Planning for highways in avalanche-prone areas in Troms County, Northern Norway

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ABSTRACT

The Norwegian Public Roads Administration (NPRA) is challenged by nature during planning of new roads or renovation of existing roads. Steep mountain sides and limited suitable land for roads force the NPRA to plan for roads in areas prone to natural hazard processes. In the last years, the NPRA has been planning for new roads at several locations in Troms County, Northern Norway. Two of them are on E8 in Ramfjord and Lavangsdalen, 20 km respective 40 km from Tromsø. Dry-snow avalanches are the main concern for these new roads. A new Norwegian method for calculating acceptable risk on roads was applied to these road sections and it proved to be a challenge to reach desired risk level at several locations. A simple cost-benefit analysis was carried out for necessary mitigation measures. Lavangsdalen proved to be the most challenging location. It is known for long dry avalanche runouts and roughly every winter road travellers are hit by avalanches. Mitigation measures for the desired safety level proved to extremely costly and therefor mitigation measures for two other and lower safety levels were also worked out. It will be up to the NPRA to decide which safety level they go for in the final stages of this work.

1. INTRODUCTION

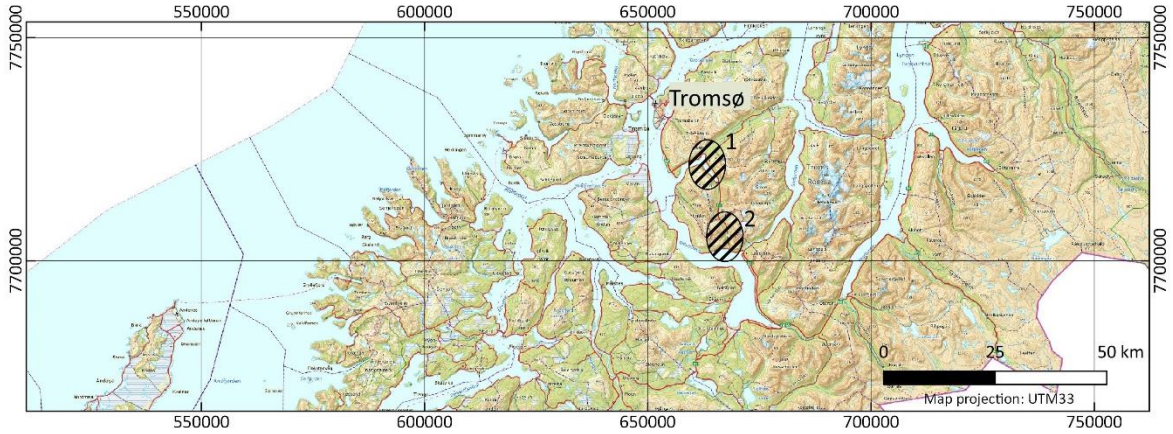

Figure 1. Overview over Troms county Norway. The road sections are shown as hatched areas. Area 1 shows the road section in Ramfjord, area 2 shows road section in Lavangsdalen. Background map: norgeskart.no.

The Norwegian Public Roads Administration (NPRA) is actively working on improvements of the road and highway network in Norway. The work on renovation of the E8 road section from

Tromsø to Balsfjorden southeast of Tromsø (areas 1 and 2 in Figure 1) has been going on for a while. The E8 is the main road and important transport route to the city from Finland. In 2015 the NPRA decided to work out a preliminary plan for mitigation measures against snow avalanches for road sections 1 and 2. These road sections are mainly threatened by snow avalanches, but slush flows may also occur. This work is described in (Norges Geotekniske Institutt NGI, 2017a, 2017b).

2. CRITERIA

2.1 Ramfjorden – Indre Laukslett/Nordbotn

2.1.1 Criteria

In 2014 NPRA presented at guidelines for acceptable risk on highways in Norway (SVV, 2014). These guidelines are the main criteria for preliminary design presented in this work.

In the work presented here NPRA has planned for annual average daily traffic in twenty years (AADT20) to be between 4000 and 8000 vehicles/day; 8000 vehicles/day was set as the design value. According to Figure 2 in the guideline this traffic volume would according to probability class VI or probability of closure f be between 1/100 and 1/1000 pr. unit length of road (1000 m in the guidelines).

