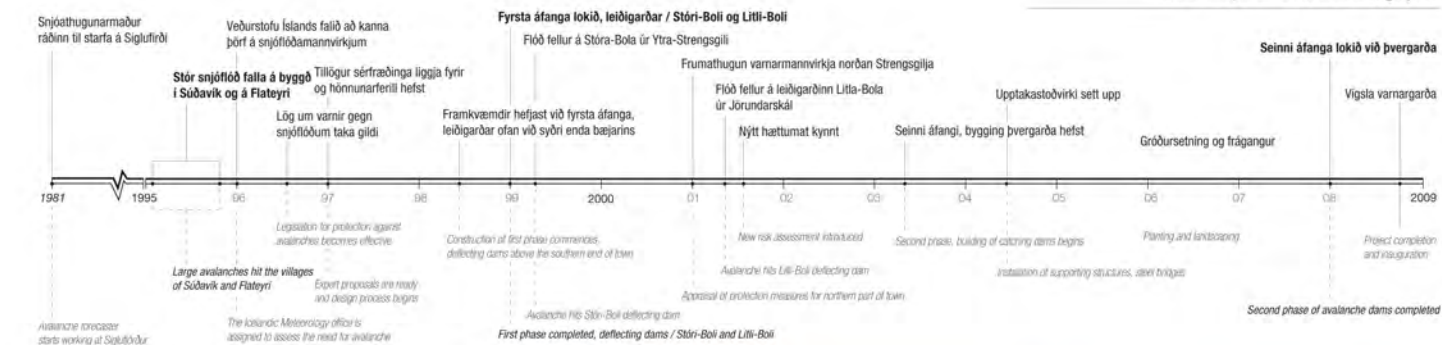
Útivistarsvæði í skjóli snjóflóðavarna

Snjóflóðavarnirnar í baksviði Siglufjarðar eru hluti af bæjarlandslaginu. Um garðana og umhverfis þá liggja fjölbreyttar gönguleiðir. Ofan af gördunum er gott útsýni yfir bæinn og yfir lægðirnar að baki garðanna.

Skipulagsverkefni af þessu tagi verða ekki leyst út frá tæknilegum sjónarmiðum eingöngu. Með mótun garðanna, uppgræðslu, trjárækt og gerð útivistarsvæða í skjóli þeirra, eru umhverfinu gefin ný gildi sem mótvægi við breytta ásjúnd.

Tímaás snjóflóðavarna við Siglufjörð

Avalanche protection timeline for Siglufjörður



Snjóflóð sem féllu á leiðgarðana 1999-2004
Avalanches diverted by the deflecting dams: 1999-2004

Enn falla snjóflóð úr Hafnarfjalli
Kortið hér að ofan sýnir snjóflóð sem fallið hafa á leiðgarðana Stóra-Bola og Litla-Bola eftir að þeir voru byggðir.

Eitt af þessum flóðum eyðilagði þjónustuhús fyrir tjaldstæði, sem var á hættusvæði sunnan flóðrásarinnar. Snjóflóðin röskuðu hinsvegar ekki ró íbúanna sem voru öðruvísi í skjóli garðanna.

Avalanches still fall fram Hafnarfjalli
The map above shows avalanches that have fallen on the deflecting dams Stóri-Boli and Litli-Boli after they were built.

One of these avalanches destroyed a service building for a campsite south of the Stóri-Boli dam. When the avalanches fell, the inhabitants of the south part of the village remained undisturbed, protected by the dams.



Brattir stallar þvergarða í byggingu.
Steep catching dams under construction. (MYND Þ.J.)



Uptakastoðvirkin minnka líkur á að snjóflóð fari af stað.
Steel bridges reduce the risk that avalanches are released. (MYND Þ.J.)



Leiðgarðurinn Stóri-Boli er vel felldur að landslaginu.
Stóri-Boli deflecting dam is designed to merge with the surrounding landscape. (MYND S.K.)



Þvergarðunum er ætlað að stöðva snjóflóð ofan byggðar.
Catching dams are intended to stop avalanches above the village. (MYND S.S.)



Leiðgarðarnir beina snjóflóðum frá byggð.
Deflecting dams direct avalanches away from the village. (MYND S.K.)



Varnargarðarnir verða hluti af grænu umhverfi bæjarins.
The protective structures will become a green part of the village. (MYND S.K.)

Ljósmyndir / Photos:
S.K. Steingrímur Kristjánsson
S.S. Steinn Sigmarsson
Þ.J. Þorsteinn Jóhannesson

UPPLÝSINGAR UM VERKID

VERKKAUPI

Fjallabyggð

FJÁRMÖGNUN

Ótanflóðasjóður 90%, Fjallabyggð 10%.
Áætlaður heildarkostnaður 1,5 milljarður króna.

VERKAFANGAR OG TÍMI

1. verkhluti (1998-1999)	2 leiðigardar (Stóri- og Lilli-Boli).
2. verkhluti (2003-2008)	5 þvergarðar og 1 leiðigardur.
3. verkhluti (2003)	Uptakastöðvirkir í Gróuskarðshnjúkur.

