Avalanche analysis and management in the ski resort Rosa Khutor regarding the 2014 Sochi Olympics Games

Authors: Fanny BOURJAILLAT[1*], Philippe BERTHET-RAMBAUD[1], Stefan MARGRETH[2], Leonid ANDREEV[4], Alexander BOYKO[4], Jean-Luc VALLIER[3]

1. *Engineerisk, consulting company, Chambery, France*
2. *WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland*
3. *Mountain manager, Compagnie des Alpes, Rosa Khutor Ski resort, Russia*
4. *Avalanche Service, Rosa Khutor Ski resort, Russia*

ABSTRACT: The 2014 winter Olympics games will take place in Russia near Sochi in the Caucasus Mountains. Several sites have been retained there: both close to the Black Sea coast and in the mountains near Krasnaya Polyana village. The site interesting to this presentation is "Rosa Khutor". This newly developed ski resort both by Russian with the cooperation of the French Compagnie des Alpes will host the alpine ski, freestyle and slopestyle competitions. About 15 lifts are planned for 2014 (including gondolas, chairlifts and carpets) to provide the access to 80 km of ski slopes.
Five years ago, there was almost nothing at this place except a National Park; it was totally virgin, a wild space consisting of large forests interrupted partly by avalanche tracks. Everything has been built from scratch. Only one ski resort exists there since 1993: Alpika Service with five chairlifts west of Rosa Khutor. This was the experience core to the development of the new modern ski areas: Rosa Khutor, Gornaya Karussel and Laura.
Rosa Khutor is a challenging zone with many large and steep slopes. This terrain is near the Black Sea and receives extreme precipitation that can lead to large and dangerous avalanche cycles. Before the construction of the ski area, the area was used by heliski operations. No avalanche hazard maps or documentation about the local avalanche history were available; so that everything had to be done about avalanche hazard management.

KEYWORDS: Olympics games, avalanche study, avalanche management

1. INTRODUCTION

The area's first avalanche studies were in 2008, and performed independently by private groups Bolognesi (2008) and Stethem (2008). Additional investigations were made by Russian research Institutes such as Roshydromet and the local engineering company, Engprotection (2010).

In 2010, Stefan Margreth from the SLF Davos was mandated to review the existing studies and to work out a final proposal for avalanche mitigation measures in the ski resort of Rosa Khutor. Engineerisk was asked to collaborate for the preventive release network and management part. Since then, more than ten missions have been organized both in summer and winter with the local avalanche service team. Several topics and questions have been investigated.

* Corresponding author address: Fanny Bourjaillat, Engineerisk, PA Alpespace, Bât. Cleanspace, 73800 Ste Hélène du Lac, France; tel: +33479722200; fax: +33479722272; web:www.engineerisk.com, email: fanny.bourjaillat@engineerisk.com

2. CONTEXT

2.1 *General situation*

The ski resort Rosa Khutor is quite large and consists of several terrain bowls. The elevation varies between 600 m and 2330 m. It has been developed from the west to the east (from Westridge to Ober Khutor). These sites are exposed to the north. Further development possibilities exist on the South side, behind Aibga ridge.

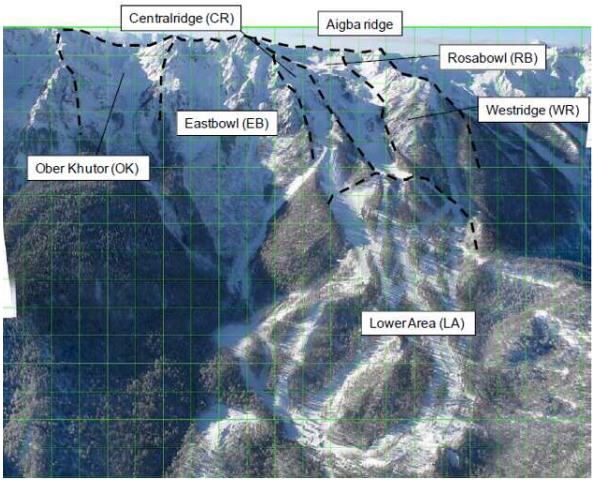

Figure.1: Rosa Khutor sectors, Margreth (2010)

2.2 *Climate*

The climate results from the interplay of cold air from the north with moist, warm air from the Black Sea. The precipitation sums are huge (exceeds 2500 mm per year) and the top parts of the main starting zones are north-facing which means on the leeward side of the mostly moisture-bearing atmospheric fronts. The result is a snow climate characterized by heavy snow fall, sustained precipitation periods and moderate temperatures. The snow fall limit is often higher than 2000 m a.s.l. According to local experts a typical avalanche period starts with rainfall up to 2300 m, afterwards, during sustained precipitation periods, the freezing level drops down to the valley floor. Storm periods with a 24 h snowfall of 1 m occur nearly every winter. Warm periods and snow fall on unfrozen ground often cause a strong snow gliding activity.

