RACS FOR AVALANCHE HAZARD MANAGEMENT ON STATE ROADS IN PINZGAU, AUSTRIA – PLANNING, CONSTRUCTION, LOCAL FORECASTING AND CENTRALIZED OPERATION

Stefan Oberaigner[1], Gottfried Seer[2], and Paul Dobesberger[3]*

1 Provincial Road Administration Salzburg (Landesstraßenverwaltung), Bruck an der Großglocknerstraße, Salzburg, Austria
2 Federal Torrent and Avalanche Control Service (WLV), Gebietsbauleitung Pinzgau, Zell am See, Salzburg, Austria
3 Wyssen Avalanche Control, Innsbruck, Tyrol, Austria

ABSTRACT: Road avalanche protection in alpine regions requires not only technical solutions but also well-coordinated organizational structures across multiple stakeholders. This paper presents a case study on the planning, construction, and operation of a RACS (Remote Avalanche Control System) program installed to protect state roads in the municipalities of Saalfelden, Maishofen, and Rauris in the province of Salzburg, Austria. The program was initiated in 2009 and has since grown to eight Wyssen avalanche towers. Project planning and construction were carried out by the federal torrent and avalanche control service, with Wyssen Avalanche Control (WAC) contributing their long-standing expertise during the planning phase. A key organizational feature of this setup is the centralized operation of all RACS – regardless of municipal boundaries – by a single road maintenance authority, which handles storing, loading and triggering of all systems. The decision to initiate avalanche control missions is made by the respective local avalanche commissions of each of the three municipalities involved. Annual maintenance of all systems is carried out by Wyssen technicians, ensuring consistent technical oversight throughout the lifecycle of the infrastructure. Since 2023, all systems have been operated using the Wyssen 2K charge – a new two-component explosive – replacing conventional avalanche explosives previously in use. This transition has been evaluated in terms of operational reliability, handling, and safety. The experience gained over several years of operation demonstrates that a clear division of responsibilities between planning, construction, and operation – combined with a centralized operational model and a defined cost-sharing framework for both construction and ongoing operation – proves highly effective for managing geographically distributed avalanche safety infrastructure. The organizational model presented here may serve as a transferable framework for similar road protection projects in alpine communities. All parties involved have expressed strong satisfaction with both the distribution of responsibilities and the successful implementation across four construction phases, as well as with the smooth running of ongoing operations.

KEYWORDS: avalanche hazard management; avalanche control; RACS; case study

1. INTRODUCTION

The provincial road administration of Salzburg (Landesstraßenverwaltung, LStrVw) maintains and operates the network of state roads across the Pinzgau region, in the district of Zell am See, Austria. Within this network, the road maintenance authority Road Maintenance Department Bruck (Straßenmeisterei Bruck, SMB) is responsible for a number of state road sections that are exposed to recurring avalanche hazard: the Rauriser Landesstraße L112 in the municipality of Rauris, threatened by the Bruderhof avalanche; the Glemmtal Landesstraße L111 in the municipality of Maishofen, threatened by the Gadenstätt avalanche; and the Pinzgauer Landesstraße B311 in the municipality of Saalfelden, threatened by the SSK avalanche and the Labeckbrunn avalanche. All three roads are essential traffic links for the local population, the regional economy, and the winter tourism industry of Pinzgau, one of Austria's principal winter destinations with up to 9 million overnight stays per winter half-year in the district of Zell am See alone.

Within the Austrian Federal Torrent and Avalanche Control Service (Wildbach- und Lawinenverbauung, WLV), the regional office (Gebietsbauleitung) Pinzgau is responsible for the technical planning, hazard assessment, and construction supervision of avalanche protection measures throughout the district, including the Remote Avalanche Control System (RACS) installations described in this paper. This paper documents the planning, construction, and operation of the RACS program on Pinzgau state roads, with a focus on the organizational model that has developed over the last three construction phases between 2019 and 2025 and presents a detailed

* *Corresponding author address:*
Paul Dobesberger, Wyssen Avalanche Control,
Archenweg 52, 6020 Innsbruck, Austria;
tel: +43 512 21934600
email: paul@wyssen.com

https://doi.org/10.15788/1790099043

case study of the most recent installation, securing the Labeckbrunn avalanche above the municipality of Saalfelden.

2. PROGRAM DEVELOPMENT: FOUR CONSTRUCTION PHASES

The RACS program on Pinzgau state roads has grown through four distinct construction phases between 2009 and 2025, summarized chronologically below.

2.1 *Early Protection Measures and the First GAZEX Installation*

Long closures of Pinzgau state roads due to high avalanche danger have repeatedly been necessary over the past decades. Closures of up to a week are documented for the winters of 1968, 1986, 1988, 2015, and 2019, each entailing substantial restrictions for the local population as well as losses for the regional economy and tourism sector. Given the importance of winter tourism for Pinzgau, this recurring situation became increasingly untenable for all parties involved.

