Wind simulation for Longyearbyen mitigation measures

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ABSTRACT

The national and local authorities in Norway have initiated the second phase of mitigation work in Longyearbyen Svalbard archipelago. The work is a continuation of earlier work carried out in 2017–2018 and the aim is to protect infrastructure, mainly houses and hotels, from processes as snow avalanches, slush flows and debris flows. The planned mitigation is a combination of physical structures and removal/relocation of buildings. Wind is not directly one of the processes leaving the infrastructure at risk but plays an important role in the snow distribution in this open and bare landscape. Any physical measures located near buildings will affect the local wind flows and it can cause unwanted snow accumulation or wind fields that can cause problems for the traffic.

The authors have earlier used wind simulation (CFD model) on a small-scale surface model to study wind fields around planned roads and highways, and mounds for snow avalanches. The aim of this work is to find out if planned deflecting dams made for slush flows along the river "Vannledningselva" will cause unfavourable wind fields for roads and buildings. Three wind directions were modelled with boundary windspeeds of 15, 20 and 25 m/s at three elevations 2, 5, 10 m height over the surface model.

1. INTRODUCTION

The aim of the second phase of mitigation work in Longyearbyen is to protect the residential area for dry snow avalanches from Sukkertoppen mountain and from slush flows from Vannledningsdalen valley. A preliminary study of mitigation measures for The Norwegian Water Resources and Energy Directorate (NVE) and the local authorities, Longyearbyen lokalstyre (LL) was carried out early winter 2018/2019 (Jonsson et al., 2018). The findings show that supporting structures in part of Sukkertoppen mountain together with a small catching dam in the runout zone will protect the centre of the town, and two deflecting dams alongside the Vannledningselva will protect the residential area below Hilmar Rekstens road and at Haugen area.

These two deflecting dams will start at the apex of the river/debris flow fan above the residential area at Haugen (Figure 1) and reach the main river, Longyear river, in the middle of the Longyear valley. The total length is approx. 600 m. The proposed measures have to cross the main road between Nybyen residential area and the town centre. The crossing is challenging in many ways such as how to divert the slush flow when it crosses/passes the road (where a new bridge will be built) and how to form the dam ends at the road side. Another problem the dams