There were no weather stations before 2006 (12 now). In winter 2006/07 a maximum snow height of 507 cm was recorded and local people said that this was not an extreme winter. In an extreme winter snow heights can reach 8 m or more, Efremov (2011).

	Data from snow surveys and automatic weather stations				Extrapolation	
Elevation	2006/07	2007/08	2008/09	2009/10	10-year	100-year
2130 m	507 cm	374 cm	310 cm	384 cm	-	-
2010 m	419 cm	258 cm	273 cm	290 cm	-	-
1580 m	271 cm	326 cm	341 cm	290 cm	-	-
2000 m	-	-	-	-	550 cm	650 cm
1500 m	-	-	-	-	350 cm	450 cm

Figure.2: Snow heights in Rosa Khutor, Margreth (2010)

Long-term snow data are missing so it is difficult to accurately determine the maximum possible snow heights and there is no reliable weather forecast for the region so avalanche forecasting and management can be difficult.

Figure.3: Example of possible snow height in the Rosa Khutor area (Alpika Service, 2300 m asl)

2.3 *Phenomenon*

Two main avalanche problems can be seen in Rosa Khutor. First, snow accumulations are particularly important along the wind exposed ridgeline at the top of the resort.

Notably in Rosa Bowl, these upper slopes directly threaten ski runs below. Depending on temperature, cold slab or heavy and wet snow avalanches can initiate almost everywhere and run into the ski area.
Additionally, in Ober Khutor or East Bowl where many bowls overhang long steep slopes, huge avalanches are possible, entraining large snow volumes able to reach the lower altitudes and especially the Rosa Lake plateau above the Olympic races finish zone.
Except for the central part of the Lower Area (Fig. 1) where the freestyle competitions will take place all of Rosa Khutor is potentially exposed to hazard.
According to the data from the automatic weather stations, the temperature of the snow pack is practically isothermal all winter. This fact in combination with the heavy snow climate promotes snow gliding. It occurs on slopes steeper than 25°, particularly when the ground is warm and the vegetation not very high or conduct to slippery interface. Glide cracks can appear early in winter but it is difficult to predict snowglide avalanches as it can occur anytime. It is considered to be one of the biggest issues in Rosa Khutor which is very difficult to manage.

Figure.4: Snow gliding in Rosa Bowl

Huge cornices with heights of more than 10 m are regularly formed in many locations of the ski resort. The biggest cornices appear along the Aigba ridge by strong winds coming from the south-west.
As they often overhang steep slopes, cornices can collapse and then release large avalanches. They can also damage or destroy remote exploders (e.g. Gazex®) situated below.

Figure.5: Cornices in Rosa Bowl, L. Andreev

1.2 *Ski resort organization*

Several patroller teams were formed similar as in Europe or USA: for rescue, slopes management, operation of lifts… and one small avalanche service (some people). The big difference in Rosa Khutor is that the different teams work mainly independently. It means that if an avalanche happens during the day, only the avalanche service intervenes. In the same way, if it's necessary to release avalanches before opening the ski resort during unstable snow conditions, the avalanche service normally does that. This originality leads to some efficiency questions. It's planned to unify the different patrollers' teams.
Concerning avalanche management, the use of explosives is usually forbidden. This point is very restrictive. Effectively, lots of little dangerous slopes, which could be treated by hand charges, are finally equipped by gas devices: Gazex®, (Shippers, 2001). More than 50 Gazex® will be in operation for the season 2012/2013 in Rosa Khutor and Ober Khutor to protect an area of 5 km^2 above 1500 m asl.
Since one year, Rosa Khutor tries to get a licence to integrate the Avalancheur system (Bolognesi, 2000) in the avalanche control plan and to use hand charges of liquid explosives. Two shooting positions have been chosen for the Avalancheur system. This would be important first to optimize organization, adapt means and to provide an alternative in the case of an unusual situation.