HÖNNUN, RÁÐGJÖF & SKIPULAG

Verkstjórnun: Framkvæmdasýsla ríkisins (1., 2. og 3. hluti)
Frummat 1. hluta: Norska jarðtæknistofan (NGI) og Verkræðistofa Siglufjarðar st; umsnagnaraðili: Veðurstofa Íslands.
Frummat 2. og 3. hluta: Swiss Federal Institute for Snow and Avalanche Research (SLF); umsnagnaraðili: Veðurstofa Íslands.
Umhverfismat: Línuhönnun hf. (1. og 2. hluti)
Verkhönnun: Verkræðistofa Siglufjarðar st., Landslag ehf. (1. og 2. hluti) og Swiss Federal Institute for Snow and Avalanche Research (3. hluti)
Verkræðileg hönnun: Hnit hf. (1. hluti), VSO Ráðgjöf ehf. (2. hluti), VST hf. (3. hluti) og Landslag ehf. Landslagsarkitektar (1. og 2. hluti)
Umhverfisskipulag og uppgræðsla: Landslag ehf. Landslagsarkitektar (1. og 2. hluti)
Framleiðandi stöðvirkja 3. hluta: J. Martin.

VERKTAKAR OG EFTIRLIT

Verktakar í gördum: Héraðsverk ehf. (1. hluti) Suðurverk hf. (2. hluti)
Verktakar í uppgræðslu: Bás ehf. (1. og 2. hluti)
Verktakar í upptakastöðvirkjum: (AV hf. (3. hluti)
Verkeftirlit: Línuhönnun hf. (1. og 2. hluti) og Verkræðistofa Siglufjarðar st. (3. hluti)

HEILDARSTÆRDIR

Massi í gördunum: 950.000 rúmmetrar
Lengd varnargarðanna: um 3000 m
Hæð helstu varnargarða: 15-18 m
Stöðvirkir: 620 m, hæð Dk=3.5 m
Göngustigar á varnarsvæðinu: 9 km
Uppgræðslusvæði: 90 ha
Trjáplöntur: 106.000 skógarplöntur

General information and key figures

CLIENT

Fjallabyggð Municipality.

FINANCING

The Icelandic Avalanche and Landslide fund 90%, Fjallabyggð Municipality 10%.
Estimated total cost 1,5 milliard ISK.

MILESTONES

Phase 1 (1998-1999)	2 deflecting dams (Stóri- and Lilli-Boli).
Phase 2 (2003-2008)	5 catching dams and 1 deflecting dam.
Phase 3 (2003)	supporting structures in Gróuskarðshnjúkur.

DESIGN, CONSULTING & PLANNING

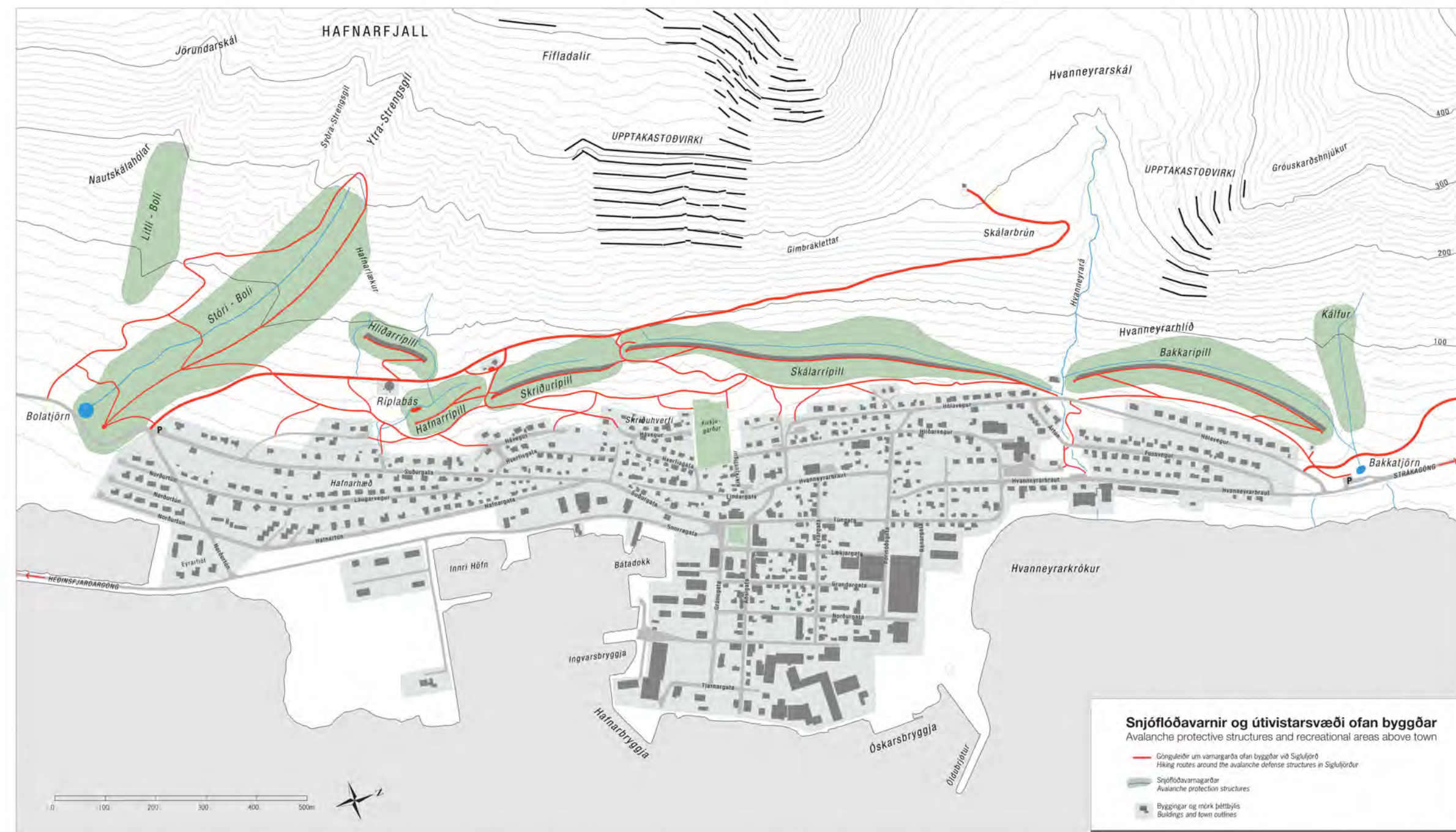
Project management: Government Construction Contracting Agency (phase 1, 2 and 3)
Appraisal (phase 1): Norwegian Geotechnical Institute (NGI) and Verkræðistofa Siglufjarðar st; review: Icelandic Meteorological Office.
Appraisal (phase 2 and 3): Swiss Federal Institute for Snow and Avalanche Research (SLF); review: Icelandic Meteorological Office.
Environmental Impact Assessment: Línuhönnun hf. (phase 1 and 2).
Predesign: Verkræðistofa Siglufjarðar st., Landslag ehf. (phase 1 and 2) and Swiss Federal Institute for Snow and Avalanche Research (phase 3).
Technical design: Hnit hf. (phase 1), VSO Ráðgjöf ehf. (phase 2), VST hf. (phase 3), and Landslag ehf. Landscape Architects (phase 1 and 2).
Landscape planning: Landslag ehf. Landscape Architects (phase 1 and 2).
Manufacturer of supporting structures (phase 3): J. Martin.