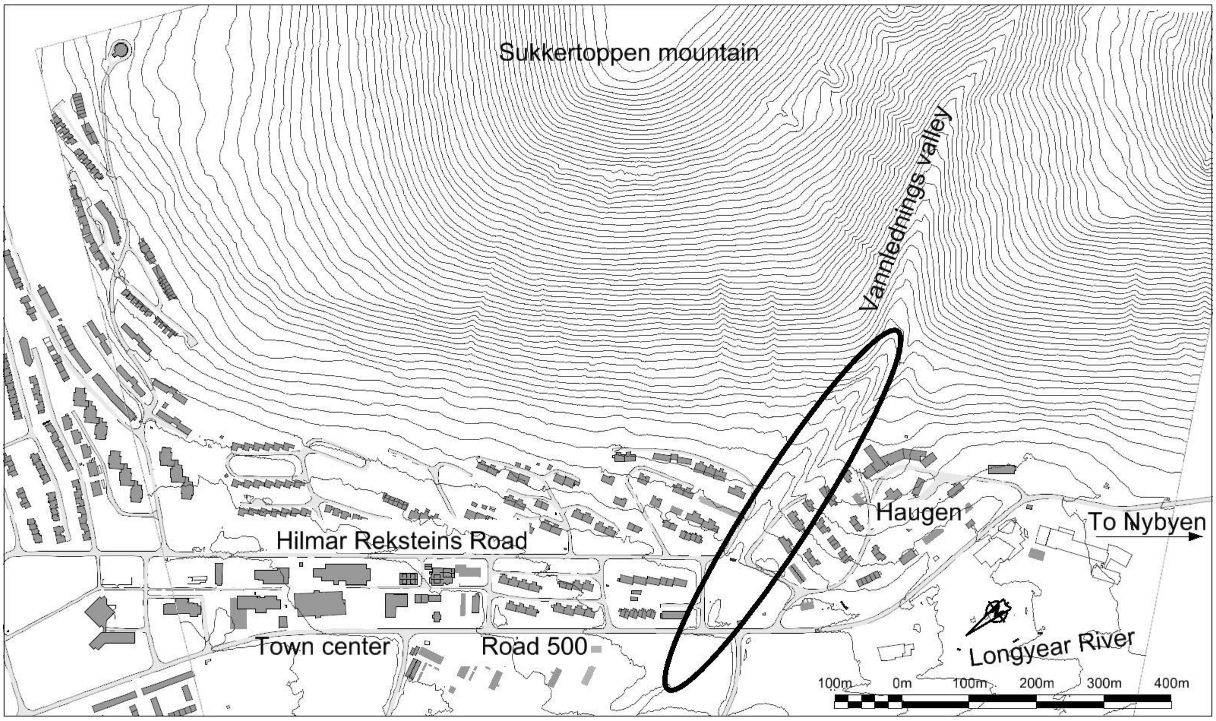

Figure 1 Overview over Longyearbyen and Vannlednings valley. The planned location of the deflection dams along the Vannledningselva is inside the ellipse.

will cause are wind currents and/or turbulences at the main road. Three main wind directions are thought to affect the road at the crossing. Wind is also the main contributor to relocation of snow and snow drifts can have unwanted effects on the roads and housing when the deflecting dams are in place.

Wind simulation for snow avalanche mitigation measures has previously been described in (Jónsson and Þórðarson, 2003) where wind fields and possible snow accumulation around mounds was studied and in (Þórðarson and Jónsson, 2005) where CFD simulation was used to try to understand snow drifts in an area with planned supporting structures in Hafnarhyrna mountain Siglufjordur Iceland.

One of the main concerns about the deflecting dams and planned new bridge is how much drifting snow will accumulate in the canal between the deflection dams during winter time and if the drifts will cause problems for slush flows to flow under the planned bridge in a slush flow incidence. Too much snow might require removal of it in order to maintain the function of the canal and bridge. Concerns are also raised about snow drifts around buildings and reduced visibility and drifts at Road 500.

The main purpose of the wind simulation is to map the wind fields around the deflecting dams at micro scale and to interpret how snow will accumulate.

2. WINDSIMULATION METHOD

There is a broad variety of CFD models on the market that can simulate wind, but fewer models simulate drifting snow. The authors have some experience of wind simulation and interpretation of the wind fields but much less experience with these particle CFD models. Neither the budget nor the time frame allowed for the study of particle CFD models.