Tests were performed with the helicopter-borne system DaisyBell® (Berthed-Rambaud, 2008) in 2010 but local weather conditions particularly constrain its use: for instance, helicopter could fly only one day during March 2011: for that, it can be just an additional option.

2. RISK & PROTECTIONS STUDY

3.1 *Risk assessment*

The site has been gradually developed. From Rosa Bowl where the Olympic race courses are situated, to Ober Khutor, a fantastic off-piste area, and possibly Yurev and Yuhsni sectors in the near future. Before evaluating the adapted mitigation measures for lifts, stations, ski tracks and other infrastructure, it was necessary to define the different avalanche starting zones, to assess the runout of possible avalanches and to define the endangered areas.

To determine at best the endangered zones without many available data, lots of field analysis, visits and avalanche simulations have been conducted. A very reliable source of information was the state of the forest which clearly showed the frequency of avalanche events. The runout distances and the avalanche actions were quantified with the avalanche dynamics software RAMMS (Christen, 2010). In parallel, the hazard zones were carefully verified in the field.

Avalanche simulations were performed for all relevant release areas. The definition of input parameters was challenging because of missing experience with RAMMS in the area. Observed avalanches were back-calculated to verify the input parameters and to get the most accurate results as possible. The assumed fracture depths vary typically between 1.0 m and 2.1m in relation to the elevation, inclination and frequency. Effectively the more the slope is steep the less there will be snow, because avalanches will release earlier. Whereas when slopes are less steep or if snow drift accumulations are likely, the fracture depths are larger.

Hazard maps were prepared for a 10-year and 100-year scenario. The 10-year scenario was applied mainly for the evaluation of ski tracks and the 100-scenario for the evaluation of lift, stations and the design of structural protection measures. The simulations permitted to determine the reference pressure, snow height, velocity values then used to design future protections (dam, pylons sizing…).

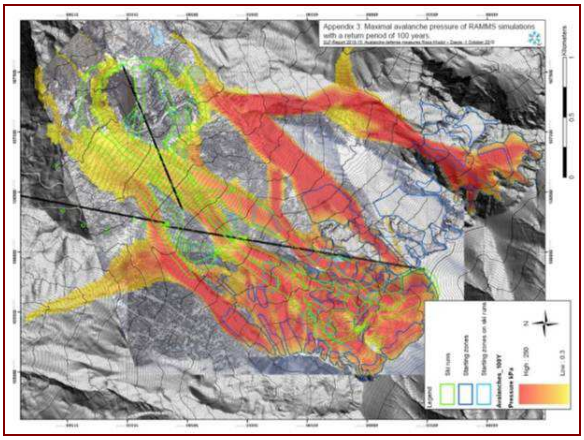

Figure.6: RAMMS simulation to get avalanche pressure for a return period of 100 years (Margreth, 2010)

2.2 *Protections against avalanche*

It was very challenging to reach an acceptable safety level without the possibility to apply explosives. After the different release areas and hazard zones were defined, the optimal protection strategies had to be defined. About passive protection, two dams have been designed.

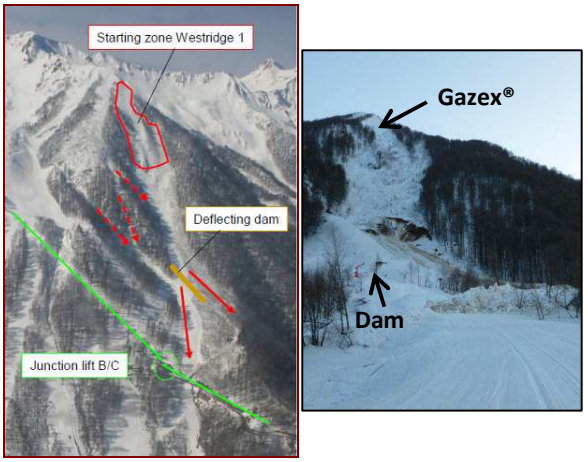

Figure.7: Deflection dam and avalanche from the starting zone Westridge 1 (Margreth, 2010)

One deflecting dam was built to protect the junction between two important lifts. This dam is 10 m high; it has been sized for a return period of 10 years knowing that the threatening zone has to be released/treated by Gazex®.
A second, catching dam, is situated below East Bowl. It protects two artificial lakes for snowmaking (lower eastern part of the ski area) and some ski slopes as well. This dam is also 10 m high.
For smaller elevations and smaller slopes, where snow glide has to be expected, snow nets were proposed. One of the key factors for the planning was the definition of the extreme snow height. The snow height is crucial for the effectiveness of the structures and the design. An overfilled structure can lead to avalanches and/or be damaged. In 2012 about 1.3 km of snow nets were built. The structure height of 4.0 m turned out not to be sufficient. In Winter 2011/12 many of the snow nets were overfilled with snow. The application of snow net was considered not to be advisable in the higher and bigger release areas because of too high snow depths and economic reasons.

