SITE-SPECIFIC SLUSH FLOW WARNING ON HIGHWAY RV80, NORTHERN NORWAY

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ABSTRACT: RV80 is the main road to Bodø, the largest city in Nordland County in Northern Norway. About 30 minutes outside the city is Ytre Kistrand, an area with several slush flow paths known to close the road almost every year. In February 2021 a contractor on duty for the Norwegian Public Road Administration (NPRA) died from his injuries after a slush flow hit his car and threw it upside down on the railway 10 meters below the road.

In November 2023 the NPRA started the construction of mitigating measures at Ytre Kistrand to protect road users. Catchment dams are constructed with drilling and blasting in the rock on the upper side of the road. The construction work progressed through the winter, which is when slush flows occur. To establish mitigating measures, workers are exposed to slush flow terrain daily. To reduce the risk of accidents it was decided to use a site-specific slush flow warning for the construction site during the winter.

A site-specific slush flow bulletin was usually published every three to four days, but daily in periods with elevated hazard level. The hazard scale was divided into 4 levels with associated measures. The published hazard level was based upon the snow cover in the release zone and the weather forecast. During the winter there was one slush flow event within the construction area. The construction site was closed due to a high hazard level.

KEYWORDS: Slush flow, site-specific, warning, mitigating measures.

1. INTRODUCTION

Highway RV80 is the main road to Bodø, the largest city in Nordland County in Northern Norway. There are several slush flow paths along the highway, most of them exposed to small slush flows that rarely affect the road. The exceptions are the paths known as Ytre Kistrand 30 minutes outside the city. Slush flow events occur on the road about once a year from 4 paths. They are usually quite small with no reported accidents, but the road has been fully or partially closed several times. The normal traffic passing the area is approximately 3000 vehicles a day.

In 2021 a contractor on duty for the Norwegian Public Road Administration (NPRA) died from the injuries he sustained after he was hit by a slush flow at Ytre Kistrand. This tragic event accelerated the process of establishing mitigating measures. The construction started in the fall of 2023, and as the work would continue through winter the need for site-specific slush flow warning arose.

2. YTRE KISTRAND SLUSH FLOW AREA

There are 4 known slush flow paths at Ytre Kistrand (*Figure 1*). They all mainly follow water streams in the terrain.

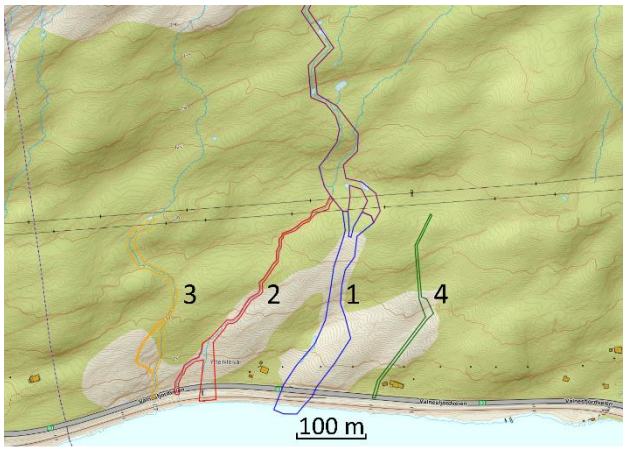


Figure 1: The slush flow paths at Ytre Kistrand.

The release area is not known for all the slush flow events, but it was assumed to be in a flat area underneath the powerlines at around 100 m.a.s.l. Slush flows are most common in the paths 1 to 3, and the latest events show that they also can be released higher up in the terrain.

2.1 Mitigation measures

The mitigating measures will consist of catchment dams constructed with drilling and blasting the rock on the upper side of the road (Figure *2*). The construction will be completed by the end of 2024.

The traffic on highway RV80 moves through the area during construction, on a single lane road controlled by traffic lights.

Figure 2: Construction of catchment dams in progress by drilling and blasting. Screenshot from a photogrammetry 3D model.

3. SLUSH FLOW WARNING

The purpose of establishing a site-specific slush flow warning was primarily to avoid accidents, but also to prevent damage to equipment and machinery. A third reason was to prevent slush flows from depositing on the road while open to traffic.

The workers in the area represent mainly three companies: the contracting client (NPRA) and two contractors. They had no prior experience with slush flows, so for the hazard warning to be effective it had to be communicated in a simple way. In addition, they were given some training to help them understand the hazard warning and how to respond.

