Summary

In August 2003, SNET and NGI carried out a common field excursion in Western Norway to study examples of protective structures constructed for protecting infrastructure (mainly living houses) from being hit by debris flows and snow avalanches. This report sums up the field excursion.

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Review and reference document

1 EXCURSION

A two day field excursion was planned for Manuel Diaz and Walter Hernandez, both from SNET (Servisio Nacional de Estudios Territoriales), to show some of the Norwegian mitigations against debris flow and avalanches.

The sites that were visited are:

- Gudvangen, Aurland.
- Kinsarvik, Ullensvang.
- Egne Hjem, Odda
- Eitrheim, Odda
- Bleie, Ullensvang
- Aga, Ullensvang

The mitigations are normally designed and built to withstand slides that can occur with an average return period of one incident every 1000 year. In some cases with mitigations for old houses this is not always possible or necessary, and the protective works are only built to improve the situation as much as possible.

2 GUDVANGEN

In this area two deflecting dams have been built to deflect snow avalanches and as a secondary effect to lead possible debris flow to the side of a hotel and a small village. (Photo no 1 and 2)

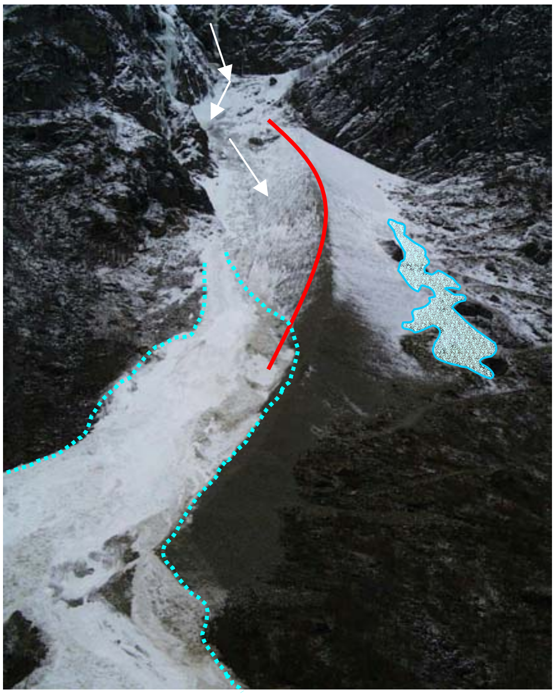

Photo no 1. Snow avalanche deposits along the deflecting dam in Langageiti (1999)

Photo no 2. Two large avalanches were deflected by the Nautagrovi dam (1998-1999)

Two wet avalanches hit the dam in the winter of 1998-99 (Photo no 2) at estimated velocities of 20 m/s (less than the design velocity vT=25 m/s) and with estimated volumes of 100 000 m3 in both events. The observed run-up heights were measured to robs≈7 m at both occasions. The calculated run-up heights with vT=20 m/s (corresponding to μ=0.3 and M/D=200 m) are rcal=8.0 m, 5.8 m, and 5.2 m for k=1.0, 0.5, and 0.0, respectively.

In the upper part of the dam a small portion of the first avalanche had a larger angle of incidence of 48o. This portion also overtopped the dam. The calculated run-up height for k=1.0 and is rcal= 13 m. This is obviously the critical part of the dam, but lack of loose deposits and steep terrain inclination prevented further expansion.

The second avalanche ran on top of the deposits of the first one. The avalanche reached the top of the dam and followed just beneath the dam crown all the way down to the sea. This is probably because the avalanche is wide (~100m) and is forced towards the dam over a long distance. The contour lines of the adjusted terrain on the upper side of the dam are perpendicular to the dam centre line. This will enhance the leading effect of the dam.

2.1 Soil conditions and stability of the dams

The natural soil deposits in the area of the two dams display a large amount of coarse material, Photo no 3. Soil samples of the finer fractions of the natural deposits (rocks and boulders excluded) were taken in a total of four shafts down to 4 - 5 m below ground level at the planned locations of the two deflecting dams at Nautagrovi and Langageiti.

Grain size distribution curves from all of the samples show that the finer fractions of the natural deposits in general can be described as a sandy, gravely material. In addition, there is a slight tendency to more fines with depth in some of the shafts, and also more fines are found in the upper sections of the scree in which the dams are constructed. The percentage of fines less than 0.075 mm is less than 10 – 15 % for most of the samples, but does in some cases reach to about 25 %.