CONTRACTORS & SUPERVISION

Dam construction: Héraðsverk ehf. (phase 1); Suðurverk hf. (phase 2).
Planting and re-vegetation: Bás ehf. (phase 1 and 2).
Installation of supporting structures: (AV hf. (phase 3).
Supervision: Línuhönnun hf. (phase 1 and 2) and Verkræðistofa Siglufjarðar st. (phase 3).

KEY FIGURES

Volume of dams:	950.000 m ³
Total length of dams:	ca. 3000 m
Height of main dams:	15-18 m
Footpaths in the dam area:	9 km
Planting and re-vegetation area:	90 ha
Trees:	106.000 tree plants
Supporting structures:	620 m, height Dk=3.5 m



Government policy

During the twentieth century, snow avalanches and landslides in Iceland caused 193 fatalities. Snow avalanches are responsible for 166 deaths, mostly in coastal villages situated below steep hillsides in narrow fjords.

In 1995, catastrophic avalanches in the villages of Súðavík and Flateyri claimed 34 lives and caused extensive economic losses. Consequently, the Icelandic government undertook a comprehensive assessment of avalanche risk. Additionally, protective measures were commissioned in potentially hazardous areas, and endangered property was purchased, in order to improve the safety of people and reduce losses caused by future avalanches.

Hazard-zoning for Siglufjörður shows that almost all the settlement north of the Stóri-Boli deflecting dam is susceptible to snow avalanches.

The protective measures are in place to ensure the public's safety from snow avalanches and landslides, as far as possible.

In Siglufjörður, three types of protective measures are in use:

1. Deflecting dams are designed to divert snow avalanches away from settlements at risk by changing the flow direction of the avalanche.
2. Catching dams are designed to stop snow avalanches in case there is not enough space to deflect them away from the settlement.
3. Supporting structures are steel constructions built in the starting zones of avalanches. They are intended to stabilise the snow cover, thus preventing avalanches from occurring.

Construction

The first phase of the project was the construction of the deflecting dams, Stóri-Boli and Lilli-Boli, above the southern part of the settlement. This work began in June 1998 and the dams were finished in September 1999.

During the winter of 1998-1999, the dams proved their effectiveness when a medium-sized snow avalanche hit the partly completed dam under Strengsgil. Since then, at least two snow avalanches have been deflected on impact with the dam.

In 2003, the design of the dams received the Rosa Barba special award in landscape architecture.