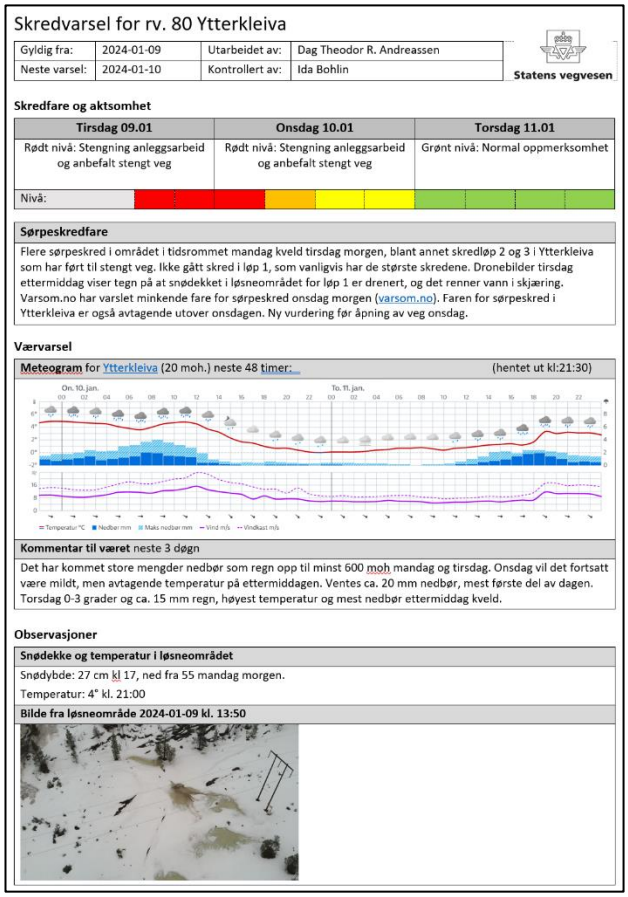
The assessed slush flow hazard was communicated to the construction site by distribution of a bulletin.

3.1 The slush flow bulletin

The slush flow bulletin was made simple with as little text as possible. The main goal was to give the recipients easy information about the snow conditions and the slush flow hazard.

The slush flow bulletin has two pages. The first page contains the assessed hazard level and information to support it, such as weather and snow conditions (Figure 3). The second page contains an explanation of the bulletin and measures associated with each hazard level. This page also defines risk owners according to recommendations approved by the European Avalanche Warning Services (EAWS) general assembly in Davos in 2022 (EAWS, 2022).

The bulletin uses a slush flow hazard scale of four levels, each level defined by a color, recommended level of caution and associated measures. Green translates to low slush flow hazard and normal activity is recommended. Yellow translates to moderate slush flow hazard, and recommended restrictions are to only allow task inside heavy machines. Orange translates to considerable hazard for slush flows, and it is recommended to close the construction site. The highest level of the slush flow hazard scale is red, and in addition to closing the construction site it is recommended to close the highway RV80 for traffic. In addition to the graphic display of the assessment a description of the situation is provided.


Skredvarsel for rv. 80 Ytterkleiva

Gyldig fra:	2024-01-09	Utarbeidet av:	Dag Theodor R. Andreassen
Neste varsel:	2024-01-10	Kontrollert av:	Ida Bohlin

Statens vegvesen

Skredfare og aktsomhet

Tirsdag 09.01	Onsdag 10.01	Torsdag 11.01
Rødt nivå: Stengning anleggsarbeid og anbefalt stengt veg	Rødt nivå: Stengning anleggsarbeid og anbefalt stengt veg	Grønt nivå: Normal oppmerksomhet
Nivå:		

Sørpeskredfare

Flere sørpeskred i området i tidsrommet mandag kveld tirsdag morgen, blant annet skredløp 2 og 3 i Ytterkleiva som har ført til stengt veg. Ikke gått skred i løp 1, som vanligvis har de største skredene. Dronebilder tirsdag ettermiddag viser tegn på at snødekket i løsneområdet for løp 1 er drenert, og det renner vann i skjæring. Varsom.no har varslet minkende fare for sørpeskred onsdag morgen (varsom.no). Faren for sørpeskred i Ytterkleiva er også avtagende utover onsdagen. Ny vurdering før åpning av veg onsdag.

Værvarsel

Meteogram for Ytterkleiva (20 moh.) neste 48 timer: (hentet ut kl:21:30)

Kommentar til været neste 3 døgn

Det har kommet store mengder nedbør som regn opp til minst 600 moh mandag og tirsdag. Onsdag vil det fortsatt være mildt, men avtagende temperatur på ettermiddagen. Ventes ca. 20 mm nedbør, mest første del av dagen. Torsdag 0-3 grader og ca. 15 mm regn, høyest temperatur og mest nedbør ettermiddag kveld.

