Landslide risk to transportation infrastructure in Nordic countries

NORDRESS annual meeting – 21 November 2019

Presented by: Farrokh Nadim

Work performed by: NGI, SGI and IMO (NORDRESS Task 5.1)

NORDRESS
Nordic Centre of Excellence
On Resilience and Societal Security

Background

- Every year a number of incidents and accidents related to slope failures impact the roads and railways in Nordic countries. These can be rock falls, landslides in natural or engineered slopes, or failure of road or rail embankments.
- Most landslides are triggered by human activity or by hydro-meteorological events like heavy precipitation and temperatures oscillating around zero.
- The frequency and intensity of the hydromet-triggered events may increase in the future with climate change.

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Many different types of landslides

rapid

Landslide types that pose the greatest risk to roads and railways in Nordic countries are:

- Debris flows
- Rockfalls
- Quick-clay slides

create significant economic costs

des
pose a greater risk with respect to loss of life

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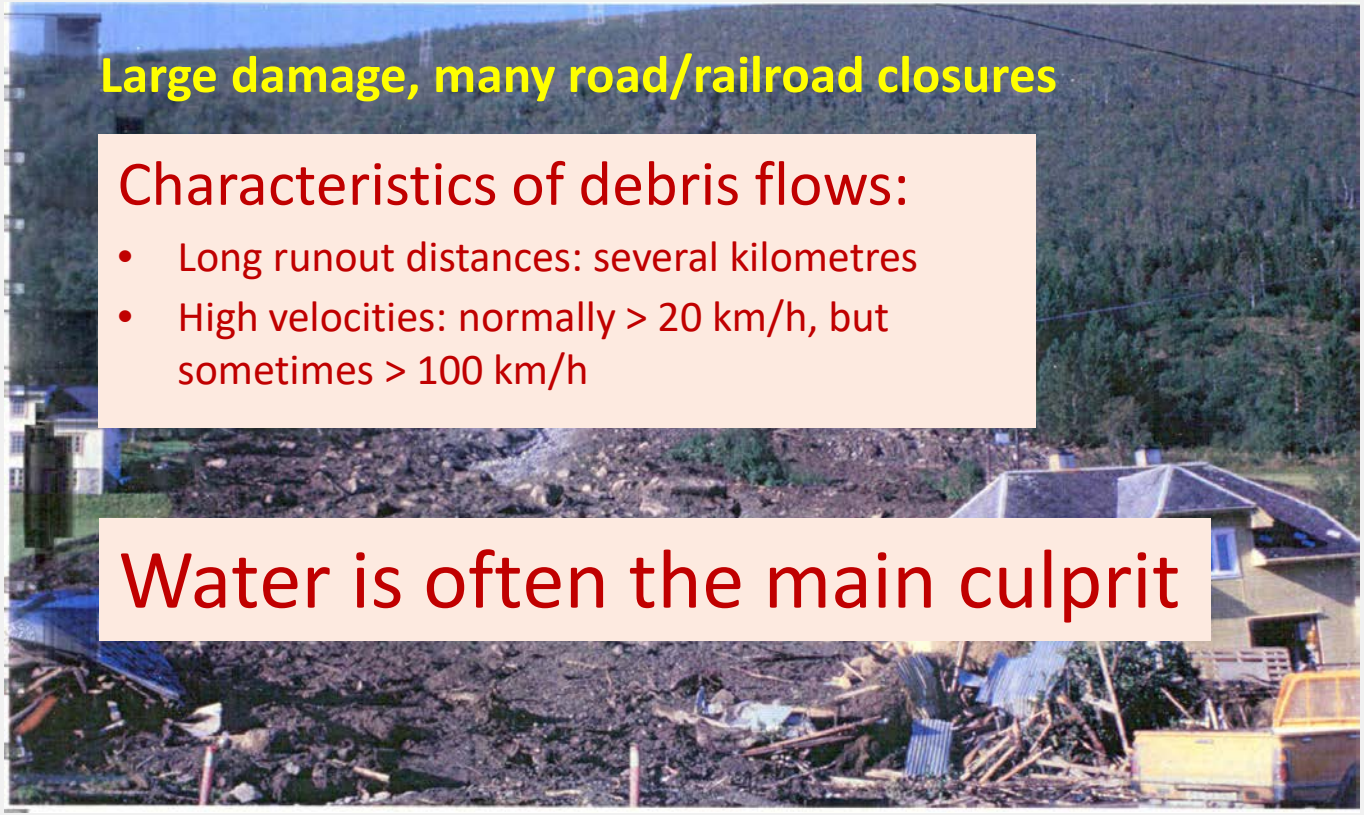
Debris flows