Photo no 3. Natural soil deposit shows large amount of coarse material

The depth to the rock surface below ground level was not determined in the scree itself, but was assumed to be located sufficiently low not to have any impact on the stability calculations.

Based on the location of creeks in Nautagrovi and Langageiti, the ground water table was assumed to be below the depth of critical slip surfaces. Further, it was also assumed that the ground water table would not rise significantly during extremely wet periods of the year.

Based on general experience and guidelines in literature, the drained friction angle of the natural soils in the scree was set to 36º and the drained friction angle in the compacted dam was set to 38º. In both cases the cohesion was set to zero. Further, the total unit weight was set to 19 kN/m3. The selection of friction angles is believed to be somewhat on the conservative side.

Stability calculations based on both circular and plane slip surfaces yielded a factor of safety of about 1.5 for the steepest upper part of the Nautagrovi dam. The critical failure mode is part of the dam sliding sideways down the scree.

The lower part of both dams has a higher factor of safety due to a gentler slope. Because the Langageiti dam more or less follows the steepest descent of the scree, it is judged to be stable as long as the upper part in very steep terrain is resting on the lower part in more gentle terrain.

3 KINSARVIK

In Kinsarvik, in the municipality of Ullensvang, several houses and an elder centre were found to be situated within reach of debris flow. Five large debris flows has hit the area the last 400 years. This have been historically documented, but not remembered by officials when housing areas was planned.

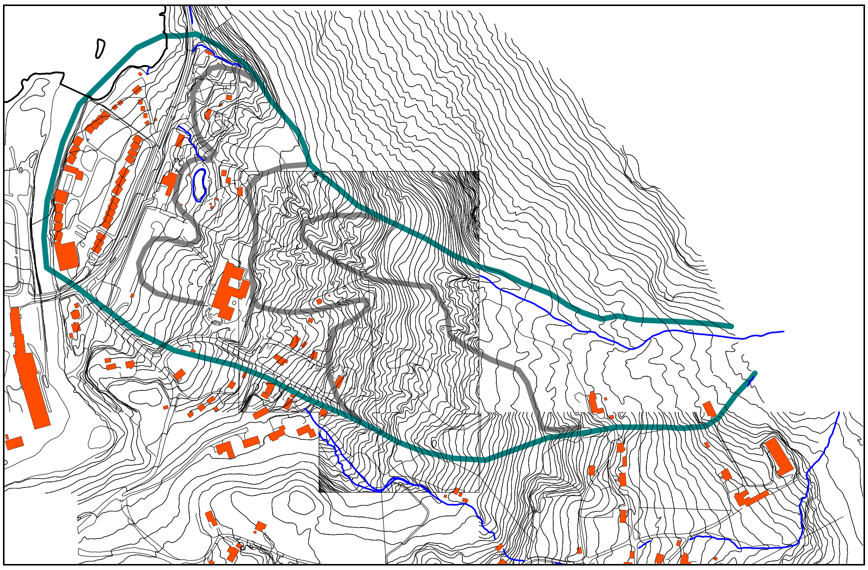

Figure no 1. Map of central part of Kinsarvik showing the maximum extent of debris flow. Three zones within the debris flow boundary indicate levels of coarser material.

Photo no 4. A 5 m – 10 m high channel dam was built to prevent housing areas in the central part of Kinsarvik to be hit by debris flows.

Photo no 5. In the lower part of the cannel area a wider accumulation basin is built, with an opening in the middle to allow water drainage. This also permits accumulated masses to be eroded out of the accumulation area. We expect some maintenance after each debris flow. A road over the dam permits access to the channel area for maintenance.

4 EITRHEIM

The main dam at Eitrheim is 350 m long and 8m - 10 m high. The dry rock wall on the side facing the river is due to expected erosion from avalanches. The excavated channel and elevated dam was built by moving 55 000 m^3 of loose deposits.