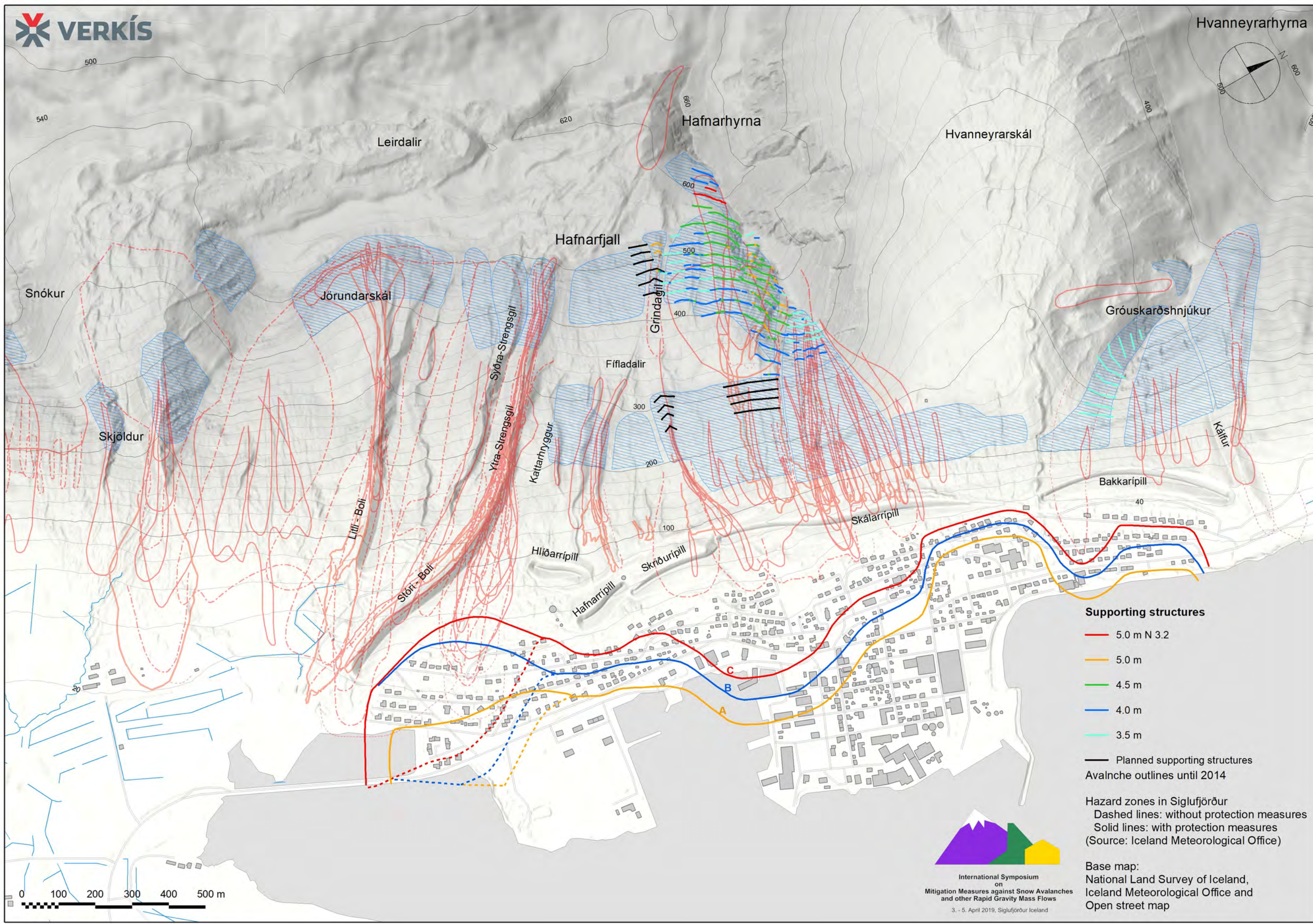
In the second phase of the project, which started in 2003 and was completed in 2008, five catching dams and a deflecting dam were constructed in the steep mountainside above the settlements.

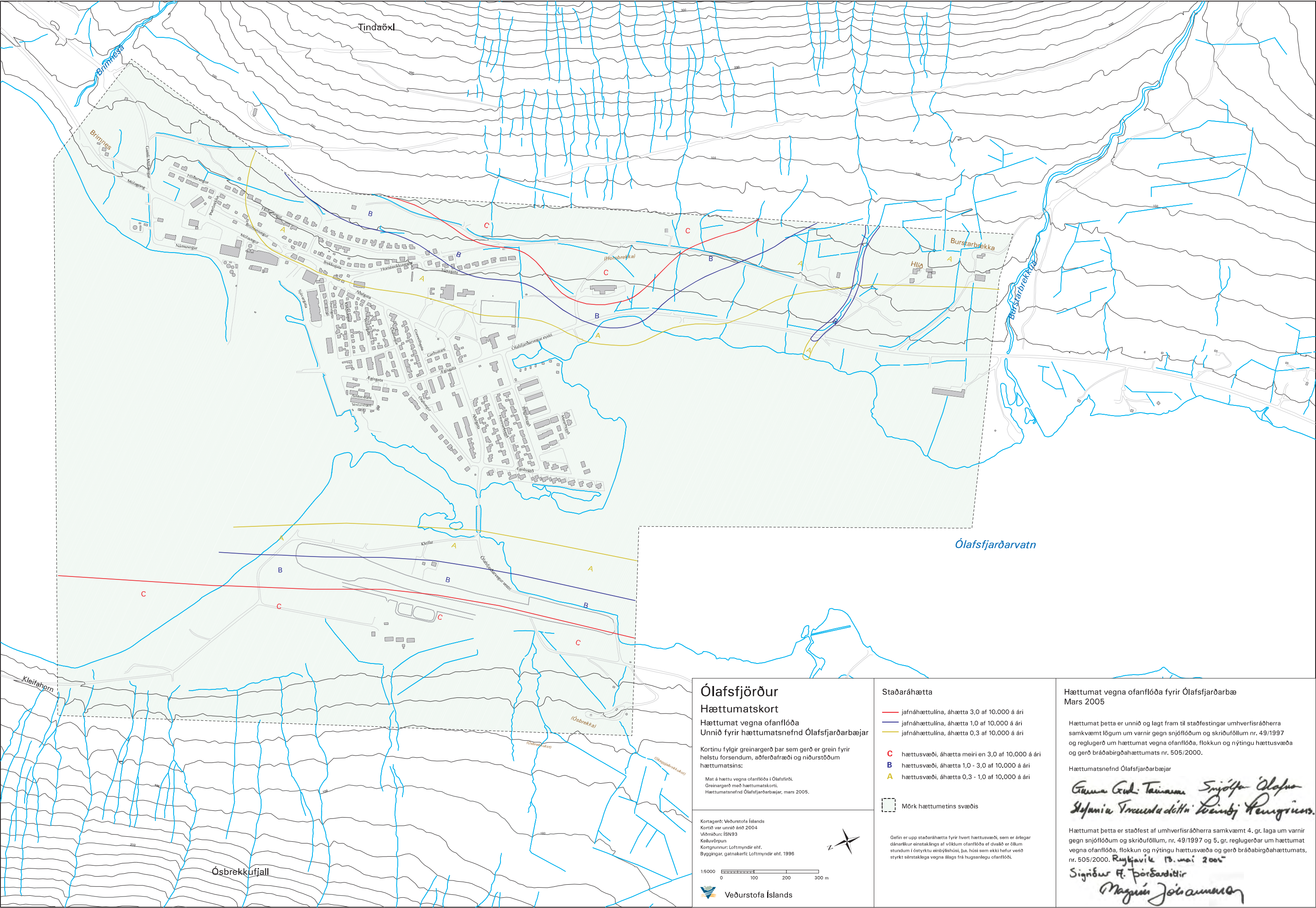
In the third phase of the project, in 2003, supporting structures were installed in Gróuskarðshnjúkur.