Characteristics of debris flows:

- Long runout distances: several kilometres
- High velocities: normally > 20 km/h, but sometimes > 100 km/h

Water is often the main culprit

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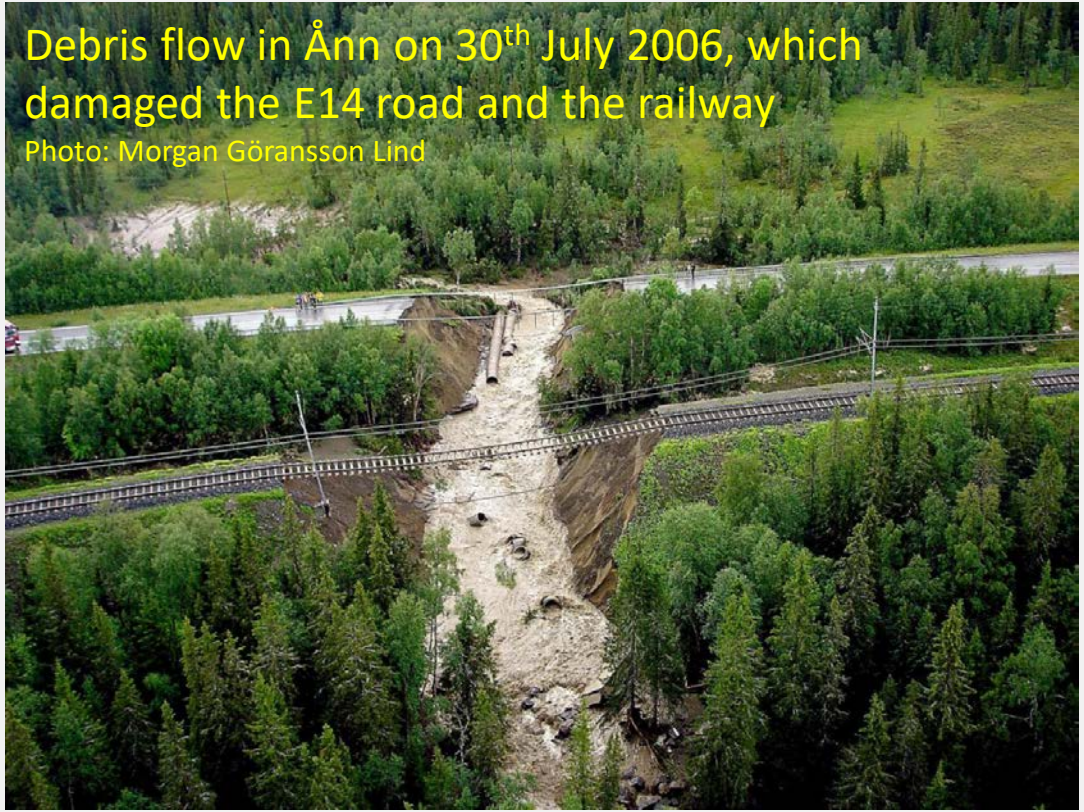
Debris flow at E14 road and the railway in Ånn, northwest Sweden



Debris flow in Ånn on 30th July 2006, which damaged the E14 road and the railway

Photo: Morgan Göransson Lind

The 8 m high road embankment and the rail embankment of similar height were destroyed when the culverts beneath the road and the railway failed to let through the water and debris