Figure.8: Covered snownets in the middle of Eastbowl

That's why the artificial release of avalanches was chosen for the protection of most of the starting zones. In the first years, fixed installed Gazex® exploders were the only authorized system available in Russia but now the use of an Avalancheur seems possible in the near future.
Most starting zones, small and big ones, have been protected with Gazex®. It led to a really big quantity of them in relation to the surface area (Fig.9) whereas lots of small slopes could have been protected with hand charges (easy access, small surface…)

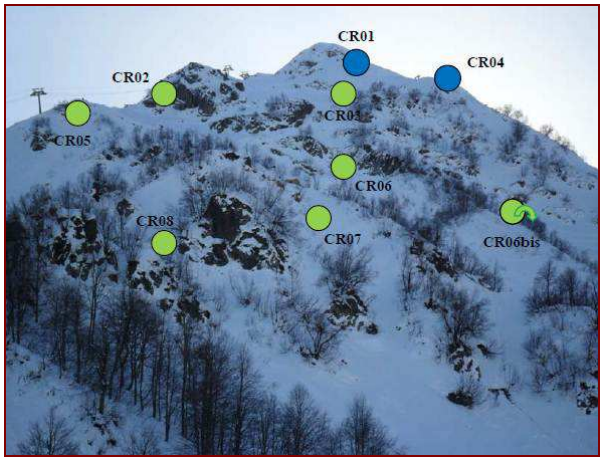

Figure.9: Example of Gazex locations, Bourjaillat (2011)

Gazex® are preventive release devices remotely controlled, which use a mixture of propane and oxygen to induce an explosion above the snowpack. There are three sizes of Gazex/exploders, according to their capacity to contain a larger or smaller volume of gas: 0.8m^3, 1.5m^3 and 3m^3. Varied sizing permits the adaption of the release system to the surface of the starting zone. Exploders are alimented by pipes linked to shelters which stock gas bottles.

Figure.10: Gazex® 3m^3 in Rosa Khutor

When installed, Avalancheurs will treat about half of the possible starting zones in Ober Khutor, especially at mid elevation where it is not

recommendable to build fixed installed systems whereas slopes remain very steep.
The Avalancheur is a civil pneumatic launcher. It launches an arrow containing 2.2 kgs of explosives. It can reach several shot points from a single place thanks to a rotary turret.
An Avalancheur constitutes an all-weather alternative in case of problem in an already equipped avalanche path. It provides an efficient release solution for secondary slopes.

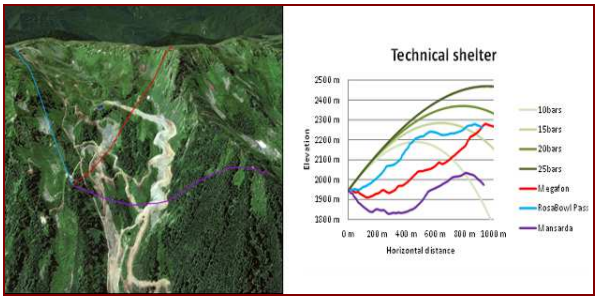

Figure.11: Avalancheur calculations (Berthet-Rambaud, 2012)

Russians also developed a short-range manual gun to release avalanches. This gun contains 200g of explosives and is able to reach a distance of 200m. It's currently in development phase.
Many starting zones are situated on or close to ski tracks. In these areas, it is planned to reduce the avalanche risk by compaction of new snow with grooming machines from the beginning of winter (as soon as it's snowing).
The avalanche service will also treat the little and accessible slopes by ski-cutting.

2.3 *Other phenomena*

To cope with cornices, snowdrift fences or jet roofs would be an efficient solution. It allows modifying the snow transport and displacing accumulation outside of starting zones. Jet roofs have also been installed in Alpika Service and show really good effects. Cornices were interrupted just behind the jet roofs.

