ESTIMATION OF AVALANCHE HAZARD IN THE SETTLEMENT OF MAGURKA USING ELBA+ MODEL

POSÚDENIE OHROZENOSTI OSADY MAGURKY LAVÍNAMI S POUŽITÍM MODELU ELBA+

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Abstract

In our study we focused on advanced software applications to allow simulation of an avalanche. We used the model ELBA+, by which we tried to assess the vulnerability of mountain environments around the old mining settlement called Magurka (1036 m a.s.l.), which lies below the main ridge of Low Tatras at the end of Ľupčianská valley. The avalanche in the Ďurková valley released on 14th March 1970 went down in history because it is still one of the largest avalanches recorded in Slovakia. Using archived data of the Avalanche Prevention Centre in Jasná, we tried its most faithful reconstruction. Then we tried to simulate an avalanche in the Viedenka valley using the same amount of snow in the release zone as it was supposed to be in 1970. Because a part of the Magurka settlement is situated at the mouth of this valley, which has more direct and shorter terrain than the valley of Ďurková, we examined the possibility of intervention by the avalanche.

Abstrakt

V našej štúdií sme sa zamerali na moderné softvérové aplikácie umožňujúce simuláciu lavíny. Použili sme model ELBA+, pomocou ktorého sme snažili zhodnotiť ohrozenosť horského prostredia v okolí starej banskej osady Magurka (1 036 m n. m.), ktorá leží v závere Ľupčianskej doline pod hlavným hrebeňom Nízkych Tatier. Do histórie sa zapísala hlavne lavína v doline Ďurková zo 14. marca 1970, ktorá dodnes patrí medzi najväčšie lavíny zaznamenané na Slovensku. S použitím archívnych údajov Strediska lavínovej prevencie v Jasnej sme sa pokúsili o jej čo najvernejšiu rekonštrukciu. Následne sme sa pokúsili o simuláciu lavíny v doline Viedenka pri použití rovnakej výšky snehu v odtrhovom pásme ako sa predpokladá pri lavíne v roku 1970. Keďže časť osady Magurka je situovaných pri ústí tejto doliny, ktorá má priamejší aj kratší priebeh ako dolina Ďurková, skúmali sme možnosť jej zásahu lavínou.

Key words:avalanches, model ELBA+, Magurka, Low Tatras Mts., upper forest limit

1 INTRODUCTION

Avalanches are a frequent phenomenon of our mountain landscapes during winter. They pose a threat to inhabitants of the mountains areas, skiers, climbers and tourists. In the past, people were looking for possibilities how to protect against avalanches. In order to avoid a formation of avalanches or minimize their destructive consequences, different measures are used. These might be in a technical, biological or organizational form [4]. In the process of making a decision about prevention and technical avalanche measures, software applications may help, mainly in the form of simulation programs. Their purpose is to faithfully describe the movement of an avalanche in an endangered area. The mentioned applications allow us to determine the parameters of potential avalanches (mainly the avalanche length) by using specific terrain and concrete conditions of snow cover. These help us to make decisions on evacuation, closure of the area or landscape planning. Furthermore, there are good accessories for dimensioning technical measures. It is necessary to say that the applications are only simulation models of upcoming situations. The degree of similarity between simulation and reality depends on the quality of input data. The models can be classified according to more aspects: one or more dimensional, fluent, powder or combination models. The best known applications are RAMMS, ELBA+, Samos AT, AVAL 1D, Alfa-Beta.

2 MATERIAL AND METHOD

2.1 Characteristics of area

Our research was carried out in Magurka, an old mining settlement. It is located at an altitude of 1 036 m.a.s.l., at the end of the Ľupčianská valley, below the main ridge of the Low Tatras Mts. (Slovakia) in the part of Chabenec - Latiborská hora Mt. (Fig.1). The settlement administration belongs to a town of Partizanska Lupča, but it is located 20 km away from it.