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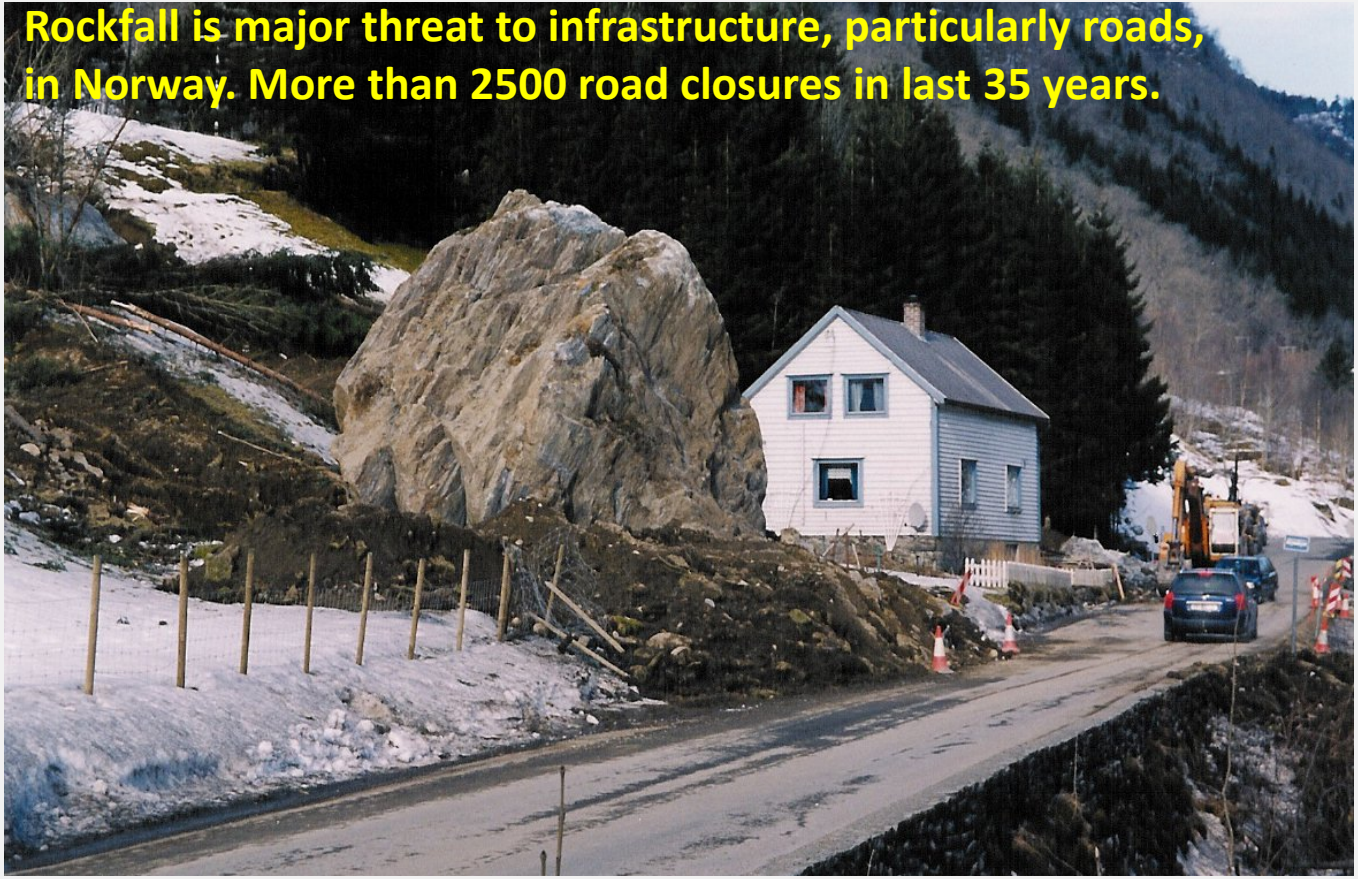
Debris slides in Kinnarfell in the spring of 2013, North East, Iceland