Figure.12: Jet roofs effects in Alpika service, L. Andreev

However, In Rosa Khutor local management didn't decide to prevent cornices formation but to manage them after or during thanks to a particular and above all, unique way: excavators.

Figure.13: Excavators on Aibga ridge (Margreth, 2010)

Two excavators spent all the winter on site to remove cornices. If the ridge is quite accessible and smooth to drive on, it remains that this technique needs time, coordination with grooming or track opening and is not so environmentally-friendly. Secondly, cornices can be treated only after storms and with sufficient visibility - on the other side the application of the excavator proved to be quite effective.
Specific snow glide measures were not yet implemented but it's proposed to position wood sleeves perpendicularly to the slope to retain the first layer of snowpack and limit its glide.

3. AVALANCHE RELEASE MANAGEMENT: PIDA

An avalanche service has been specially created in Rosa Khutor and is assisted by European consultant. The ski resort is young and experience is short. Obviously it needs to spend many years in one site to know well its specificities; where the starting zones are exactly, where are snow accumulations, where is the perfect shooting point… At the same time, standards to reach are high, the 2014 Winter Olympic Games are coming!
The avalanche service was really involved to understand best how to manage avalanches and try to compensate this lack of time.
To help them, a PIDA (French term for avalanche control plan), Bourjaillat (2012), was used by the Russian team during the last winter. This document is being introduced both technically to correspond to the local avalanche context and organization and legally to fit the Russian law requirements (including the need to get a license to deal with weather station and avalanches triggering).
A PIDA is an operational document, compulsory in France, which consists of a map of the ski resort with all avalanche zones, shooting points, closed zones during operation and an "intervention plan". In this plan, the organogram of the organization is specified. This document lists the different tasks during the release operations and defines the specific instructions for use of the different devices.
It is a guideline to assist operations to work as safely and efficiently as possible.
The first main point was to make the avalanche service aware of the avalanche problem, its features and its dangerousness. Especially that they will have to use Gazex®. To optimize the use of remote controls systems, it's crucial to release avalanches as soon as conditions need it. It was important for the service to understand that the purpose is not to wait/undergo but to act quickly, logically and as safely as possible.
The problem is still due to the lack of accurate snow forecast: will it be snowing? When? How much?
The "Russian" PIDA should also be adapted to their mode of operation, knowing that they were primarily different parallel and independent services: this is helping everybody to work together.
An avalanche atlas has been developed to support the PIDA. This atlas is a complement to the general map. It represents each path thanks to pictures, indicating in which zone it is, how it's managed…

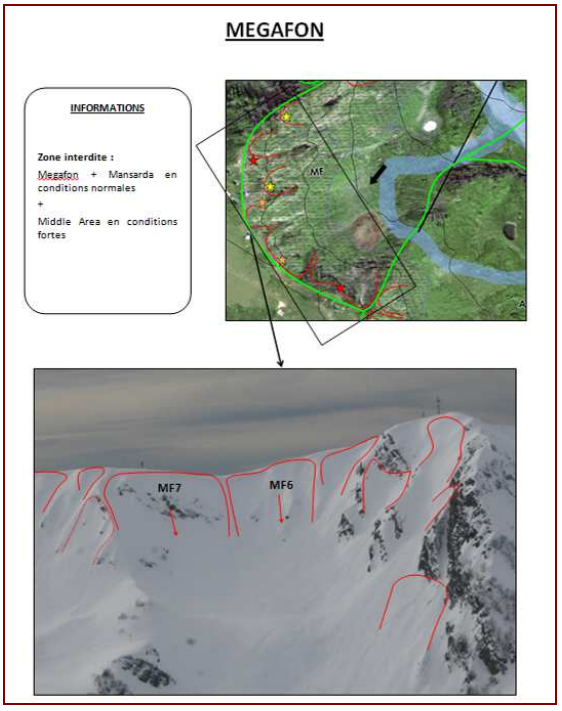

Figure.14: Example of the Avalanche Atlas, (Bourjaillat, 2012)

4. CONCLUSION

There were lots of issues there:
We had to compensate for a lack of data and local experience by using as much as possible the current and available tools at disposal and field opportunities knowing that the deadline was quite short.
We had to quickly understand Russian context and adapt all protection strategies according to local snow conditions, internal organization concerns and regulations...
We had to secure an entire ski resort without using any explosives. This was obviously a challenge; especially when 4m snownets at middle elevations get buried during an average winter.

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