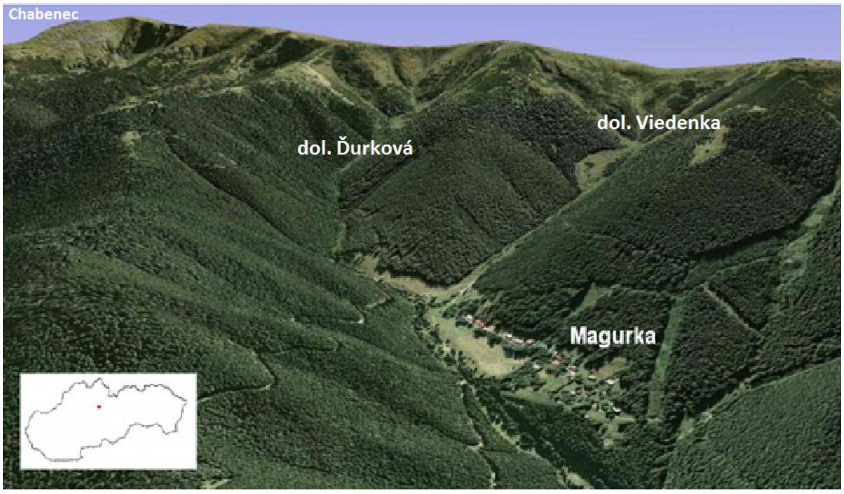

Fig. 1 Magurka settlement and its surroundings [4]

Surroundings of Magurka are from a geological aspect mainly made from rocks of Tatricum crystalline [10], on which cambi-podzolic soil and at higher altitudes modal and humus-iron podzolic soil [9] are found. The forest consists mostly of spruce (*Picea abies*) with addition of fir (*Abies alba*) and beech (*Fagus sylvatica*), at higher altitudes with addition of rowan (*Sorbus aucuparia*), alder (*Alnus viridis*) and dwarf pine (*Pinusmugo*) [8].

2.2 ELBA+ model

ELBA + is fully integrated into ArcGIS 10. When working with geographical data, it is not necessary to convert input or output data. The program development has been running for 15 years by the NiT-company located in Pressbaum, Austria. At present, we work with the 3th edition. The program creates a 2D simulation model and was used in countries such as Russia, Bulgaria and Switzerland. The utilisation for the purpose of education is free. For the data administration, it is necessary to create a database of programs. This is directly possible from ArcGIS, which is the most frequent GIS-application [7]. The input data for the simulation are represented by Catchment, Size of release area and Digital elevation model (DEM). The following layers were shown automatically during opening the database:

ELBA_CATCHMENT – definition of area

ELBA_CONTOURS – in these layers we can see the results of simulation, lines of selected avalanche characteristics (max. pressure, max. velocity, max. flow height, deposit, avalanche front ...)

ELBA_PROFILES – interesting lines as roads, power lines, tunnel…

ELBA_RELEASEZONES – release zone

ELBA_SIMCLIPS – layer with supplementing data for simulation, for example forest cover…

Catchment, Profiles, Release zones and Forest cover are loaded using the order editor. The next step is to import terrain in a form of DEM or TIN. The suggested pixel resolution of the DEM is 5-10 metres. Later, the following parameters are inserted for the simulation: Snow height in release zone, Height of snow entrainment in avalanche path, Roughness and Terrain model. These input parameters can be entered for the whole area, or possibly for a raster or a polygon. Now we can choose from three roughness models: Voellmy, Mohr-Coulomb and their combination. Here we can edit further parameters as Minimal flow height, Snow density and Critical stress.