Two avalanche simulation models are used for this road section, Voellmy MoT (from NGI) for Indre Laukslett area and RAMMS (Christen et al., 2010) for the Nordbotn area. Data from RAMMS simulation were already available for the Nordbotn area when this work started, and it benefitted from it.

2.1.2 Hazard assessment and mitigation measures

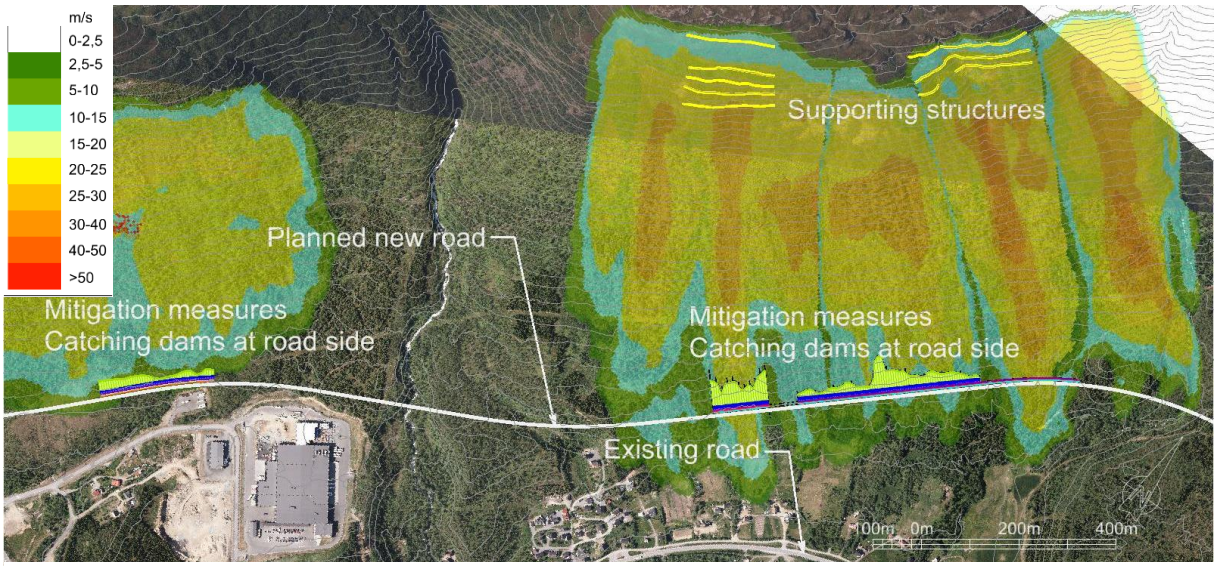

Figure 2 The figure shows the location of new planned road E8 at Indre Laukslett (to the left) and Nordbotn (to the right) in Ramfjorden. Proposed supporting structures are shown with yellow lines and the colored areas are avalanche simulations from Voellmy MoT to the left and RAMMS to the right. The simulations shown are without any mitigation measures. The distance between the light gray contour lines is 10 m. Aerial photo: Norgeskart.no.

The avalanche site to the left in Figure 2 does not have any registered avalanches to the planned road but tree damages at the starting zone indicate some activities and the topography indicates the possibility that avalanches can reach the road. There are several registered avalanches at the avalanche site to the right some of them stopping just above the residential area.

The planned relocation of the road E8 at the residential area at Indre Laukslett and Nordbotn in Ramfjorden has the aim to improve the road geometry and move the traffic from the residential and coastal area further away. However, this relocation comes with a cost as the avalanche hazard must be mitigated for parts of the road.

The avalanche risk at planned road at Indre Laukslett area (to left in Figure 2) is little and only small, approx. 6.5 m high catching dam above the planned road is needed to mitigate the risk to an acceptable level. The catching dam geometry is similar to the one shown in Figure 3.

At Nordbotn the planned road is in steep terrain where mitigation measures are needed, and only limited space is available for large catching dams. By combining small catching dams and supporting structures in the starting zone the risk for the road traffic is mitigated to an acceptable level. Figure 3 shows a typical cross section in planned road and a catching dam at Nordbotn.

