IMPLEMENTATION OF THE LARGE-SCALE AVALANCHE HAZARD MAPPING INTO RUSSIAN PRACTICE

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ABSTRACT: The snow avalanches endangered regions in Russia occupy 18% of the territory. But the large-scale avalanche hazard zoning is not yet used for the land use planning in the country. In this research, the importance of the avalanche hazard zoning implementation in Russian practice is discussed on the example of Krasnaya Polyana, Sochi (West Caucasus). We applied internationally-accepted avalanche hazard zoning approach for “Gorky Gorod” mountain resort. Using GIS technologies in combination with DEM and remote sensing as well as data of field observations, 87 potential avalanche release zones have been indicated. Numerical simulations of avalanches using avalanche dynamics program RAMMS were performed for understanding the avalanches dynamics and to determine the avalanche runout distances and impact pressures. The numerical simulation results were applied as a basis for the avalanche hazard zoning. First, we applied Swiss avalanche hazard zoning approach when avalanche hazard zones were indicated according to avalanches return period and impact pressures. Second, we considered the avalanches impact pressure values in relation to their destructive effect and present the obtained results as a map. The developed avalanche hazard zoning maps were analyzed in respect to already constructed infrastructure and organized avalanche protection measures.

KEYWORDS: avalanche hazard, risk, land use planning, numerical modeling, RAMMS

1. INTRODUCTION

Avalanche hazard maps are widely used for spatial planning in avalanche-endangered areas for assessing risk and for planning of mitigation measures. While avalanche hazard regions in Russia occupy 18% of the territory (Myagkov & Kanaev, 1992), large-scale avalanche hazard zoning presenting areas endangered by avalanches of different intensity (when the avalanche hazard is a function of the return period and impact pressure of an avalanche) widely accepted worldwide is not yet used by land planning authorities in Russia as a tool of preventing buildings construction and planning the mitigation measures in avalanche hazard zones.

The huge extent of Russian territory and its mountainous regions resulted in small-scale mapping to become a priority direction for the development. Avalanche mapping in Russia has been significantly impeded due to the mountain regions’ low accessibility and the lack of historical data in most of them. Small-scale avalanche mapping approaches have been developed basing on the relations between climatic and geomorphological characteristics of the territory and avalanche parameters (Kotlyakov, 1997, 1997; Glazovskaya, 2004).

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Despite existence of approaches to large-scale avalanche mapping (Bozhinskiy & Losev, 1998) as well as risk assessment (Komarov et al., 2016) experience accumulated so far in Russia, there is still no clearly represented guideline on the large-scale avalanche hazard mapping in our country.

In this research the importance of the avalanche hazard zoning implementation into Russian practice is discussed on the example of Krasnaya Polyana, Sochi (West Caucasus). First, we applied Swiss avalanche hazard zoning approach (BFF/SLF, 1984) for the territory of “Gorky Gorod” mountain resort. Second, we considered the avalanches impact pressure values in relation to their destructive effect (Perla, 1980; Bozhinskiy & Losev, 1998) and present the results as a map for the research area.

The snow avalanche dynamics program RAMMS (Christen et al., 2010; Bartelt et al., 2017) in combination with GIS (ArcGIS 10.3) as well as the Russian engineering guidelines (SP…, 2012) were used as the main research tools.

2. STUDY AREA

The constant growth of winter sports activities after the 2014 Winter Olympic Games and therefore the increased avalanche hazard and risk are taking place in Krasnaya Polyana.

The region is characterized by: subtropical climate; the highest amount of precipitation in Russia (National Atlas…, 2012), with more than 50% during the winter seasons; very intense snowfalls; typical slopes inclinations between 30° and 45°; slopes partially covered by deciduous forest. The snow height reaches 3 m and more in the avalanche release zones to the end of winter seasons. The record snow height value (7.96 m) among the former Soviet Union weather stations was recorded in local Achishkho weather station (1880 m a.s.l.) in April 1987 (Pogorelov, 1988). Snow avalanches are widespread in these relief and climatic conditions. Snow avalanches with a volume of more than 1 million m^3 can occur in this area (Shnyparkov et al., 2012).

Gorky Gorod is one of the year-round mountain resorts (30 km of ski pistes) located in Krasnaya Poliana. The complete touristic infrastructure of Gorki Gorod is located at the altitude from 500 m up to 2400 m a.s.l.

The snow avalanche warning service is in operation as well as various built avalanche protection infrastructure.