Fig. 2 Input data for avalanche simulation from year 1970

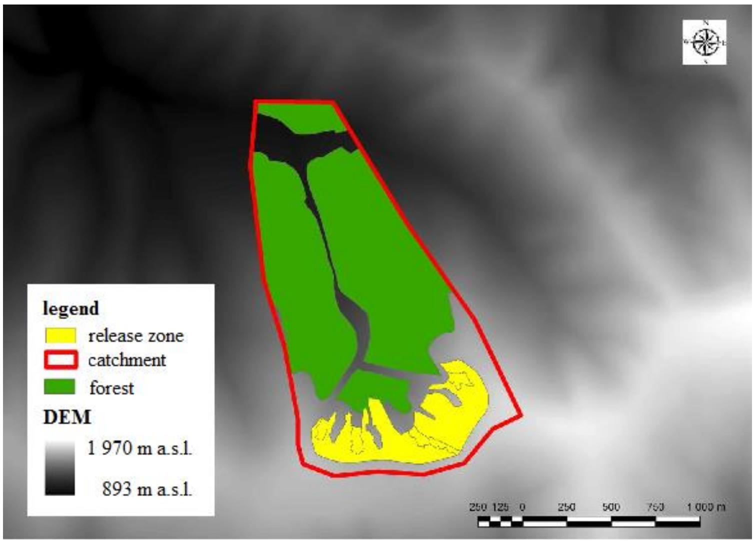

Fig. 3 Input data for avalanche simulation in Viedenka valley

In the first step of our work, we tried to create the most faithful reconstruction of the avalanche released on 14th March 1970. We used archived data from the Avalanche Prevention Centre in Jasná: the layer of avalanche, the data on deposit, snow density, weather, the snow height in the release zone and photos. The best model for this avalanche was the combined roughness model with an average snow height in the release zone of 1.7 meters, a roughness coefficient for the forest 1 and in an non-forest area 0.2, a minimal flow height of 1 metre and the height of snow entrainment in the avalanche path of 0.5 meter. Accordingly with these parameters, the potential avalanche in the Viedenka valley and the real avalanche released on February 2013 were simulated.

The data for simulation were obtained from an archive from the Avalanche Prevention Centre. The actual orthophotos, DEM, polygons of the release zone, the forest position in past were obtained from the Centre. The actual forest position was obtained from the orthophotos with a pixel size of 0.5 meters in a coordinate system S JTSK Krovak East North. DEM with a pixel size of 5 metres was generated from a contour line with the vertical interval of 5 metres. Figs. 2 and 3 show the input data of simulations.

3 RESULTS AND DISCUSSIONS

3.1 Reconstruction of avalanche from year 1970

We confront our results with another two sources: Milan and Kresák[5]and Biskupič et al. [2]. The first source consists of information from avalanche observers, employees of the Avalanche Centre who accurately recorded the avalanche path and the deposit. The avalanche released on 14th March 1970 was the third largest in Slovakia and it aroused much interest. Thus, at present, we have good information about the position of the release zone, the avalanche path and the deposit size. Biskupič et al.[2] used these data for the faithful reconstruction by using the RAMMS model. This two-dimensional numerical simulation tool is used to calculate the geophysical mass movements as snow avalanches, hillslope landslides and debris flows. The model was developed at the WSL Institute for Snow and Avalanche Research, SLF in Davos [1].

Our result of the avalanche reconstruction from the year 1970 is characterized by a high value of conformity, mainly in the avalanche length. Our simulated avalanche length is 8 metres shorter than the measured value of the avalanche length. In this avalanche with a length of 2 200 metres, the difference is 0.4 %. We remind that the pixel size in the raster result was 5 metres. We summarize that our simulation of the avalanche length corresponds exactly to reality. Biskupič et al. [2] who used the RAMMS simulation brings a similar conclusion.

When evaluating the avalanche cubature, we obtained a little underestimated result (- 10 %). This result was influenced by the parameters like Snow height in release zone and Snow entrainment in avalanche path. In our simulation, we used a snow height in release zone of 1.7 metres and an entrainment snow height of 0.5 metres. Especially these parameters show the most significant uncertainty. In an avalanche report, Milan and Kresák[5] estimated a minimal snow height in release zone of 1.8 metres, in glens 12 metres and an average snow height of 2.6 metres. The most accurate is the exact snow allocation in the release zone for each raster cell. This is not simple and it is possible only with exact weather data, such as wind speed, wind direction, snow fall amount during the time period before the avalanche fall.

Tab. 1 Comparison of model results from ELBA +, RAMMS with reality

Parameter	Measured value[5]	RAMMS result [2]	ELBA+ result	Difference between reality and ELBA+	Difference
Avalanche length [m]	2 200	2 221	2 192	8	-0.4%
Deposit length [m]	1 800	1 725	1 800	0	0 %
Deposit cubature [m^3]	625 000	626 029	563 858	- 61 142	-9.8%
Avalanche front height [m]	20-25	4-5	4-5	-16-20	-80%
Total area [ha]	39.1	51.4	51.2	12.1	+30.9 %

The most significant undervaluation (80 %) we can see in the avalanche front height. In the first place, the possible deviation sources might be the non-ability of the model to simulate the entrainment of other materials into the avalanche flow. The forest covered lower and peripheral upper parts in the avalanche path (Fig. 2). In such large avalanche, the forest was totally destroyed in the avalanche path. Materials as broken trunks and boughs, which were in the avalanche flow, changed their inner friction. The avalanche decelerated and the force from backside uplifted its front. In the Elba+ simulation, the forest is only an external braked factor which changed from the value of 0.2 in the non-forest area to the value of 1 in the forest. Other materials (such as wood, rocks…) in the avalanche increase its destructiveness [3]. Milan[6] states that the avalanche destroyed 3.6 ha of the forest with 600 m^3 of wood.

