

## **Monitoring and early warning of rock avalanches**

Rock avalanches are rare but can cause significant damage/injury. The Norwegian Water Resources and Energy Directorate (NVE) surveys mountain sections on which rock avalanches could develop. Thus far, four mountains have been assessed as constituting such a high risk that they are monitored round-the-clock, three in the county of Møre og Romsdal and one in the county of Troms.

*Bernt Lyngstad from the NVE is studying one of many cracks in Jettan, the unstable mountain section in Nordnesfjellet in Kåffjord municipality. In the picture we also see a satellite reflector that measures movement in the mountain. Lyngseidet is at the rear edge to the left. PHOTO: Ørjan Bertelsen.*

A rock avalanche is the rapid collapse of a large volume of rock, from 100,000 to several million cubic metres. History shows that two to three major accidents occur in Norway every one hundred years, and that the majority of rock avalanches have triggered tsunamis. The best known are the incidents in Loen in Sogn og Fjordane county in 1905 and 1936 and Tafjord in Møre og Romsdal county in 1934. These three rock avalanches cost the lives of 174 people.

Developments along littoral zones and increasing tourism have made us more vulnerable to such rock avalanches and tsunamis. The NVE is responsible for assessing the rock avalanche risk in Norway and for monitoring rock slope failures at high risk. Several hundred rock slope failures that could develop rock avalanches have been identified. Although, thus far, only four represent a high risk.

## **ROCK AVALANCHES PROVIDE THEIR OWN ALERT**

In areas with low earthquake activity, like Norway, rock avalanches virtually always originate from rock slope failures in slow movement, typically up to a few centimetres per year. Such movement may last for several decades or centuries. Sometimes the movement increases significantly and will often end in a rock avalanche. In this way, the rock avalanche provides its own alert.

Experience from the Alps, in which rock avalanche have occurred from several monitored mountains, indicates that the acceleration phase prior to a rock avalanche lasts from a couple of weeks to just over one month. Historically, the same can be said for rock avalanche in Norway. Prior to the rock avalanches, the rock slope failures have been unstable with frequent minor rock falls, and expanding cracks have been observed in the mountain.

## **LANDSLIDE EMERGENCY PREPAREDNESS IN NORWAY**

Extensive instrumentation is used on the four rock slope failures in Norway that are continuously measured and monitored: Tie-backs, lasers, radar, GPS, total

stations, electronic angle gauges, borehole sensors, seismic sensors and weather stations. Each rock slope failure is monitored by three or more independent measuring systems.

Measurement data is continuously transferred to the NVE's monitoring centres in Stranda in Møre og Romsdal or Kåfjord in Troms. Geologists working in rotation analyse the data.

At any given time, the monitored rock slope failures have a hazard and warning level on a scale of one to four: green/low, yellow/moderate, orange/high and red/extreme. The mountain's movement is the most important factor in determining the warning level. If NVE change the hazard level, the NVE alerts other emergency preparedness players such as municipalities, the police, county governors, etc. For each change of warning level, the NVE and other emergency preparedness players will intensify their preparedness correspondingly.

#### **MOUNTAIN SECTIONS IN NORWAY WITH ROUND-THE-CLOCK MONITORING**

**ÅKNESET IN MØRE OG ROMSDAL:** A rock slope failure up to 54 million cubic metres would trigger a tsunami that could affect up to ten municipalities. The number of people in the danger zone varies with the season from some hundred to five–six thousand.

**HEGGURAKSLA IN MØRE OG ROMSDAL:** A rock slope failure up to 3 million cubic metres would trigger tsunami primarily within Norddal municipality. The number of people in the danger zone varies from several tens to several hundred.

**MANNEN IN MØRE OG ROMSDAL:** A rock slope failure up to 20 million cubic metres would cross Romsdalen and may lead to damming and floods. The number of people in the danger zone varies with the season, from relatively few to a couple of hundred.