In this research, we consider the avalanche hazard zoning scenario without any operating avalanche protection measures taking into the account. Therefore, the results are more theoretical then practical.

3. APPROACH

The avalanche hazard zoning map for the area of Gorky Gorod mountain resort was developed through the following steps: (1) analysis of terrain with all available large-scale topographic and landscape maps as well as DEMs; (2) analysis of existent remote sensing (aerial and satellite images) data; (3) analysis of historical as well as recently obtained avalanche data in the research region; (4) analysis of climatic conditions and all the available snow data; (4) winter and summer field work (2017): detailed topographical and forests structure and state check; identification of snow conditions and avalanche activity; (5) avalanche release zones and the corresponding avalanche fracture height indication depending on the avalanches return period; (6) numerical simulations of snow avalanches using avalanche dynamics program RAMMS; (7) avalanche hazard zones indication depending on the avalanches frequency and intensity.

Non-forested terrain with a slope angle between 30° and 60° was considered as the potential release area. Using GIS (ArcGIS) technologies in combination with DEM as well as with data of field observations 87 potential avalanche release zones (see Figure 1) have been identified and analyzed in the research area for the numerical modeling of 30-year return period avalanches. For the numerical modelling of 300-year return period the identified avalanche release zones were combined in 29 larger zones depending on the slope aspect.

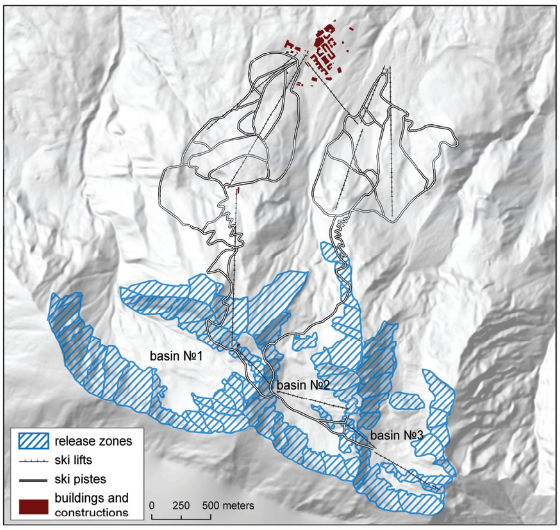

Figure 1: Potential avalanche release zones and infrastructure in the research area.

The period of observations is too short for predicting extreme avalanches fracture heights in the research region. However, potential avalanche fracture heights have been estimated and extrapolated using the data received from local avalanche warning services and reports on snow and avalanches prepared for the region before the 2014 Winter Olympic Games. Avalanche fracture heights turned out to be from 0.96 up to 1.5 m for 30-year return period avalanches and from 2.14 up to 4.4 m for 300-year return period avalanches depending on the slope angle.

Numerical simulations of avalanches using two-dimensional avalanche dynamics program RAMMS (Christen et al., 2010; Bartelt et al., 2017) were performed for understanding of avalanches dynamics and to determine the avalanche runout distances and impact pressures.

RAMMS was calibrated using well-documented extreme avalanche events recorded in the Mt. Elbrus region in the Caucasus. It has been established that RAMMS could be used for simulating of rare extreme avalanches in the Mt. Elbrus region using friction values recommended for Switzerland with no modification (Turchaninova et al., 2015). Therefore, these friction values (Bartelt et al., 2017) were applied in this research area as well.

A total of 116 simulations have been done for the development of the avalanche zoning map. 87 avalanches with the 300-year return period and 29 avalanches with the 30-year return period have been simulated using RAMMS and analyzed in respect to the avalanche hazard zoning using GIS (ArcGIS). The estimated volumes of avalanches and their maximum impact pressures calculated using RAMMS are presented in Tables 1–2.

Avalanche basins	Avalanches release volumes, m^3	Max Pressure, kPa
№1	15 920–145 260	245–720
№2	10 930–75 785	80–535
№3	15 430–135 810	95–590
under №1	15 220–75 550	100–650
under №2	5 350–55 500	320–680

Table 1: Volumes and maximum impact pressures of avalanches with a 30-year return period.

Avalanche basins	Avalanches release volumes, m^3	Max pressure, kPa
№1	155 890–840 470	620–1080
№2	35 425–780 900	230–1205
№3	40 490–715 970	260–1030
under №1	15 690–380 660	265–1135
under №2	275 000–465 590	695–1105

Table 2: Volumes and maximum impact pressures of avalanches with a 300-year return period (Fig. 3).