In our case, the total avalanche area is overestimated by about 31 %. Our simulated avalanche is more widespread in side, more diffluent. In reality, it was more located in the valley. The primary result was widespread, but after an adjustment of the minimal flow height from 0.1 m to 1 m, it reached better conformity with reality. The problem with too wide simulated avalanche was indicated by Volk [12] as well. Fig. 4 shows the

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differences between the deposit and the path in our simulation of the avalanche and the layout from the year 1970.

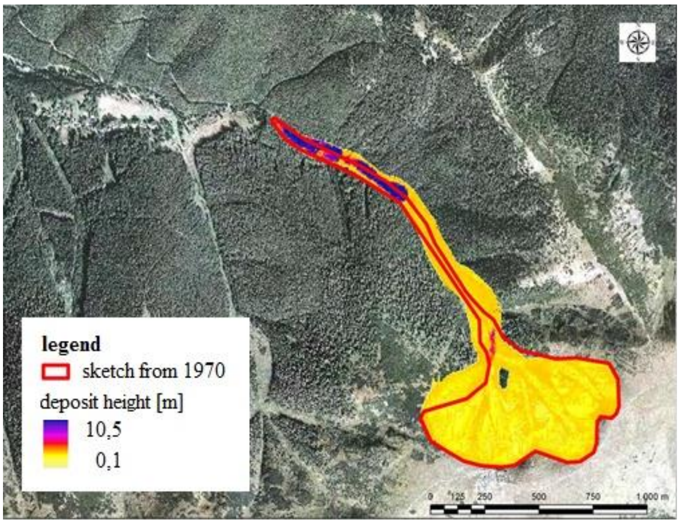

Fig. 4 Comparison of ELBA+ result with reality

3.4 Avalanche in Viedenka

We tried to simulate the avalanche in the Viedenka valley with the same parameters as in Durkova, with an average snow height in the release zone of 1.7 m. The simulated avalanche has a length of 2 230 m, and cubature of 610,000 m^3 and a total area of 58 ha. Because a part of the Magurka settlement is located at the mouth of this valley (Fig. 5), our result shows a possibility of hit.

Fig. 5 Mouth of Viedenka valley with part of settlement

Fig. 6 shows a potential deposit, because the valley has a direct shape and a shorter distance between Magurka and the main ridge of the Low Tatras Mts. From the view of historical sources, there are no observations of such large avalanches. The avalanche in the year 1984 took one victim, but its deposit was shorter and shallow [6]. Marks from the other avalanche can be found even today. It fell down from the left glen (downstream) and destroyed the forest of the opposite slope totally.

Our results show that if the avalanche hits the settlement, it could reach a flow height of 5-7 metres, pressure up to 70 kPa and velocity up to 15m.s^{-1}. These results can be much undervalued. The pressure and also the destroyed potential would be significantly higher, because the flow cannot exist without other materials originated from the destroyed forest by the avalanche.

At the end of February 2013, a medium to large avalanche fell down in this valley[11]. It probably came spontaneously from two glens in the release zone centre. We surveyed its area with a GPS-device. The deposit was 1-2 metres high and contained broken trees, wood and soil. The avalanche was 1 200 m long and destroyed the forest of 1,5ha (Fig.7). We estimated a one-meter snow height in the release zone. Immediately we tried to simulate this avalanche in Elba+. Figure 8 shows the difference between the simulation and our mapped path.

The deposit allocation simulated that the avalanche is very similar to its real state. Its length is 25 m longer, which differs by 2 % form the total length. In this simulation we used other parameters as in previous cases, because this avalanche was significantly smaller and fell down under other conditions (snow, weather …). We changed the friction coefficient μ in the avalanche path from the value of 0.155 to 0.3 and in the accumulation zone from the value of 0.35 to 0.4 for better conformity with a real avalanche. These parameters were determined by interpolation.