An outdoor recreation area as a part of the protective measures

The protective measures are highly visible in the background of the settlement in Siglufjörður, and they are part of the landscape of the town. Foot paths have been made on the dams and several walking paths cover the surrounding area. Good views of the settlement and the surrounding area can be seen from the top of the dams.

Design and planning projects of this type cannot be solved only from a technical viewpoint. By forming the dams in harmony with the surrounding terrain, and through re-vegetation, planting of trees and construction of recreation areas near the dams, the environment has been given a new role that compensates for otherwise disruptive changes of the mountainside.





Ólafsfjörður Hættumatskort Hættumat vegna ofanflóða Unnið fyrir hættumatsnefnd Ólafsfjarðarbæjar

Kortinu fylgir greinargerð þar sem gerð er grein fyrir helstu forsendum, aðferðafræði og niðurstöðum hættumatsins:

Mat á hættu vegna ofanflóða í Ólafsfirði.
Greinargerð með hættumatskort.
Hættumatsnefnd Ólafsfjarðarbæjar, mars 2005.

Kortagerð: Væðurstofa Íslands
Kortið var unnið árið 2004
Viðmiðun: ÍSN93
Kortgrunnur: Loftmyndir ehf.
Byggingar, gatnakerfi: Loftmyndir ehf. 1996

1:5000
0 100 200 300 m
Væðurstofa Íslands

- Staðaráhætta**
- jafnáhættulína, áhætta 3,0 af 10.000 á ári
 - jafnáhættulína, áhætta 1,0 af 10.000 á ári
 - jafnáhættulína, áhætta 0,3 af 10.000 á ári
- C** hættusvæði, áhætta meiri en 3,0 af 10.000 á ári
B hættusvæði, áhætta 1,0 - 3,0 af 10.000 á ári
A hættusvæði, áhætta 0,3 - 1,0 af 10.000 á ári

□ Mörk hættumetins svæðis

Gefin er upp staðaráhætta fyrir hvert hættusvæði, sem er árlegar dárarlikur einstaklings af völdum ofanflóða af dvalið er öllum stundum í östryktu einbýlshúsi, þ.a. húsi sem ekki hefur verið styrkt sérstaklega vegna álags frá hugsanlegu ofanflóði.

Hættumat vegna ofanflóða fyrir Ólafsfjarðarbæ Mars 2005

Hættumat þetta er unnið og lagt fram til staðfestingar umhverfisráðherra samkvæmt lögum um varnir gegn snjóflóðum og skriðuföllum nr. 49/1997 og reglugerð um hættumat vegna ofanflóða, flokkun og nýtingu hættusvæða og gerð bráðabirgðahættumats nr. 505/2000.

Hættumatsnefnd Ólafsfjarðarbæjar

Guðna Guð. Tainarinn Snjólfur Ólafsson
Stephanie Tainarinn dóttir Sveinbj. Þengils.

Hættumat þetta er staðfest af umhverfisráðherra samkvæmt 4. gr. laga um varnir gegn snjóflóðum og skriðuföllum, nr. 49/1997 og 5. gr. reglugerðar um hættumat vegna ofanflóða, flokkun og nýtingu hættusvæða og gerð bráðabirgðahættumats, nr. 505/2000. Reykjavík 13. maí 2005

Sigríður H. Þórðardóttir
Magnús Jóhannsson

ÓLAFSFJÖRÐUR - SNJÓFLÓÐAVARNIR

STEFNA STJÓRNVALDA OG MARKMIÐ

Í kjölfar mannskæðra snjóflóða sem féllu á Súðavík og Flateyri 1995 og urðu 34 manns að bana, mörkuðu stjórnvöld stefnu um skipulagt áhættumat á hættusvæðum vísvegar um landið og í kjölfarið markvissa uppbyggingu snjóflóðavarna.

Markmið með byggingu varnarmannvirkja er að tryggja svo sem kostur er öryggi fólks gagnvart snjóflóðum sem og öðrum ofanflóðum.

Samkvæmt hættumati fyrir Ólafstjórð sem staðfest var af umhverfisráðherra 13. maí 2005 er Hornbrekka, dvalarheimili aldraðra og heilsuæðislistóð á hættusvæði C. Leiðararfi fyrir ofan og sunnan heimilið er ætlað að verja það fyrir ofanflóðum.

Bygging leiðigarðsins hófst sumarið 2009 og lauk haustið 2010. Á árunum 2010 og 2011 var unnið við uppgræðslu, sáningu og frágang umhverfis.

Bygging leiðisröns tryggir áramhaldandi rekstur stofnunarinnar og gefur möguleika á frekari uppbyggingu á löðinni. Með mótun snjálldávarna, uppgræðsu, trjáætti og sligæðu er umhverfinu gefin ný gildi sem málævi við breytt útsýni og ástand. Göngustígar og skíðagönguleiðir eru óhindraðar um fjallið og greið gönguleið er upp í fjallið um leiðisröndin en af garðinum er ótt útsýni yfir Ólafstöð.