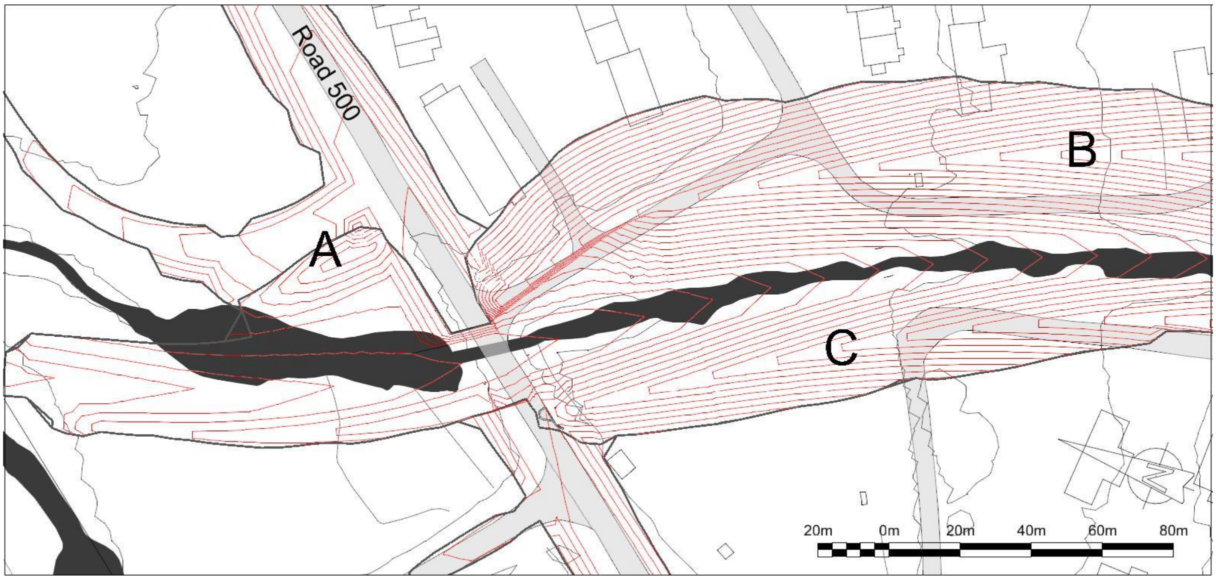

Figure 2 The figure shows Vannledningselva (dark shapes), Road 500 and the planned deflecting dams on both sides of Road 500 (red contours). Letters A-C depict top of dams. The distance between contour lines at the dam is 1 m. This digital elevation model of the deflecting dams was used in the wind simulation in early stage, but the final design will be somewhat different at Road 500, but it is expected that the main principles will be the same. The model shows the cut through road 500 for the river.

The wind flow was simulated using the WindSim software which is a specialized tool for wind simulation in complex terrain. The engine of WindSim is a PHOENICS solver which is a general-purpose CFD software package widely used in different industrial and research communities.

The digital surface model (DSM) for the area is based on a high-resolution point cloud model were existing buildings were part of the model. The deflecting dams were merged onto the DSM with grid resolution of 2 m. In addition, Aster Gdem v2[1] Worldwide Elevation Data was used for the outer domain. Roughness is based on GLC30[2] and roughness contours manually captured from Google Earth imagery. The size of the DSM was 2,4x2,65 km and the total simulation domain is a box with dimension of 2,4x2,65x4,7 km. The total number of cells was approx. 2,9 million (WindSim AS, 2018).

The inlet wind directions were: 40°, 220° and 340° and wind speed 10 m/s, 20 m/s and 25 m/s. In total 9 simulations were performed to have 3D wind field for ±15° around the inlet directions. Wind velocity plots are shown at 2 m, 5 m and 10 m above ground for the wind direction of 40°, 220° and 340°. The wind directions 40° and 220° are in and out Longyear valley and 340° is along Vannlednings valley. The wind directions 40° and 220° are used in the further work as they represent wind approx. perpendicular to the dams.

[1] https://asterweb.jpl.nasa.gov/gdem.asp
[2] Global Land Cover with 30 m resolution.