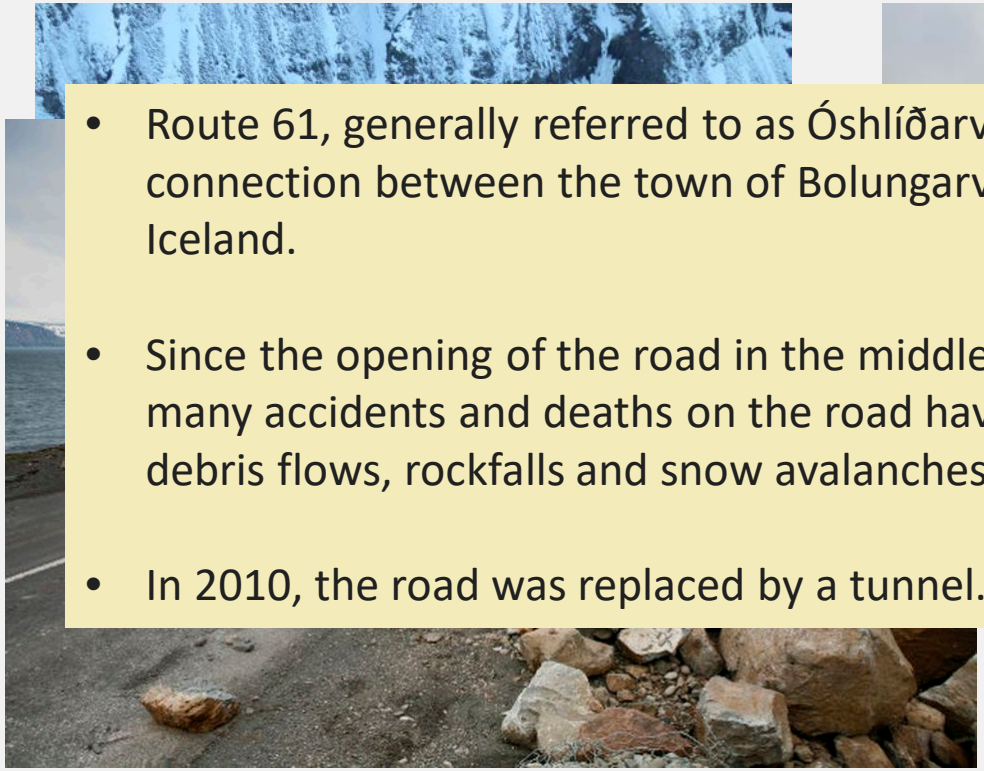
Several small mudflows and four big slides occurred in an area known as Kaldakinn between 28th May and 5th June.

Cause of slides: Heavy precipitation and rapid snow melt in late May and early June

Rockfall, a common hazard in Norway



Rockfall problems at Óshlíð road Westfjords, Iceland

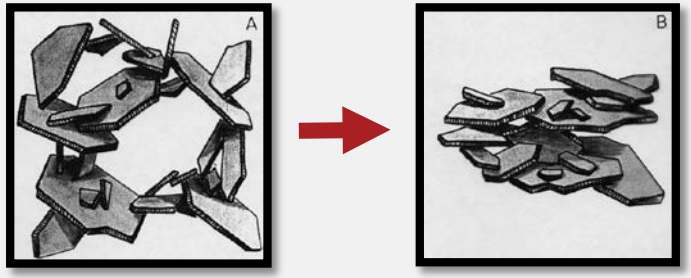


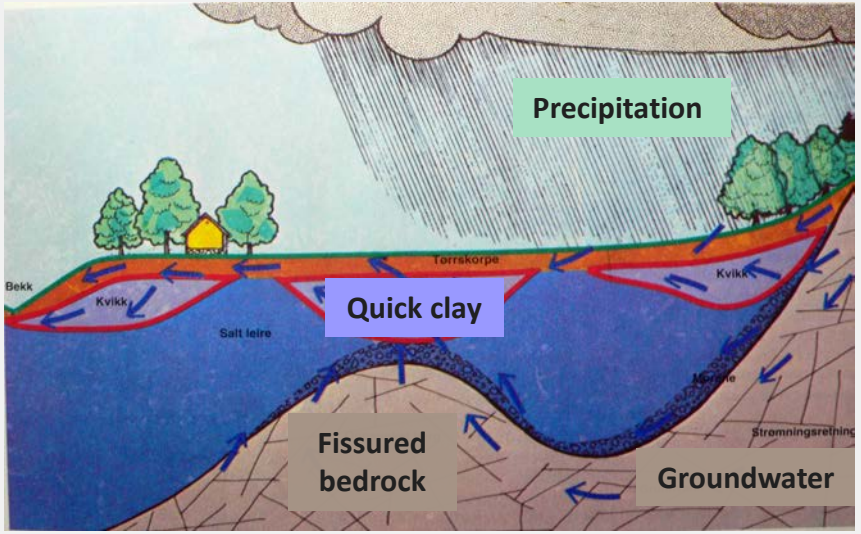
- Route 61, generally referred to as Óshlíðarvegur, was the only connection between the town of Bolungarvík and the rest of Iceland.
- Since the opening of the road in the middle of the last century, many accidents and deaths on the road have been related to debris flows, rockfalls and snow avalanches.
- In 2010, the road was replaced by a tunnel.

Landslides in quick clay

Quick clay is a very sensitive clay that appears to be firm, but loses almost all strength when it is disturbed.