The numerical simulation results have been applied as a basis for the avalanche hazard zoning because there is no “historical” avalanche data in the region.

4. RESULTS

As the result, we obtained two avalanche hazard zoning maps for the research territory.

First, the Swiss avalanche hazard zoning approach (BFF/SLF, 1984) when the avalanche hazard zones were indicated according to the avalanches return period and the impact pressure has been applied. The result is presented as a map (see Figure 2). Only red and blue zones were considered.

Second, the 300-year avalanches impact pressure values were analyzed in relation to their destructive effect (Perla, 1980; Bozhinskiy & Losev, 1998). The result is also presented as a map (see Figure 3).

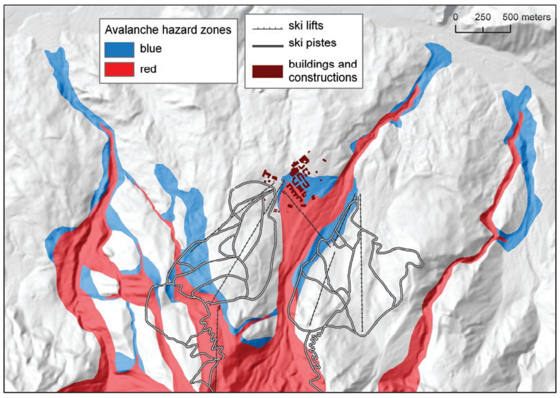

Figure 2: Avalanche hazard zoning map developed according to the Swiss approach (BFF/SLF, 1984).

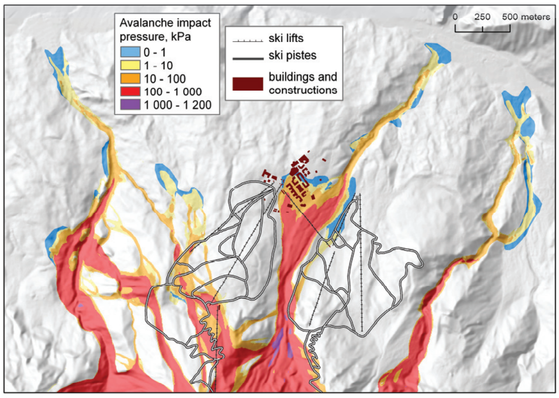

Figure 3: 300-year avalanches impact pressures classified in relation to their destructive effect.

Buildings and ski infrastructure (ski lifts and pistes) are located in red (elevated danger) and blue (medium danger) avalanche hazard zones (see Figure 2). According to the Swiss System, the construction of new buildings is prohibited in the red zone. The construction of new buildings is possible in the blue zone under certain conditions (mainly proofing of the building against the impact of avalanches). Safety service and evacuation plans must be provided in both zones. However, new buildings have been built in the red zone recently.

Buildings (950–960 m a.s.l.) and ski pistes (1035–1175 m a.s.l.) are located in the zone with the 300-year avalanches impact pressure values from 1 up to 10 kPa (see Figure 3). Avalanches are dangerous for people in this zone.

Buildings (960–1210 m a.s.l.), ski lifts (1450–1460 m a.s.l.; 2065–2105 m a.s.l.) and ski pistes (1120–1420 m a.s.l.) are located in the zone with the 300-year avalanches impact pressure values from 10 up to 100 kPa (see

Figure 3). Avalanches are dangerous for people, wooden buildings and cars in this zone.

Buildings (1000–1010 m a.s.l.), ski lifts and pistes (1340–2055 m a.s.l.) are located in the zone with the 300-year avalanches impact pressure values from 100 up to 1000 kPa (see Figure 3). Avalanches are dangerous for constructions made from stone and metal in this zone.

5. CONCLUSIONS

Since construction rates and property values have risen considerably since the 2014 Winter Olympic Games, land use of avalanche hazard zones (including “red zones”) has become widespread in Krasnaya Polyana.

Huge efforts and money are spent for protection of touristic infrastructure from snow avalanches. However, there were still no possibility to check whether a building is located in hazard or safe zone and what kind of avalanche protection does it have.

Avalanche hazard zoning identifying areas endangered by avalanches of different intensity (when the avalanche hazard is a function of the return period and impact pressure) should be implemented into Russian practice and used by land planning authorities as a powerful tool to prevent buildings construction in avalanche hazard zones.

The large-scale avalanche hazard system should be transparent and easy to understand. It should be based on guidelines and recommendations which are supported nationwide. A legal framework must be involved to implement avalanche hazard and risk maps into the land use planning practice in Russia.

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