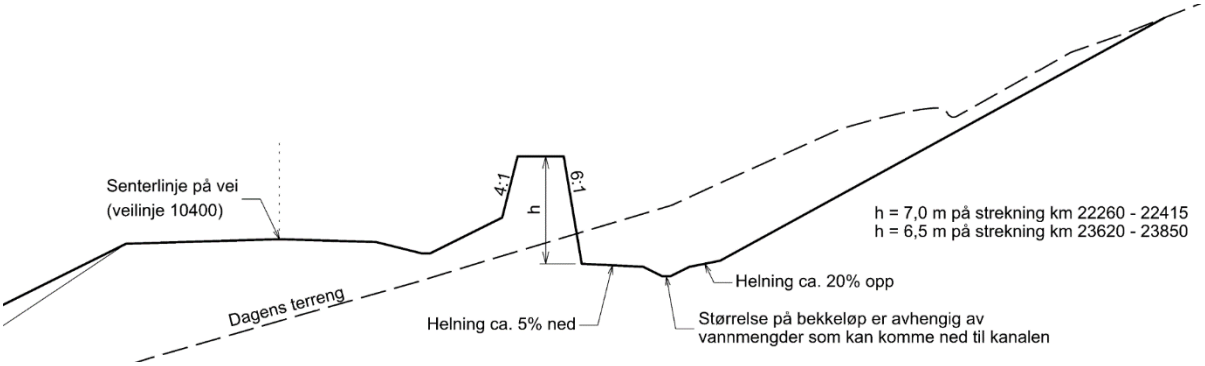

Figure 3. Typical cross section in planned road and a catching dam in Nordbotn.

2.2 **Ramfjorden-Sørbotn**

2.2.1 Criteria

AADT20 and safety level is the same as in chapter 2.1.1.

RAMMS avalanche simulation model was used for this road section as most of the simulation had already been done when planning the mitigation measures started.

2.2.2 Hazard assessment and mitigation measures

Hazard assessment for this road section was done by NPRA in 2014 (Larsen, 2014) and in 2015 NGI worked out hazard assessment for large area of Troms county where Sørbotn was part of the work (Norges Geotekniske Institutt NGI, 2015).

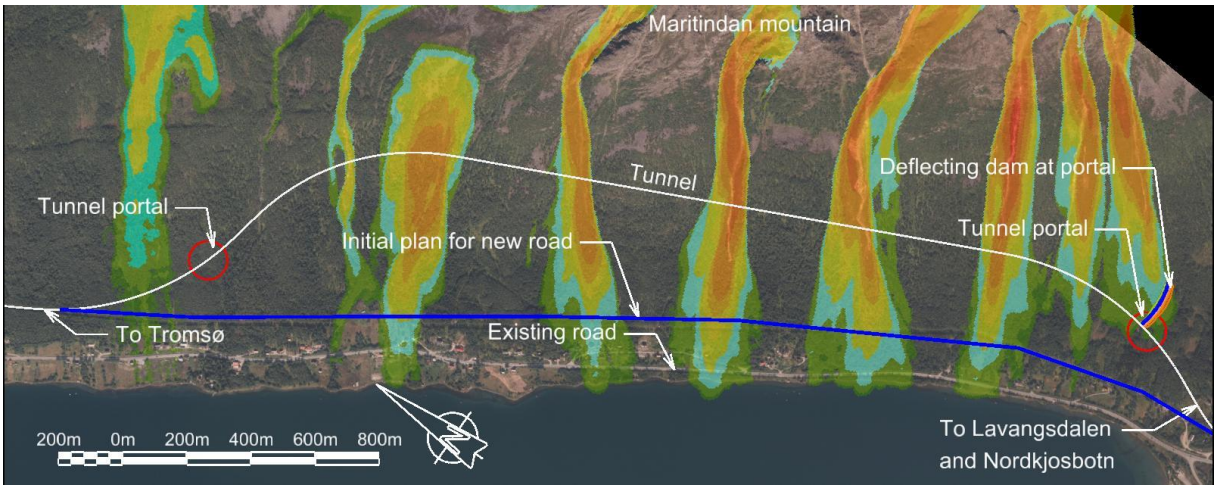

Figure 4. The figure shows avalanches from Maritindan mountain in Sørbotn, Ramfjorden. Blue line shows initial road alignment, white line shows the new planned road E8 in a tunnel and red circles show the tunnel portals. The main avalanche tracks are shown with colored areas (RAMMS simulation), avalanche velocity scale is shown in Figure 2.