- Marine clay the salt in the pore water is leached out and solid particles have a very unstable structure.
- Found in large regions in Norway and Sweden that are lower than 150-200 m.a.s.l.
- Majority of of quick clay slides are induced by human activity, but river erosion is also important.

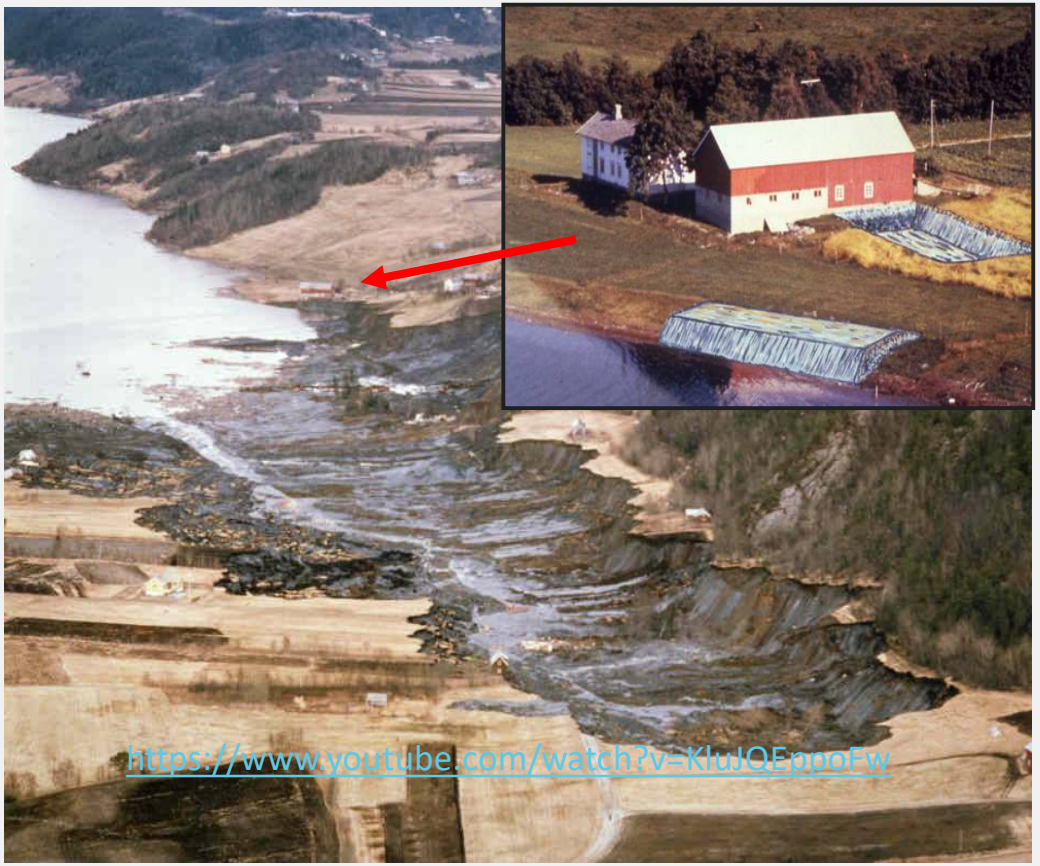




From firm clay to ‘soup’

Thakur and Degago (2012)

Classic quick clay slide: Rissa landslide in 1978



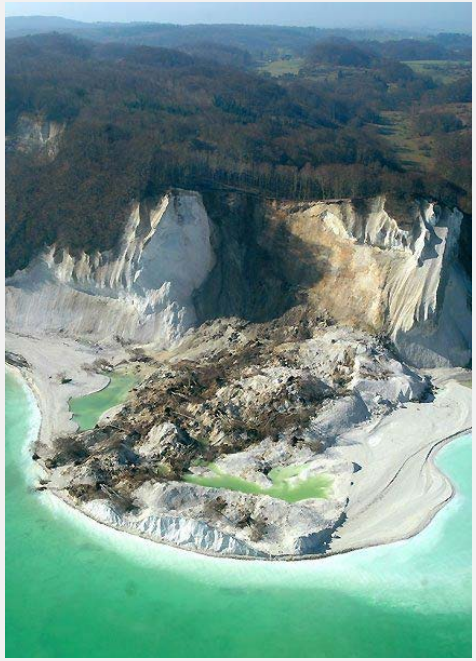
Lyngen, Norway 2010 – Quick clay slide triggered by fill in the shoreline

February 2015 quick clay slide at Skjeggestad bridge, southern Norway, closing 2 lanes of E18 Expressway for several years

Munkedal landslide of 20 Dec. 2006 in Sweden closing the E6 Highway between Oslo & Gothenburg

Cause: Construction activity and a thin layer of quick clay that was not detected.