Observasjoner

Snødekke og temperatur i løsneområdet

Snødybde: 27 cm kl 17, ned fra 55 mandag morgen.

Temperatur: 4° kl. 21:00

Bilde fra løsneområde 2024-01-09 kl. 13:50

Figure 3: An example on the layout of the first page of the slush flow bulletin.

The bulletin contains assessments for three or four days, including the rest of the day of publishing (day zero). Each day is divided into four periods: night, morning, afternoon and evening. To support the assessment the bulletin includes a graphical view of the weather forecast, a short summary of the weather forecast, observations of snow depth and temperature as well as a photo of the release area.

The bulletin was produced by avalanche staff from the Norwegian Public Road Administration.

3.2 Slush flow training

As a precaution it was mandatory to wear an avalanche beacon in the slush flow area when the assessed slush flow hazard was yellow or higher. This also applied when conducting tasks inside machines.

Most of the workers had never seen an avalanche beacon, so education was necessary.

A short lesson of theory was conducted at the office rig next to the construction area. The workers were divided into smaller groups and taken outside for a lesson in practical use of the avalanche beacon.

The layout of the slush flow bulletin was carefully explained to all the recipients at a meeting at the construction site rig. This was important to secure a common perception of the bulletin.

3.3 Observations in the release area

To get information on the conditions in the release area, it was decided to install a small weather station and two trail cameras.

The weather station was attached to a power line mast at the edge of the release area (*Figure 4*), and measured snow depth and temperature every hour. The data was sent 3 times a day to save battery and could be accessed through a web portal.

The cameras were attached to trees and overviewed the release area, sending pictures every hour. Due to trouble with connectivity and battery life, the trail cameras were replaced by a camera with pan, zoom and tilt functionality that could be accessed through an app.

Irregular UAS flights were also carried out to get an overview of the area.

Additionally, snow pits were made in the release area approximately once a month to study snow metamorphism.

Figure 4: A weather station was mounted at the edge of the release area.

3.4 Publication of the bulletin

The slush flow bulletin was normally published Monday, Wednesday and Friday on the common web platform between the contracting client and the contractors. If the hazard level was raised, an update was sent out daily in addition to an SMS containing hazard level and recommended measures.

The contractor started each day with a morning meeting where the bulletin was part of the fixed agenda.

4. RESULTS FROM THE SLUSH FLOW WARNING

The slush flow bulletin was produced for 152 days during the period from 2023-11-30 to 2024-05-08. The number of days with the different hazard levels can be seen in Table 1, with a total of 7 days of closed construction site. The 2 days of hazard level “red” was caused by a slush flow event on the 9 January 2024, where two slush flows hit the construction site and the highway RV80.

Table 1: Results from the slush flow bulletin, number of days with belonging hazard level.

Assessed level	Green	Yellow	Orange	Red
Number of days	137	8	5	2

4.1 Slush flow event 9 January 2024

On Monday 8 January the snow depth in the release area was 55 cm. The weather forecast indicated up to 50 mm of rain in 24 hours in the area. The Norwegian Meteorological Institute published a hazard forecast for rain with the amount of 70-90 mm rain in 24 hours from Monday to Tuesday.

Because of the relatively shallow snow depth in the release area, the anticipation was smaller slush flows. These small slush flows were considered a hazard for the construction site, but it was not expected that they would severely impact the highway. The hazard level was set to orange.

Monday evening the amount of rain and meltwater coming down the mountain entailed a small flood on highway RV80 in the slush flow area. Due to the amount of water and the high slush flow hazard it was decided to close the highway.

The next morning two slush flows were registered on the road, from slush flow paths 2 and 3. They caused no significant damage, but the construction site and road were filled with debris.

Figure 5: The slush flows registered 2024-01-09.

To open the road, the contractor would have to send a crew to clear the debris. It was still raining and the water content in the snow cover in the release area was high. Due to the risk of a slush flow in the primary path 1 (*Figure 1*) during clearing of the area, the high hazard level persisted. On Wednesday, the rain subsided, and the water content in the snow cover decreased. It was considered safe to begin work on opening the road and construction site.

5. EXPERIENCE FROM THE USERS OF THE BULLETIN

In the beginning of May there was no more snow in the release area, and the last day of the slush flow forecasting project was 2024-05-08. Afterwards, an evaluation was conducted to get feedback from the users. The feedback was positive from both the contracting client and the contractors. The slush flow bulletin was very useful for the construction site, and they respected the recommended hazard level. Despite working in a slush flow-prone area, the workers had confidence in the warning system and felt safe.

REFERENCES

European Avalanche Warning Services (EAWS). Site-specific avalanche warning, definitions and recommendations, 2022.