**NORDNESFJELLET IN TROMS:** A rock slope failure up to 11 million cubic metres would trigger tsunami within three municipalities. Up to a couple of thousand people could find themselves in the danger zone.

The Norwegian Water Resources and Energy Directorate (NVE) is a directorate under the Ministry of Petroleum and Energy.

NVE is responsible for managing Norway's water and energy resources. NVE is also responsible for managing Norway's handling the State's administrative functions as regards flood and avalanche/landslide prevention.

NVE's mandate is to ensure an integrated and environmentally sound management of the country's water resources, promote efficient energy markets and cost-effective energy systems, and contribute to effective energy use.

NVE plays a central role in the national flood contingency planning and for the prevention of damage caused by landslides and waterways, and is in charge of the national power supply emergency preparedness.

NVE is involved in research and development and international collaboration within its specialised fields. NVE is the national centre of expertise for hydrology in Norway.

## CONTACT

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*The rock slope failure by Mannen in Romsdalen. . PHOTO: Einar Anda/NVE.*

*The rock slope failure by Åknes. Two lasers have been placed in the fixed part of the mountainside and measure distances and movement in the rock slope failure. PHOTO: Einar Anda/NVE.*

## WHAT HAPPENS DURING THE RESPECTIVE HAZARD LEVELS?

A GREEN HAZARD LEVEL represents a normal situation. No rock avalanche is anticipated in the near future (weeks/months). The geologist on duty evaluates the condition of the monitored mountain sections once every 24 hours. If the velocity of the mountain exceeds specified threshold values, the geologist on duty is automatically notified.

If the hazard level rises to a YELLOW HAZARD LEVEL, there is an increased risk of a rock avalanche, although it would not be expected to occur for several weeks, possibly longer. The geologist on duty evaluates the condition of the mountain section at least every other hour. The police, municipalities, the NVE, etc., remain in close contact. A yellow level does not usually involve the implementation of mandatory measures, such as moving or evacuation, although preparations will be made for measures to be implemented in the event of a higher warning level.

If the hazard level rises to an ORANGE HAZARD LEVEL, the likelihood of a rock avalanche has further increased, and will be expected to occur within one week, possibly longer. The condition of the mountain section is evaluated continuously, 24/7. In this phase, municipalities will move vulnerable enterprises such as kindergartens, schools and health care institutions. Aquaculture cages within the danger zone will be moved to reserve locations outside the danger zone. Fjords will be closed to shipping traffic.

If the warning level rises to a RED HAZARD LEVEL, an imminent rock avalanche is very likely. The mountain section is evaluated continuously, 24/7. The NVE has a mandatory obligation to issue a red warning alert no later than 72 hours prior to a rock avalanche, and evacuations must have been completed no later than 12 hours after a red warning alert has been issued. When a red warning alert is issued, the police will immediately implement the evacuation of defined

evacuation zones. Roads, railways and other traffic within the danger zones will be closed/stopped.

*[I kartene: Monitoring centre]*

*Map of mountain sections in Norway with round-the-clock monitoring. MAP: NVE.*

Sometimes several rock avalanches will occur in succession, such as in Loen in 1936, when three major rock avalanche occurred in the course of two months. A return to a green (or yellow) hazard level assumes that the monitoring systems have been restored and that the hazard assessment indicates a green (or yellow) warning level.

If the assessment of a mountain section after a landslide indicates that there is no longer a risk of further landslides representing a high risk, the rock avalanche emergency preparedness for this mountain section will be terminated.

#### **THE MAIN PLAYERS ARE:**

- The Norwegian Water Resources and Energy Directorate (NVE)
- Municipalities
- County governors
- The police

Other players include a number of sector authorities and other authorities. A national emergency plan for major landslides has been prepared.

#### **Contact information**

The NVE's 24-hour emergency phone line:  
+47 22 95 93 60 | +47 909 92 231

See also [www.nve.no](http://www.nve.no)

Reference is otherwise made to the websites of the relevant municipalities and police authority.