Landslides are not just a problem for transportation infrastructure



Landslide at Mons Klint, Denmark, in January 2007

Large rockslides and rock avalanches could have catastrophic consequences

- Tsunamis triggered by a large rockslide into fjord or lake is a major threat in Norway

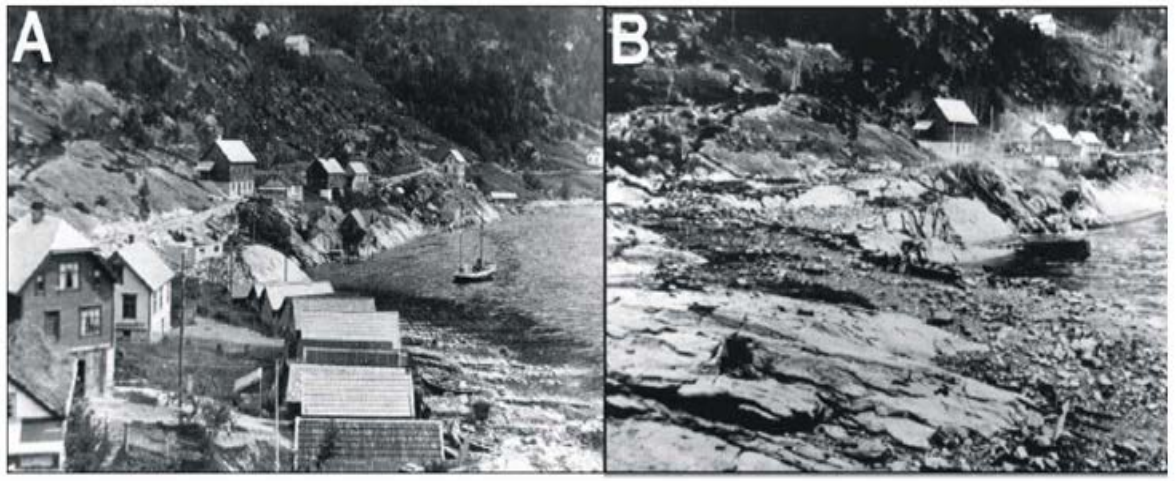
Rockslides with tsunami in Norway

- **3 major disasters in 20th century**
- Loen 1904 and 1936: 61 and 74 deaths
- Tafjord 1934: 40 deaths

Other large rockslide disasters:

- Arnafjord slide, 1811, 45 deaths
- Tjellefonna, 1756, 32 deaths
- 2-4 large disasters / century