Avalanches from Maritindan mountain are well known but they have not reached the settlement in recent years. The initial plan for new road alignment is shown in Figure 4 as a blue line just above the settlement along the coast line. Passing the avalanche paths was a huge challenge as all changes in existing terrain might contribute to unforeseen consequences for the settlement below. Galleries were considered but they would have been costly and might have increased the avalanche runout distance. Steep terrain is not favorable for large catching dams of earthen material and they were not really an alternative here. Tunnel was the only option left but there was a problem to find a suitable location for the portals due to excess of loose material and bad rock. The white alignment in Figure 4 shows the proposed location today. A short deflecting dam above the east portal is proposed as avalanches might hit the portal and cause closures. The height is set to approx. 5 m, but it has to be reconsidered in the detail design phase as snow drift might reduce the effective height.

2.3 **Lavangsdalen**

2.3.1 Criteria

The traffic volume AADT20 is the same as for previously mentioned sections and in the beginning the probability of closure f was between 1/100 and 1/1000 pr. unit length of road. As work progressed NPRA wanted also to check the magnitude of mitigation measures for probability of closure f 1/50 - 1/100 and 1/20 - 1/50.

Vollemy MoT avalanche simulation model from NGI was used for this road section.

2.3.2 Hazard assessment and mitigation measures

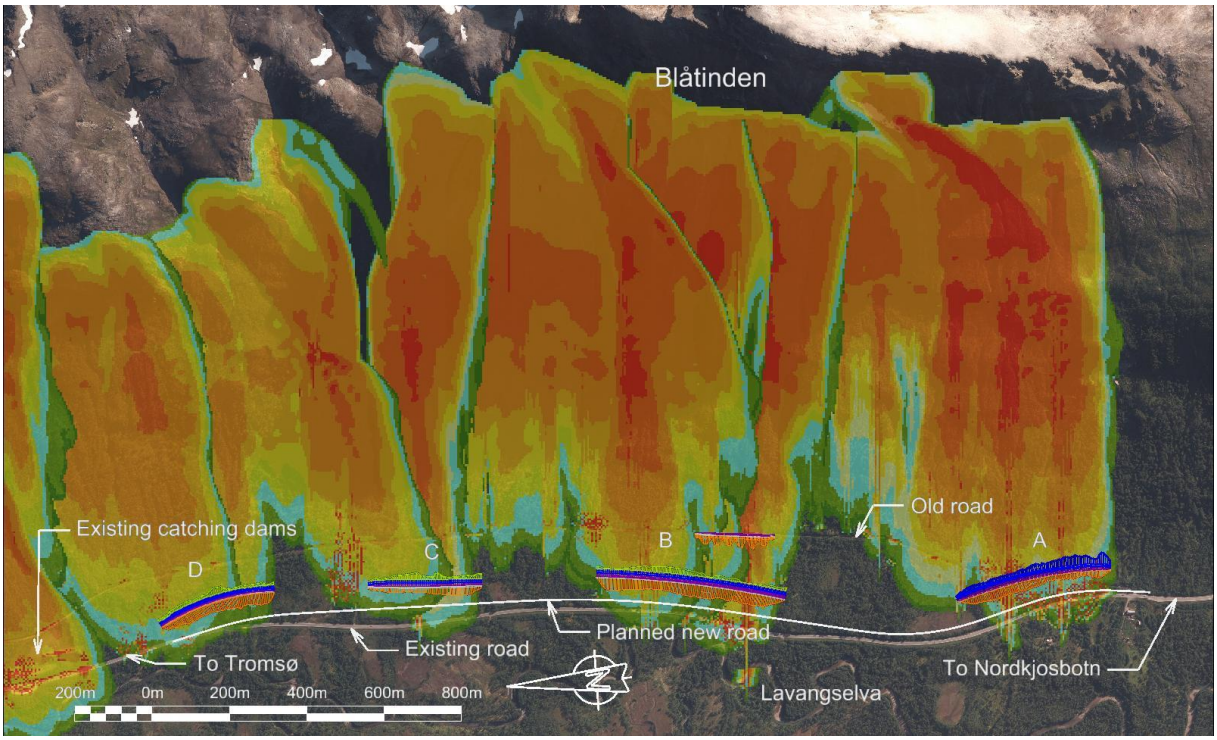

Figure 5. The avalanche site in Lavangsdalen. Planned new road E8 is shown with white line, proposed catching dams are shown with orange and blue colors, and avalanche paths and simulated avalanche velocities (with Voellmy MoT) are shown as the colored areas. Velocity scale is shown in Figure 2.