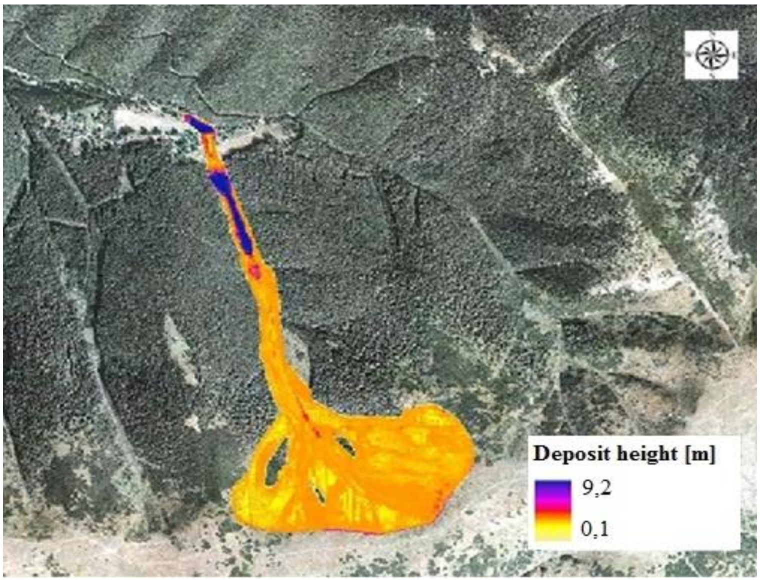

Fig. 6 Simulated avalanche in Viedenka valley

Fig. 7 Avalanche in Viedenka valley from February 2013

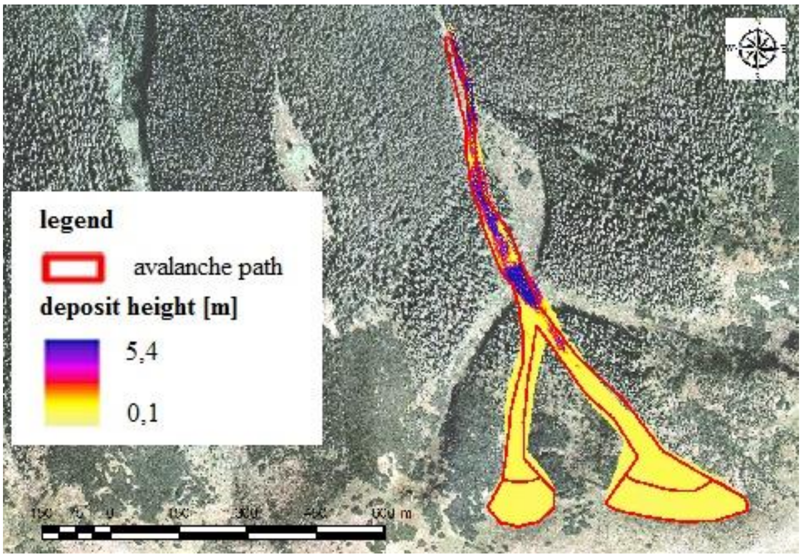

Fig. 8 Simulated avalanche from February 2013

4 CONCLUSIONS

The models used for the avalanche simulation give us a picture about the size and impact of potential avalanches. We can use them in avalanche prevention, projection and in dimensioning technical avalanche measures. The other usage area is landscape planning. In our work we used the model ELBA+ for the reconstruction of a historical avalanche and the evaluation of a possibility to hit Magurka, the old mining settlement located in the Ľupčianska valley below the main ridge of the Low Tatras Mts. Surroundings of this settlement were hit by avalanches many times. Our results are summarized in these points:

- We were able to successfully reconstruct the avalanche released on 14th March 1970 with differences in length of 0.4 % and cubature of 10 %.
- The front height of the simulated avalanche is significantly undervalued (80%) and the total area of the simulated avalanche is overestimated by about 31 %.
- In case that the avalanche falls from all release zones and with an average snow height of 1.7 m in Viedenka, it is possible that it hits a part of the settlement.
- This avalanche with its cubature and the area of 58 ha can overcome the avalanche in Ďurkova from the year 1970.
- In case of an impact on the settlement by an avalanche, the flow height could reach 5-7 metres and stops in the grass field below.
- For the evaluation of simulation results, there is a need of facticity to realize approximate calibration or research of a situation in environment marks and historical date.

REFERENCES

[1] BARTELT, P. et al. *RAMMS-User Manual v1.4 Avalanche*.2011. [cit.02-04-2012] Available at: http://ramms.slf.ch/ramms/downloads/ RAMMS_AVAL_Manual.pdf

[2] BISKUPIČ, M.et al. Rekonštrukcia historickej lavíny s využitím moderných nástrojov GIS. *Životné prostredie*. 2011, 45. 2. pp.83-88.