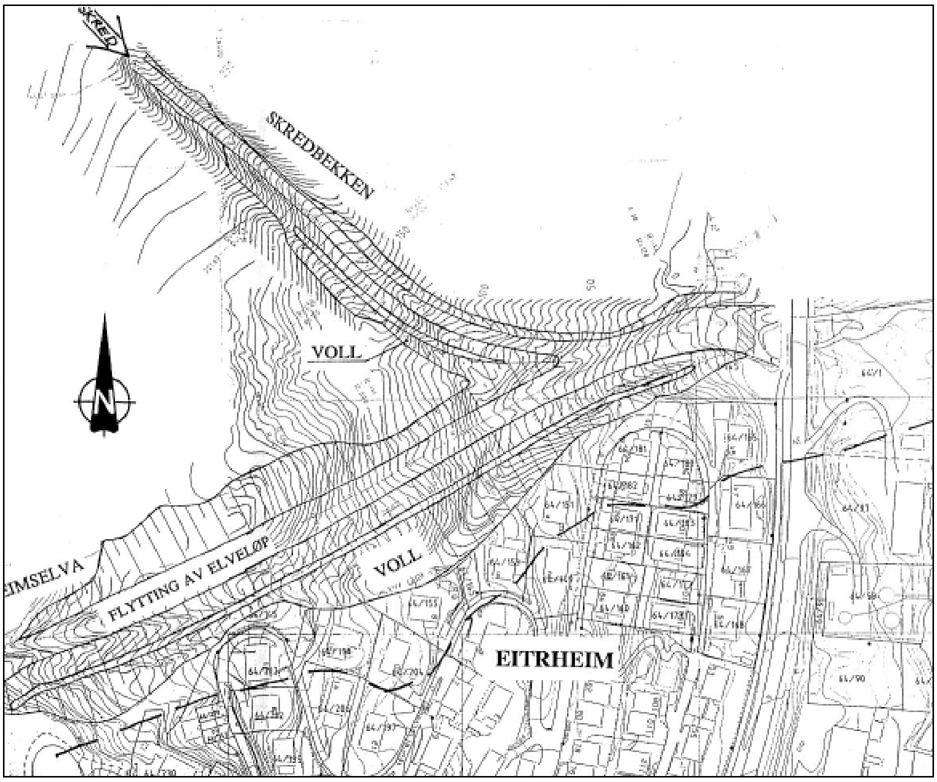

Figure no 2. Map showing the channel leading slides, water and avalanches along the side of a housing area at Eitrheim

Photo no 6. View of the deflecting dam at Eitrheim seen from the road

5 EGNE HJEM

A deflecting dam and breaking mounds have been built to secure the housing areas on both sides of the Tokheim River. The dimensions are based on calculations of velocity and volume on the avalanche. The effect of the mitigation work is questioned, due to several avalanche incidents during a single winter season.

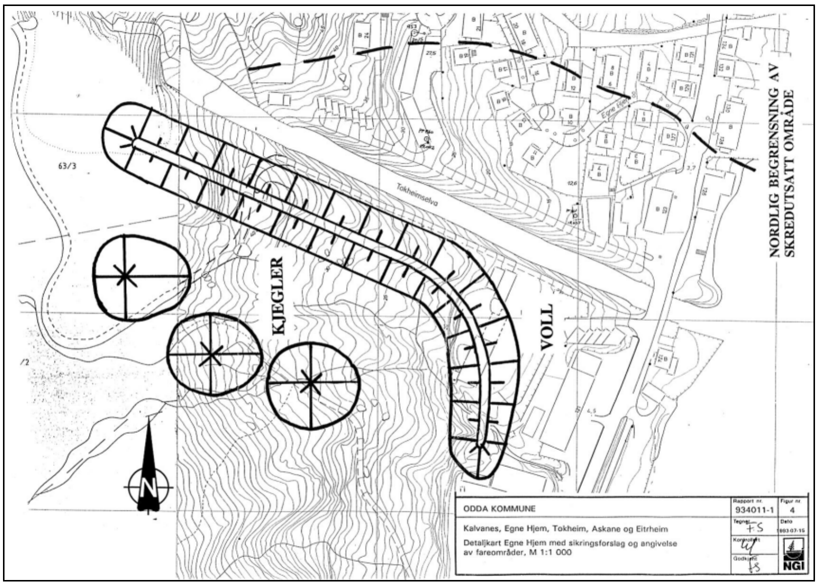

Figure no 3. Sketch of the deflecting dam and earth mounds at Egne Hjem

Photo no 7. View of the mitigations at Egne Hjem securing the housing area and the road against avalanches

6 BLEIE

A major a snow avalanche hit the farms at Bleie, municipality of Ullensvang, January 27 1994. 3 dwelling houses were completely destroyed, and one house severely damaged. One barn and three other buildings were either damaged or destroyed. The written history of the Bleie farms dates back to 1293 a.d. In this period no avalanches are known to have hit the farms or having been nearby the farms. The return period for the avalanche was calculated to 800-1000 years, based on historic evidence and climatic records. The horizontal length of the avalanche was 3600 m. Based on velocity and volume calculations different methods of protections were planned.