No hazard assessment was available for this area prior to this work. The aim of this work was not to make hazard maps but to assess the hazard and plan for mitigation measures.

Lavangsdalen is known for its avalanche problems during winter time. In recent times avalanches have hit vehicles in the northern part of the valley but fortunately without any fatalities. As NPRA is planning to relocate approx. 3 km of existing road E8 at the southern part of Lavangsdalen (Figure 5) an assessment of the avalanche danger was worked out for the new location. Several scenarios of simulated avalanches were checked, Figure 5 shows the case for probability of closure 1/50 - 1/100. The other simulation scenarios 1/100-1/1000 shows longer runouts and larger volumes, and 1/20-1/50 shows shorter runouts and less volumes.

To mitigate the avalanche hazard supporting structures were considered in the starting zone as well as catching dams just above the planned road. A large volume of supporting structures, approx. 20000 m to 40000 m, were considered to fulfill the initial safety criteria or 1/100 to 1/1000, but the estimated cost proved to be enormous and therefore not a realistic alternative and was put aside.

Figure 5 shows the avalanche simulation for probability of closure 1/50-1/100. Four main areas A-D in Figure 5 are identified where avalanches can hit the road. Of those four area B has the largest volume and highest avalanche velocity. It was necessary to add one line of approx. 8 m high mounds some 80-100 m uphill to reduce the velocity at catching dam enough to be able to build a catching dam.

Ground investigations revealed that catching dam B was located on a quick clay area and the geotechnical stability could not be secured without extensive ground/base stabilization. Also, one of the criteria for stability is to excavate as little as possible above the dam as the upslope stability would be threatened.

The proposed height of catching dam B is 15 m with the mound's upslope, other catching dams at areas A, C and D are between 8 and 13 m high. The geotechnical engineer's advice for the other catching dams is also to reduce excavation upslope due to possible stability problems. Almost all building material must be transported to the site.

The proposed cost of these catching dams is high and therefore NPRA asked for further study of mitigation measures with reduced level of safety or 1/20 to 1/50. Avalanche simulation for this level reveals that only area B will need a catching dam to meet acceptable safety level. The proposed dam height in this case is 13 m and the length are approximately 280 m.

3. EPILOG

The renovation and relocation of highway E8 in Ramfjord and Lavangsdalen is as of today still in a planning phase. It is unclear when NPRA will be able to fund the construction of these road sections and it is also unclear which safety level they will accept for the road sections.

REFERENCES

Christen, M., Kowalski, J., Bartelt, P., 2010. RAMMS: Numerical simulation of dense snow avalanches in three-dimensional terrain. Cold Reg. Sci. Technol. 63, 1–14. https://doi.org/10.1016/j.coldregions.2010.04.005

Larsen, J. O., 2014. E8 Sørbotn – Lauksletta. Vurdering av skredfare og sikring på østre alternativ. Statens vegvesen/NPRA, Oslo.

Norges Geotekniske Institutt NGI, 2017a. E8, Indre Laukslett – Sørbotn. Vurdering av skredfare og forslag til sikring til reguleringsplan (No. 20150792-02-R). Oslo.

Norges Geotekniske Institutt NGI, 2017b. E8 Laksvatn–Storskreda. Vurdering av skredfare og forslag til sikring til reguleringsplan (Foreløpig) (No. 20150792-01-R). Oslo.

Norges Geotekniske Institutt NGI, 2015. Skredkartlegging i Tromsø (No. 20150388-01-R). Norges Geotekniske Institutt NGI, Oslo.

SVV, 2014. NA-rundskriv 2014/08. Retningslinjer for risikoakseptkriterier for skred på veg. (No. 2014/08). Statens vegvesen/NPRA, Oslo.