Við gerð mannvirkisins var notast við umframefni úr Héðinsjarðagöngum auk tilfallandi jarðvegs vegna landmótunar við Hornbrekku.

GOVERNMENT POLICY AND GOALS

Almost 200 people have been killed in snow avalanches and landslides in Iceland since 1900. Many of these avalanches and landslides have fallen on coastal villages that are located below steep slopes in narrow fiords.

After 34 people were killed by snow avalanches that hit the villages Súðavík and Flateyri in the Vestfjords in NW Iceland in 1995 the Icelandic government decided to make a systematic risk assessment for settled areas in the country and a plan was drawn up to construct avalanche protection measures for endangered areas.

The purpose of protection measures against snow avalanches and landslides is to ensure as far as possible the safety of people in endangered areas.

According to the hazard assessment for Ólafstjórður, which was officially signed by the Minister for the Environment on 13 May 2005, the health clinic and elderly people's home at Hornbrekka are located in a type-C hazard zone, implying that protection measures for the area are required. A deflection dam located above and south of the area is intended to divert snow avalanches and landslides away from the building.

The construction of the deflecting dam was started in the summer of 2009 and the dam was completed in the fall of 2010. Landscaping and revegetation took place in 2010 and 2011.

The construction of the deflecting dam ensures the continued operation of the health clinic and the elderly people's home at Hornbreikka and makes further development of the area possible. Landscaping, revegetation, planning of trees and construction of walking paths have been utilized to compensate for the environmental impact of the dam. There is good access from the area to the mountain through walking and skiing paths and a walking path along the dam crown provides a good trail to the mountain with an excellent view over the fjord. Construction material for the dam fill was excavated from the Hólmisfjörður road tunnel and soil from the dam site was used for the landscaping.

VERKKAUPI / Client:

Fjallabyggð

FJÁRMÖGNUN / Financing:

Ofanflóðasiðður 90%/The Icelandic Avalanche and Landslide Fund 90%, Fjallabyggð 10%

HÖNNUN, RÁÐGJÖF & SKIPULAG / Design and consulting:

HÆTTUMAT / Hazard zoning:

Veðurstofa Íslands / The Icelandic Meteorological Office

VERKSTJÓRNUN / Project management:

Framkvæmdasýsla ríkisins / Government Construction Contracting Agency

FRUMATHUGUN / Appraisal of protection options:

Verkfæðistola Siglufjarðar st.

Teikn á lofti eht.

VERKFRÆÐILEG HÖNNUN / Technical design:

Verkfæðistofa Austurlands ehf

UMHVERFISSKIPULAG OG UPPGRÆDSLÁ / Landscape planning:

Landslag ehf. Landslagsarkitektar

VERKTAKAR OG EFTIRLIT / Contractors and control:

BYGGING I FIDIGARDS / construction of the collecting

G. V. Gröftur eht.

LIMS.IÓN OG VERKEFTIRI IT / Supervision and project control:

Frámhvarðingarsíða ríkisins / Government Construction Contracting Agency

HEILDAR STÆRÐIR / Overall dimensions:

MASSI I GÖRÐUM / Mass of the deflecting dam: 150.000 m³

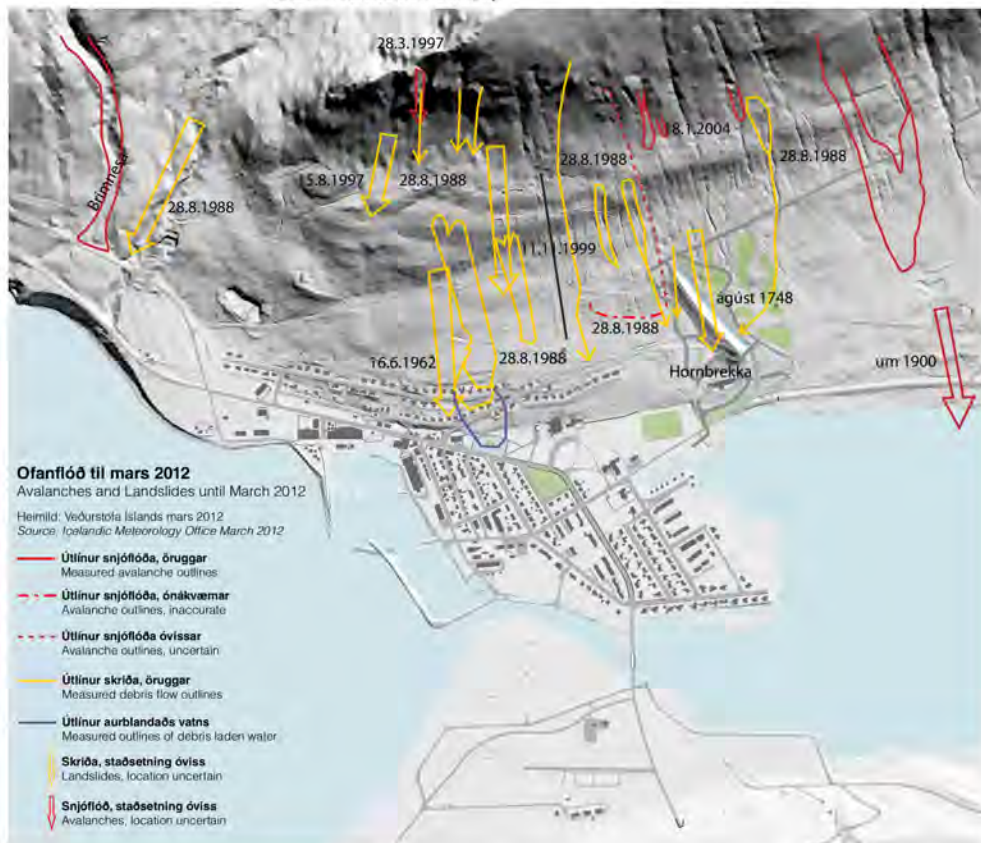
LENGÐ VARNARGARÐS / Deflecting dam length: 320 m