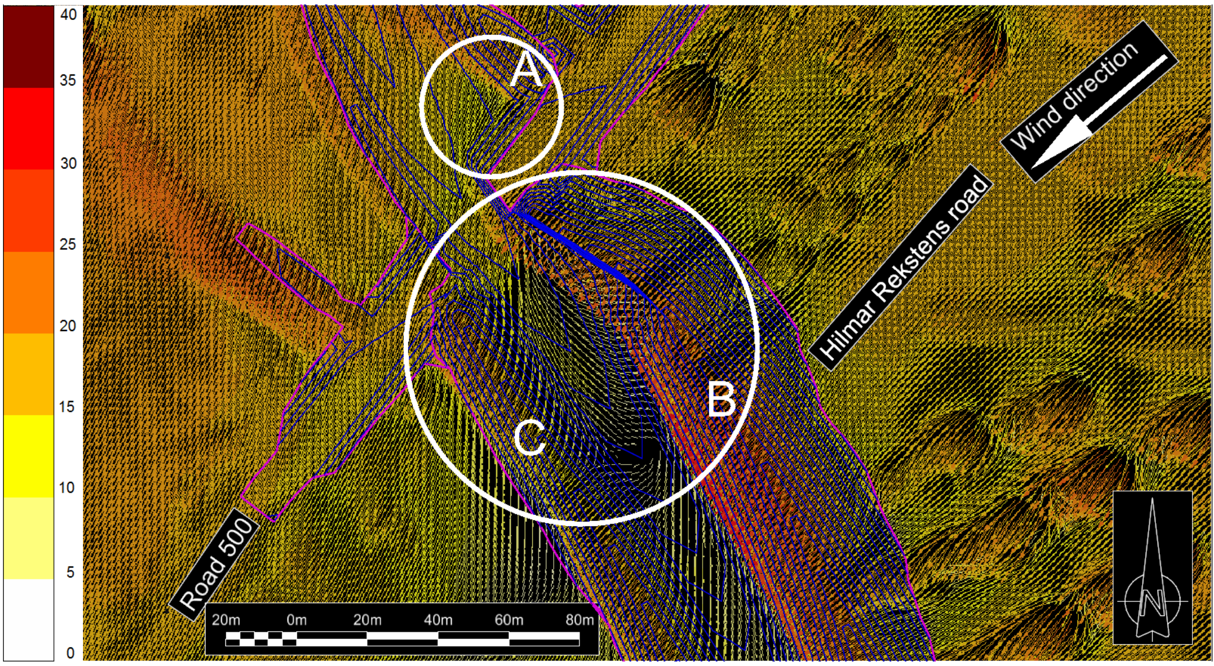

Figure 3 The figure shows wind speeds as colored vectors. Wind speeds in m/s are shown on the scale to the left. The deflecting dams and Road 500 (blue contour lines) are shown as blue contour lines in the background. Boundary wind direction (40°) is shown at the upper right corner and boundary wind speed is 20 m/s for wind 2 m over surface. Letters A-C shows the location of the dams.

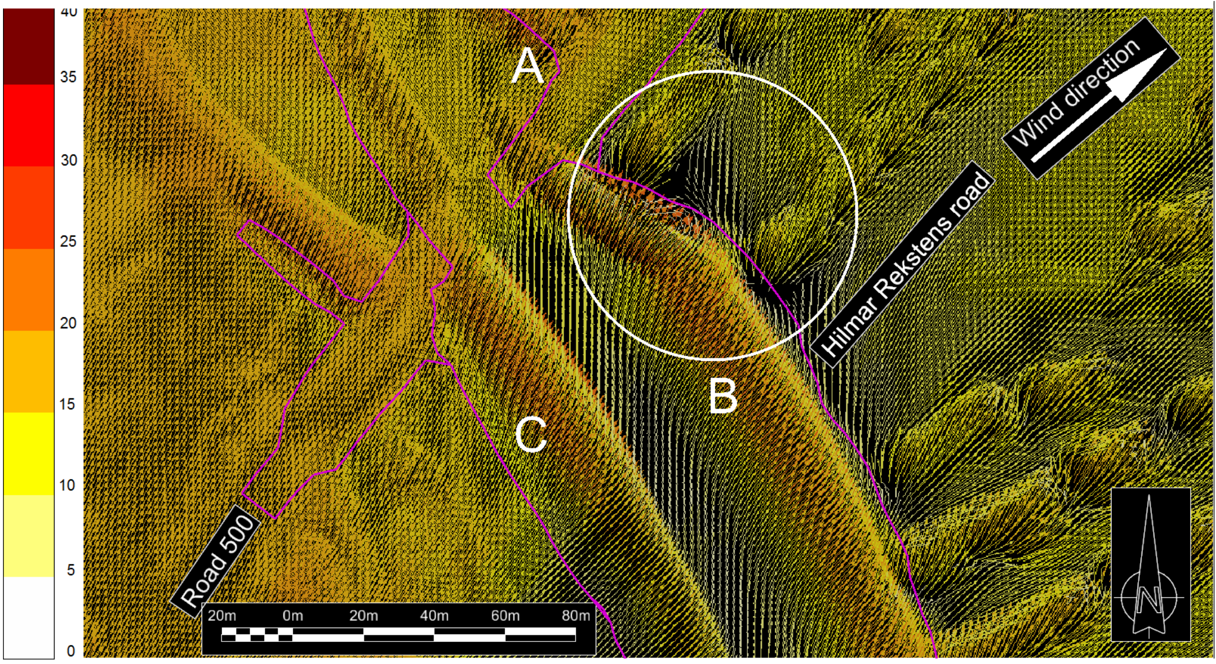

Figure 4 Wind speeds are shown here as colored vectors. Wind speeds in m/s are shown on the scale to the left. The deflecting dams and Road 500 (purple outlines) are shown in the background. Boundary wind direction (220°) is shown at the upper right corner and boundary wind speed is 25 m/s for wind 2 m over surface. Letters A-C shows the location of the dams.