Vilalge of Fjøra at Tafjord, before and after the tsunami



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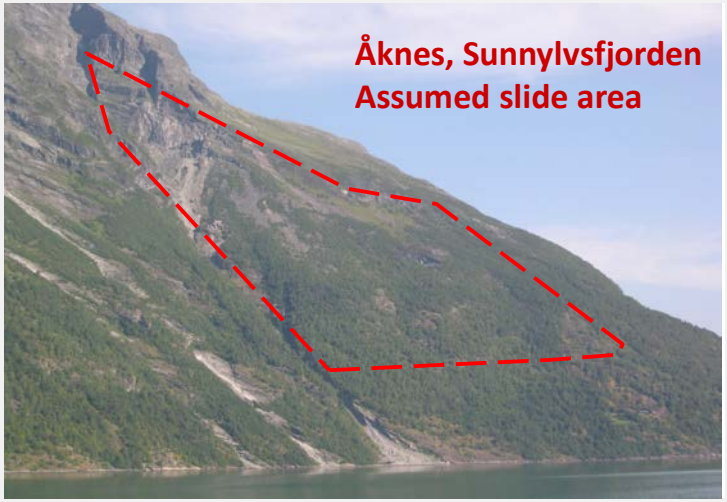
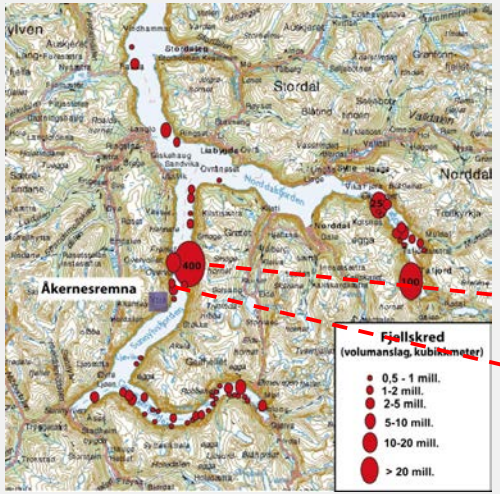
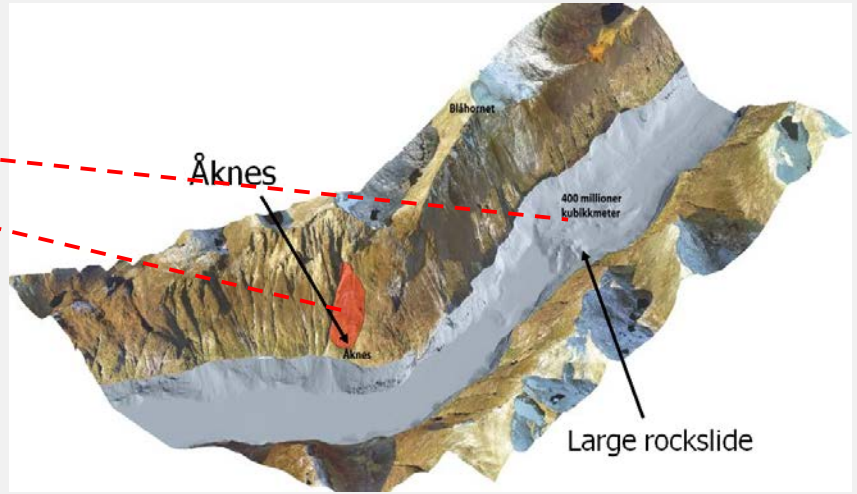
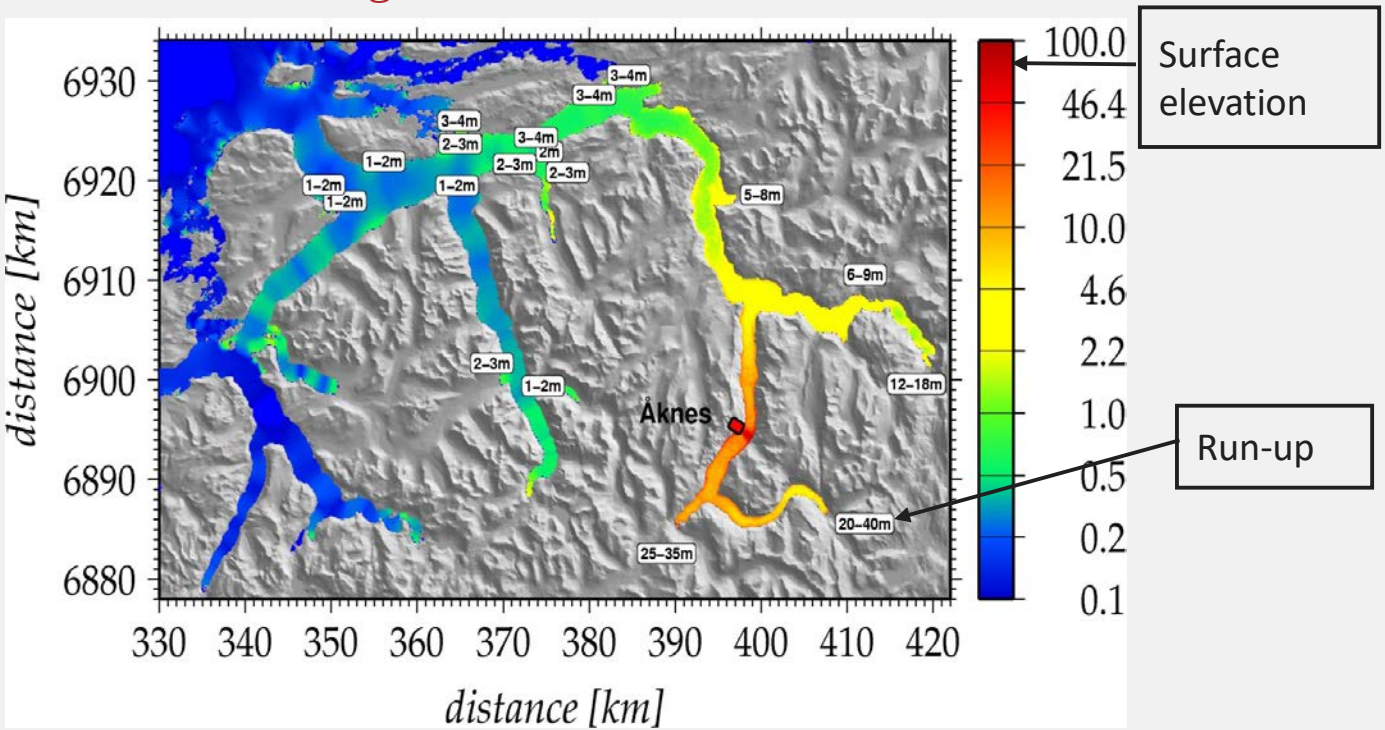
Åknes
NORWAY
SWEDEN