HÆD VARNARGARÐS / Deflecting dam height:

UPPGRÆÐSLUSVÆÐI / Revegetation: 7,3 tta

TRJÁPLÖNTUR / Trees: 8.000 plöntur / plants

LENGD GÖNGUSTÍGA / Length of hiking paths: 2.000 m



ÓLAFSJÖRÐUR OG NÆRUMHVERFI

ÓLAFSJÖRÐUR AND IMMEDIATE SURROUNDINGS



SKÍÐAIDKUN Í ÓLAFSFIRÐI

Skíðaiðkun í Ólafsfirði hefur frá upphafi byggðar verið samofin mannlífi í firðinum. Á löngum og snjópungum vetrum ferðadist fólk um á skíðum milli bæja og nágrannasveita bæði sér til skemmtunar og við aðdrætti á vistum. Þegar samgöngur breyttust og bótunúð hélt fólk áfram skíðaiðkun sér til skemmtunar og hefur íþróttin verið stunduð af miklum krafti. Um áratugaskeið hafa Ólafsfirðingar verið meðal öflugustu skíðamanna á landinu og jafnvel átt skíðamenn á heimsmeðalvarða. Á þessum grunni er byggð sérstök skíðagöngubraut í útjaðri bæjarins en ganga í brautum hentar bæði leikum og lærðum. Við gerð snjóflóðavarnargarðsins var sérstaklega tekið tillit til göngubrautarinnar og það haft í huga að svæðið frá útjaðri bæjarins í suðri að Hlíð verði almennt útivistarsvæði með skíðagöngubrautum á vetrum og almennum útivistastígum á sumrin. Á milli stiga er byrjað að planta trjá sem ætti að verða skemmtilegur útivistarskógur í nánustu framtíð.

SKIING IN ÓLAFSJÖRÐUR

Skiing has been an inseparable part of daily life in Ólafsfjörður throughout the years. In the long and snowy winters, skiing was the main means of travel through the community and for transport of supplies. With modern communication and travel, skiing is still a very popular recreational activity and in the last decades the inhabitants of Ólafsfjörður have been amongst the most energetic skiers in the country. Some have even become world class skiers. Tracks for cross country skiing have been developed on the mountainside in the outskirts of the town. These tracks, which function as hiking paths during the summer, are taken into account in the design of the deflecting dam and its surroundings, bearing in mind that the mountainside is a public outdoor area. Trees and scrubs have been planted in the area which will add to the recreational value in the near future.

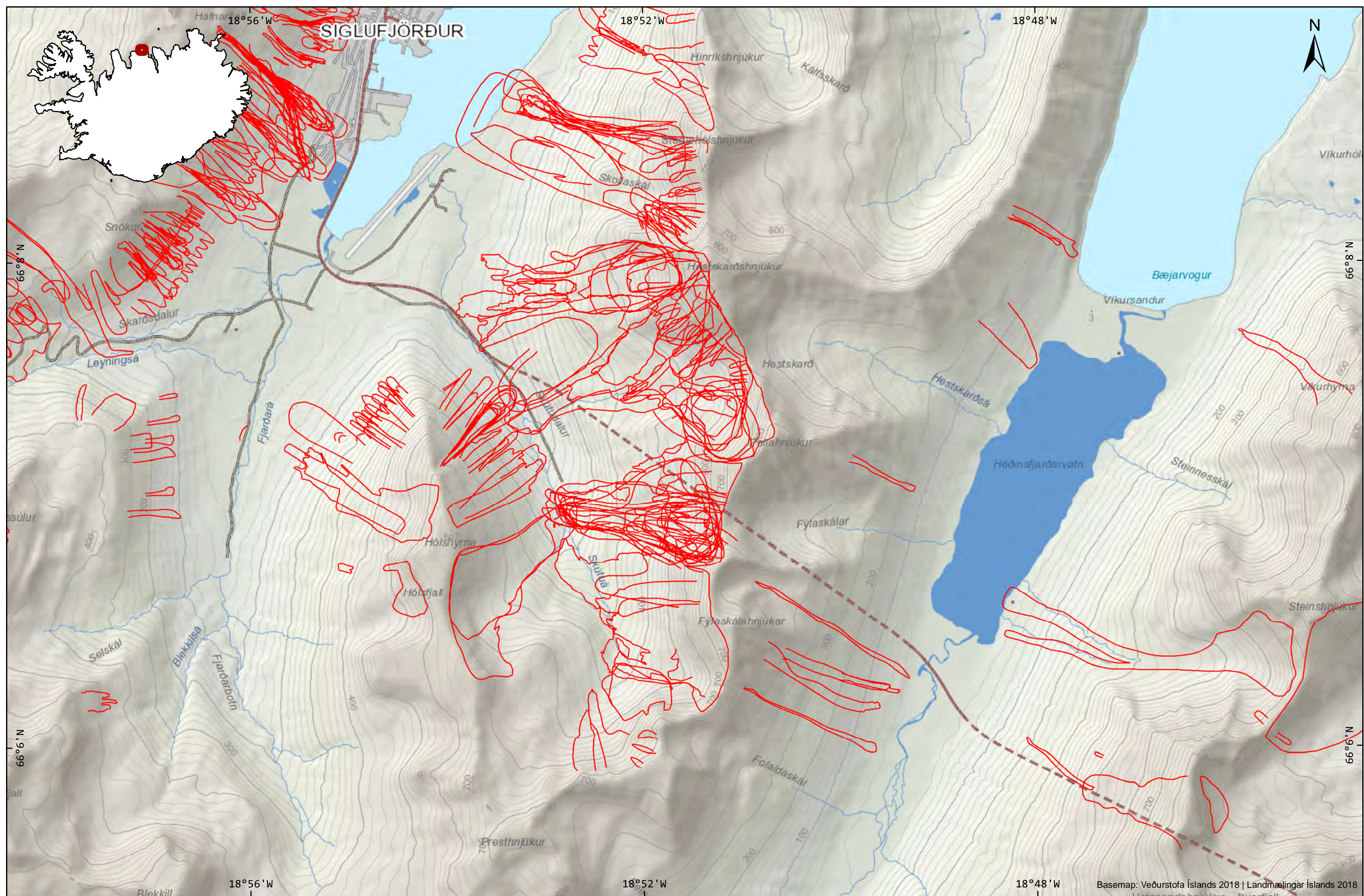
- SKÍÐAGÖNGULEIÐIR / GÖNGULEIÐIR
TRACKS FOR CROSS COUNTRY SKIING / HIKING PATHS
- SKÍDALYFTA
SKI LIFT
- GÖNGULEIÐIR
HIKING PATHS