3. RESULTS

The results from the high-resolution wind simulation at the crossing of Road 500 and the deflecting dams are shown in Figure 3 and Figure 4. No wind simulation has been done for the existing terrain/surface and infrastructure and therefore we do not know if wind from 40° or 220° will cause increase in wind and snow drift accumulation due to the dams.

Figure 3 show relative strong wind flow along the Road 500 past dams A and B (see also numbering in Figure 2). A small "lee" zone can be seen below the Road 500 and dam A. The most important and interesting area is between dams B and C and Road 500. The wind simulation indicates a large lee zone up to 100 m from Road 500. At the same stretch the dam height is changing from 8 m near the road to 12 m further up. The vector lines show the wind blows around the dam end at the road and then turns up the canal; part follows the steep dam face at northern deflecting dam and a bit stronger wind turns to the south and passes the southern deflecting dam (C). The wind blows also over the dam top and it is quite strong. A combination of these wind fields seems to cause a vortex starting at Road 500 and fading out approximately at line between B and C on Figure 3 (the black spot in the canal). A contributor to all this might also be the wind around the buildings along Hilmar Rekstens road which also hits the dam just about where the dam has reached its highest part. Snow drifts can expect from the road and upward in the canal. It is also interesting to see how the buildings below and above Hilmar Rekstens road contributes to lower wind speed at the dam compared to the open space at Hilmar Rekstens road.

Further up the dam one can expect cornices at lee side of dam top on both deflecting dams. The wind simulation shows the wind blowing up the canal for some 40-70 m before the it turns to south and over the south deflecting dam C.

As mentioned earlier the wind simulation indicates increase in wind on Road 500 at the dam crossing for wind blowing in the valley (40°). Prior to the wind simulation work snow drifts were expected to form at the end of the dams at the road but the simulation does not indicate this in the same extend.

For wind direction out the Longyear valley (220°) the wind simulation indicates much less force in the wind at the deflecting dams than for the opposite wind direction (Figure 4); here wind speed is 25 m/s to make coloured vectors more visible. The residential area on Haugen contributes to relatively large lee area from the buildings to dam C. Interesting is the lee side just above Road 500 north of dam B. Wind that passes the dam hits the roof tops with little lower wind speed but between the buildings and the dam appears to be a vortex that might contribute to snow accumulation at planed pathway and buildings at the north side of the dam.

Above the residential area, at the apex of the fan, the simulated wind flows partly down Vannlednings valley between the dams and large cornices are not expected but further down cornices are expected.

A similar condition to the upper part of the dams at Vannledningselva are the catching dams in Bolungarvik Iceland, Figure 5. Wind did blow along the dams and none or only small cornices were formed at dam top. Further to the left (outside the figure) a curvature in the dam geometry caused a lee area outside the dam where snow accumulated. The opening between the dams canalize the wind and that might help clearing the dam slopes of snow.

Figure 5 Snow drifts around houses and catching dams in Bolungarvík Iceland after a storm period; wind was blowing from upper right corner to the left, see yellow arrow. Source: Google.com/Maps.

4. CONCLUSIONS

The deflecting dams discussed in this work have not yet been built and therefore we cannot verify the findings discussed in this article. The wind simulation results are interpreted and correlated to the authors knowledge from other works and observations from real dams and residential areas. The authors claim that wind simulation software like in our case WindSim are useful tools for studying small scale wind fields around mitigation measures like dams. From the wind fields the snow accumulation areas can be predicted by studying the gradient and lee areas but the limitation is that the volume of snow cannot be predicted.

It will be interesting to follow up this work when the deflecting dams have been built, maybe around 2024-2025, and some experience has been gained from winter conditions.

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