Åknes, Sunnylvsfjorden
Assumed slide area


Stordal
Norddal
Åkernesremna
400
Fjellskred
(volumanslag, kubikkmeter)
0,5 - 1 mill.
1-2 mill.
2-5 mill.
5-10 mill.
10-20 mill.
> 20 mill.


Åknes
Blåhornet
400 millioner
kubikkmeter
Åknes
Large rockslide

The Åkneset rock slide (50 mill m^3): Results from numerical tsunami modelling



Most infrastructure along the fjords are located below 50m asl. The impact of an event today would be immense.

Artist’s depiction of tsunami approaching Tafjord

Tsunami caused by rockslide

Landslide risk mitigation measures

Barriers to lead debris flows away from infrastructure

Often very large structures. Efforts are made on the esthetics, by using local material, revegetation, etc.

Debris flow mitigation along streams and ravines

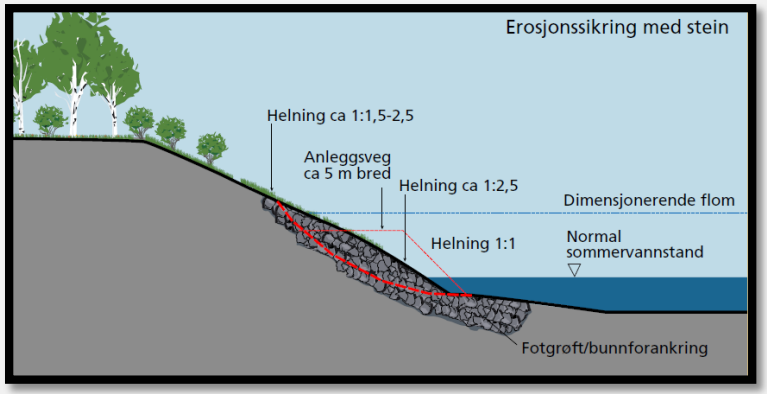
Erosion protection, barriers and check dams with sedimentation basins.

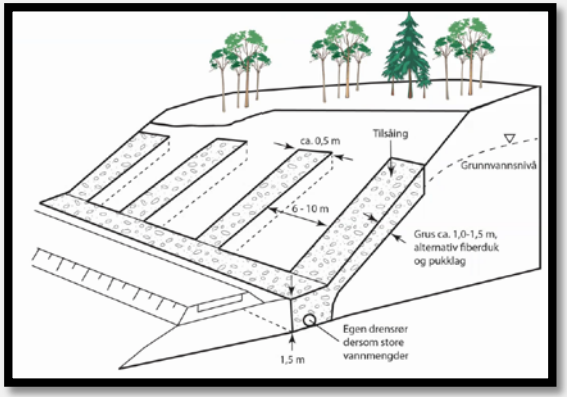
Mitigation for rockfall and rock avalanche

- Land use planning – follow national regulations
- Structural, engineered solutions for rockfalls: bolts, nets, barriers, etc.
- Rockfalls: Put road/ailway in tunnel
- For rock avalanches: monitoring and early warning

Mitigation for quick clay slides

- Land use planning – follow national regulations and guidelines
- Mapping and good knowledge about the ground conditions
- Awareness, particularly in rainy periods
- Physical measures: erosion protection, drainage, chalk-cement piles, terrain modification, etc.





…and still others!

…or, none of the above!

Hot research topic in Europe and Asia:
Nature-based solutions


Thank you for your attention!