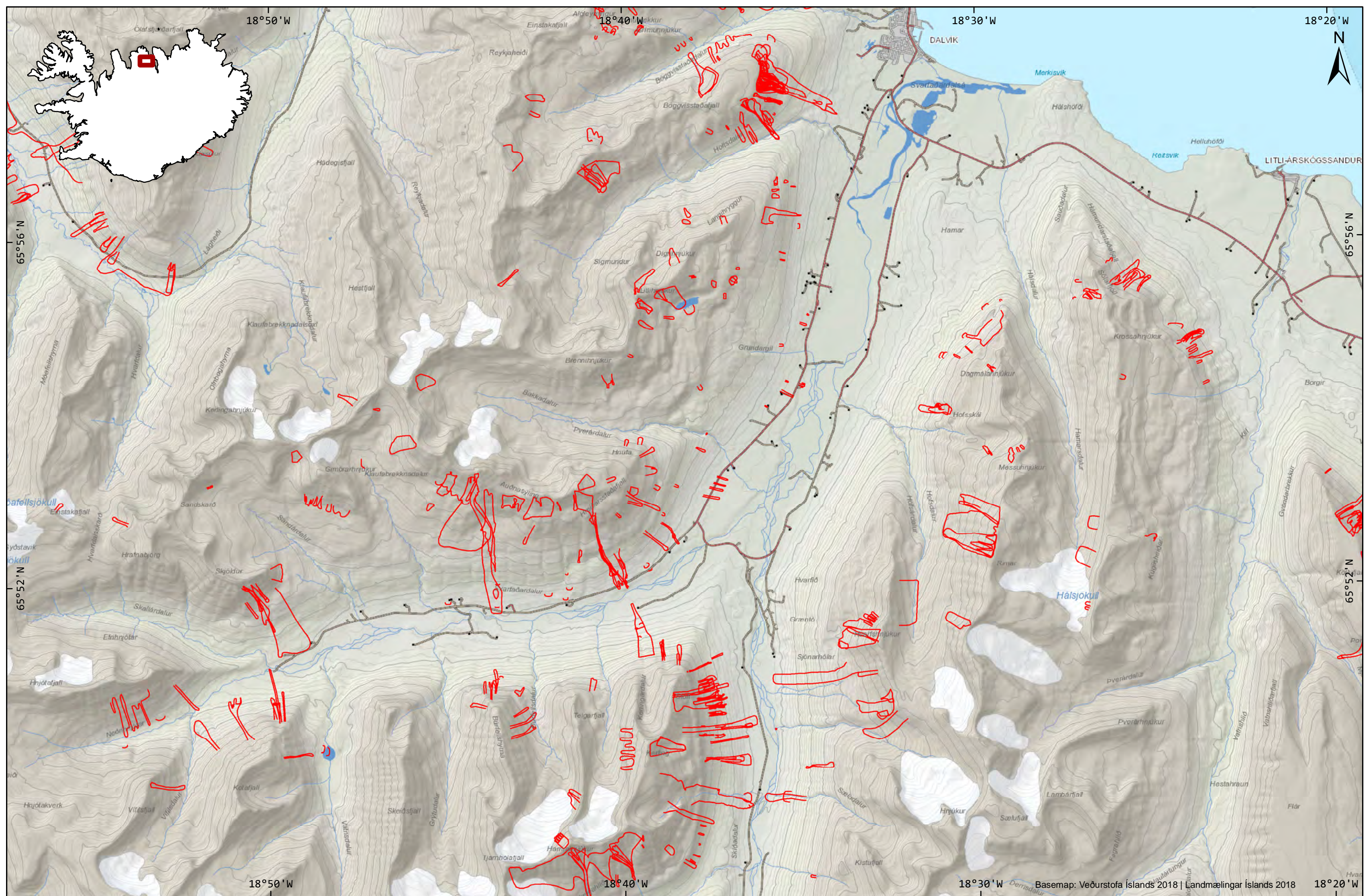
HORNBREKKA MARS 2009



ÓLAFSJÖRÐUR JÚLÍ 2012



— Outlines of Recorded Avalanches



0 1 2 km

Outlines of Recorded Avalanches