Photo no 8. The 1994 snow avalanche hit three farms at Bleie and destroyed some of the houses

KEY DATA

<u>Client:</u>
Ullensvang Herad, Hardanger, Norway

<u>Consulting Civil Engineer:</u>
INSTANES A/S, Bergen, Norway

<u>Contractor:</u>
NCC Eeg-Henriksen Anlegg A/S, Bergen, Norway

<u>Design loads:</u>
Norwegian Geotechnical Institute, Oslo, Norway

<u>Geometry:</u>
Total length: 113.4 m
Height (min): 10 m
Wall thickness: 0.35 m

<u>Construction materials:</u>
Concrete: C45 - 650m^3
Reinforced steel: K 500 TE - 120 000 kg
Rock anchors: 22 x 2800 kN, total capacity 61 600 kN

<u>Construction period:</u>
5 months

<u>Construction costs:</u>
NOK 5.6 million (incl. access road)

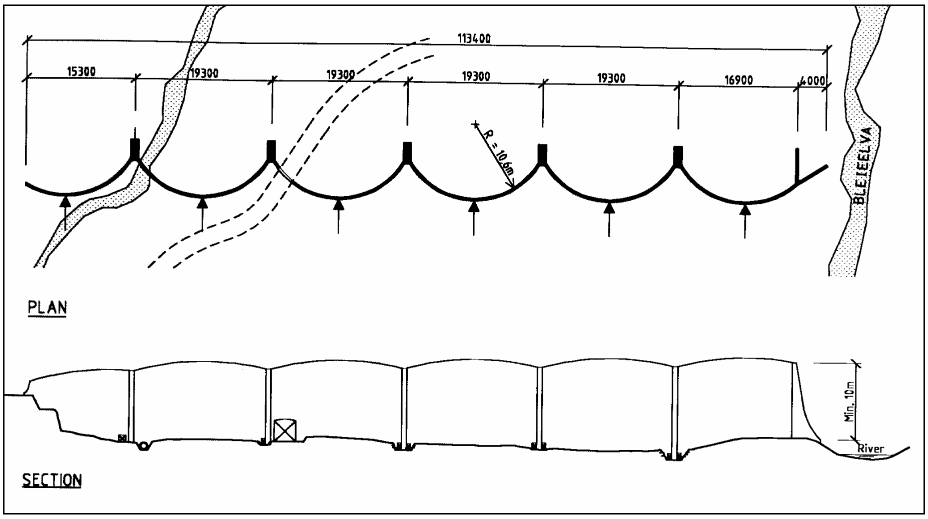

Figure no 4. The wall consists of five-and-a-half half-cylindrical shells monolithically connected to form the 113.4 m long wall

Photo no 9. View of the catching wall at Reiseter

7 AGA

The farm houses at Aga can be reached by debris flow, avalanches and slush flow (water and snow mixture). We expect that the most endangered houses can be reached once each 50 – 100 years on the average. Figure no 5 show the known boundaries of a debris flow in 1992.