[3] BUKOVČAN, V.*Lavíny a lesy*. Bratislava: Slovenské vydavateľstvo pôdohospodárskej literatúry n. p. 1960. 196 pp.

[4] GOOGLE EARTH, 2012 [cit.02-04-2012].Available at: http://www.google.com/earth/index.html

[5] MILAN, L.&KRESÁK, K. *Správa o lavínovej udalosti zostavená dňa 10. 6. 1970*. Jasná: Archív SLP HZS,1970.15 pp.

[6] MILAN, L. 2006. *Lavíny v horstvách Slovenska*. Bratislava: Veda, 2006. 152 pp. ISBN 80-224-0894-8

[7] NIT TECHNISCHES BUERO GmbH, *ELBA+*. 2013. [cit.02-04-2013]Available at: http://www.elba-plus.net/

[8] NLC, *Lesnícky informačný systém*. 2012. [cit.02-04-2012] Available at: http://lvu.nlcsk.org/lgis/

[9] ŠÁLY, R.& ŠURINA, B. Pôdy.*Atlas krajiny Slovenskej republiky*. Bratislava: MŽP SR, 2002.pp.106-107. ISBN 80-88833-27-2.

[10] ŠGÚDŠ,*Geologická mapa SR*. 2008. [cit.02-04-2012] Available at: http://mapserver.geology.sk/pgm_sk/mapviewer.jsf?width=1368&height=808

[11] TIROL. LANDESREGIERUNG, *Ausbildungshandbuch der Tiroler Lawinenkommissionen*. Innnsbruck: Amt der TirolerLandesregierung, 2009. 290 pp.

[12] VOLK, G.*ELBA+*. Pressbaum: NiT Technisches Buero GmbH, 2005. 94 pp.

RESUMÉ

V našej práci sme sa zamerali na moderné softvérové aplikácie umožňujúce simuláciu lavíny. Tieto programy využívame pri hodnotení ohrozenosti horského prostredia zásahom lavínou, ako aj pri dimenzovaní technických protilavínových opatrení. Na základe zvolených vstupných údajov, ku ktorým väčšinou patrí model terénu, tvar a rozloha pásma odtrhu ako aj údaje o snehovej pokrývke, nám tieto aplikácie podávajú obraz o možnom dosahu lavíny, ako aj charakteristikách jej priebehu, či už maximálny tlak, rýchlosť a výška toku. My sme vo svojej práci používali model ELBA+, pomocou ktorého sme snažili zhodnotiť ohrozenosť horského prostredia v okolí starej banskej osady Magurka (1 036 m n. m.), ktorá leží v závere Ľupčianskej doline pod hlavným hrebeňom Nízkych Tatier. Okolie osady bolo mnohokrát zasiahnuté lavínami, ktoré si vyžiadali obete na ľudských životoch, ako aj rozsiahle škody na lesných porastoch. Do histórie sa zapísala hlavne lavína v doline Ďurková zo 14. marca 1970, ktorá dodnes patrí medzi najväčšie lavíny zaznamenané na Slovensku. S použitím dochovaných archívnych údajov Strediska lavínovej prevencie HZS v Jasnej sme sa pokúsili o jej čo najvernejšiu rekonštrukciu. Následne sme sa snažili nasimulovať o simuláciu lavíny v doline Viedenka pri použití rovnakej výšky snehu v odtrhovom pásme ako sa predpokladá pri lavíne v roku 1970. Keďže časť osady Magurka je situovaných pri ústí tejto doliny, ktorá má priamejší aj kratší priebeh ako dolina Ďurková, skúmali sme možnosť jej zásahu lavínou. Lavínu z roku 1970 sa nám podarilo relatívne presne nasimulovať, čo sa týka hlavne dĺžky (rozdiel 0,4 %) a objemu (rozdiel 10 %). Po zhodnotení výšky nánosu a celkovej plochy bola skutočná lavína viac lokalizovaná v dolinke, ako naša výsledná namodelovaná lavína, ktorá sa vyznačuje výrazným postranným rozširovaním a tým aj nižšou výškou čela lavíny (rozdiel 80 %). Pri páde totožnej lavíny v doline Viedenka by pravdepodobne došlo k zásahu časti osady. Výška toku lavíny by mohla pri vniknutí do časti osady dosiahnuť 5 až 7 metrov a zastavila by sa pri náraze do protisvahu na lúke pod ňou.