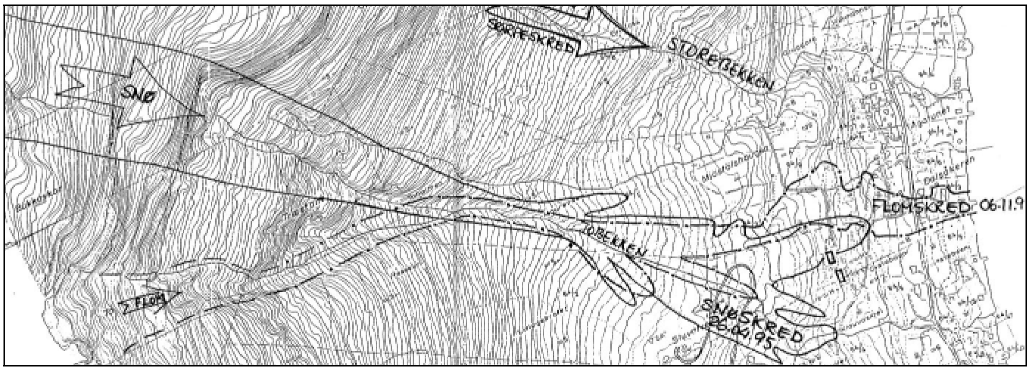

Figure no5. Extent of debris flow in 1992

Figure 6 show the extent of the hazard zone related to the demands in the legislations and building codes. The alternative that was chosen and built, see photo no 10, is a 10 m – 12 m high and approximately 350 m long catching dam.

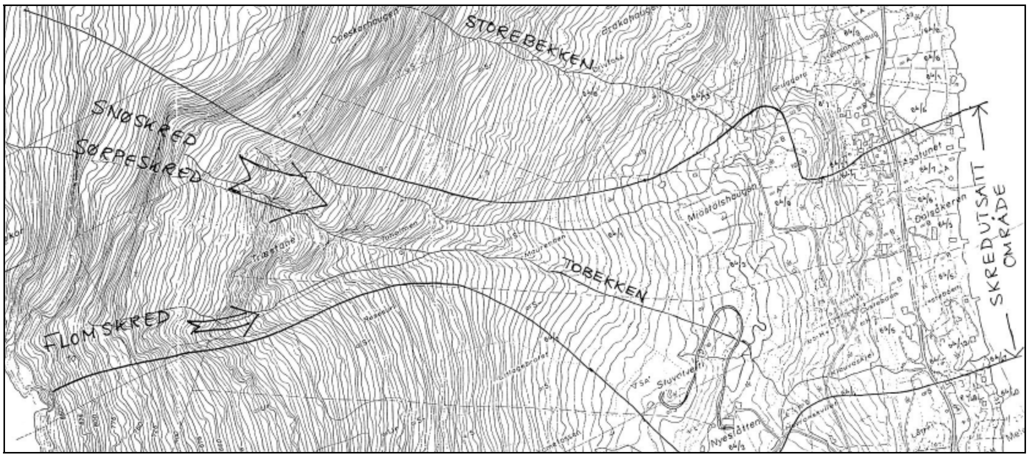

Figure no 6. Hazard zone at Aga

Photo no 10. Catching dam at Aga

Photo no 11. Detail of the opening in the catching dam

Kontroll- og referanseside/
Review and reference page

NGI

Oppdragsgiver/*Client* Norwegian Ministry of Foreign Affairs v/ Lillian Wikstrøm **Kontraktsreferanse/** ***Contract reference*** *SLV 102 0257*	**Dokument nr/*Document No.*** 20021283-5 **Dato/*Date*** 12 December 2003
Dokumenttittel/*Document title* SNET/NGI Field Excursion in Western Norway August 2003. Protective constructions. **Prosjektleder/*Project Manager*** Oddvar Kjekstad **Utarbeidet av/*Prepared by*** Ulrik Domaas	**Distribusjon/*Distribution*** ☐ **Fri/*Unlimited*** ☒ **Begrenset/*Limited*** ☐ **Ingen/*None***
Emneord/*Keywords* Protective constructions, dikes, debris flow, snow avalanche	
Land, fylke/*Country, County* Norway **Kommune/*Municipality*** Aurland, Ullensvang, Odda **Sted/*Location*** **Kartblad/*Map*** **UTM-koordinater/*UTM-coordinates***	**Havområde/*Offshore area*** **Feltnavn/*Field name*** **Sted/*Location*** **Felt, blokknr./*Field, Block No.***

Kvalitetssikring i henhold til/*Quality assurance according to* NS-EN ISO9001

Kon-trollert av/ *Reviewed by*	Kontrolltype/ *Type of review*	Dokument/*Document*		Revisjon 1/*Revision 1*		Revisjon 2/*Revision 2*	
		Kontrollert/*Reviewed*		Kontrollert/*Reviewed*		Kontrollert/*Reviewed*	
		Dato/*Date*	Sign.	Dato/*Date*	Sign.	Dato/*Date*	Sign.
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