The first permanent protection measure, a catching dam, was built in 1968 to protect the B311 from wet-snow avalanches released from the Labeckbrunn avalanche path (Figure 3). Between 1986 and 1988, several large slab avalanches overtopped this dam, prompting the LStrVw to substantially enlarge its retention volume. A variant study carried out by the WLV, weighing construction and operating costs against effectiveness, showed that a gallery was too expensive both to build and to maintain given the length of the affected road section. Securing the extremely steep starting zones with steel snow bridges alone would have been very costly and enlarging the catching dam alone was only feasible with disproportionate effort given the confined terrain. In 2005, the WLV therefore decided on a combination of measures: partial securing the starting zones with steel snow bridges, controlled release of the most exposed starting zones by RACS, and a catching dam in the runout area. This should prevent large, damaging avalanches and the avalanches, released in small, controlled portions, should be caught by the dam.

Construction of the steel snow bridges and the enlarged catching dam began in 2006. In 2009, the first permanent installation for controlled avalanche release on a Salzburg state road - two GAZEX mini-containers with three ignition pipes - was built by an external contractor in the Labeckbrunn starting zone. GAZEX was chosen because the terrain was inaccessible for a blasting cableway and no other remote avalanche control system was yet established on the Austrian market. The first experience with the controlled, small-portion release of avalanches and the avoidance of long road closures, was received very positively by all stakeholders, and so also other local avalanche commissions and affected municipalities began to push for RACS protection of their state road sections. However, due to increasing reliability issues with the GAZEX systems and the manufacturer's failure to perform regular maintenance, the LStrVw decided to use explosive-powered RACS in future tenders. It was also agreed that a cost-sharing model for operation and maintenance should be pursued for future projects, as the LStrVw had fully funded the operation of these this first RACS.

2.2 *2019: Bruderhof and Gadenstätt – the First Wyssen Avalanche Towers*

The Bruderhof and Gadenstätt avalanches were given the highest priority for the next projects, as both the need and the expected benefit were high and no difficulties were anticipated in the permitting process. Given the excellent working relationship between the LStrVw and the WLV, it was quickly agreed that future RACS projects of this kind would be planned and executed together with the WLV Pinzgau specialists. Following the exceptionally snow-rich winter of 2018/19, during which the avalanche paths earmarked for RACS again caused road closures of up to six days, a meeting was held with representatives from the state government, the affected municipalities, the Salzburg avalanche warning service, the WLV and the LStrVw. Based on a detailed cost breakdown prepared by the WLV, construction and its financing were decided, and the cost-sharing key was negotiated in the same meeting. The LStrVw subsequently tendered three RACS installations to secure the Bruderhof avalanche (municipality of Rauris, combination of steel snow bridges and one RACS) and the Gadenstätt avalanche (municipality of Maishofen, two RACS). Wyssen Avalanche Control (WAC) won the tender with the best price-performance ratio of all RACS available on the Austrian market at the time.

Each RACS installation consists of a Wyssen Avalanche Tower LS12 with a deployment box holding twelve 5 kg explosive charges. Individual charges are triggered remotely and the resulting detonation applies a pressure load to the snowpack that causes unstable snow layers to release. The tower is founded on a concrete block secured by drilled ground anchors, whose length is adapted to the ground conditions found on site. When the charges in a deployment box are used up during the winter, the box is flown down to the valley by helicopter, refilled and repositioned on the tower, without the need for any personnel to be present at the tower location.

2.3 2023: SSK Avalanche and the Wyssen 2K Charge

Based on the positive experiences of the last tender, in 2023 the SSK avalanche was tendered following the same process – the LStrVw again coordinated the cost-sharing key between the federal government, the province, and the municipalities and carried out the tender. The WLV Pinzgau handled project planning, cost estimation, foundation and tower assembly. WAC won also this tender and secured the SSK avalanche with three LS12 Wyssen Avalanche Towers, with the project handled analogously to the Bruderhof and Gadenstätt installations. One of the three new RACS at the SSK avalanche was additionally equipped with a Wyssen LIA Laser Scanner, which measures snow height directly in the starting zone of the avalanche and could also verify blasting success at night or in poor visibility.

With the 2023/24 winter season, all RACS in the program were switched from conventional avalanche explosive to the Wyssen 2K Charge, a two-component charge consisting of two separate containers of dangerous goods (ammonium nitrate and nitromethane) that are joined immediately before loaded into the avalanche tower, and which mix into an explosive only after being released from the deployment box. The 2K charge brings several operational advantages: The two components are subject to different, simpler transport regulations than conventional explosive and can be stored directly at the Straßenmeisterei in dedicated hazardous-goods cabinets (Figure 1), removing the need for deliveries coordinated with an explosives distributor timed to each helicopter take-off. The operating personnel no longer need to handle explosive itself while assembling and loading charges, improving personnel safety (Figure 1). After the season the ignition system is completely removed from the charges, and the two components are again separated and stored over summer in the hazardous-goods cabinets. The storability of the 2K charge is five years – more than three times that of conventional explosive (18 months) – which, combined with the fact that on average only four to six blasting actions per avalanche path and winter are needed, provides a significant saving in resources and cost.

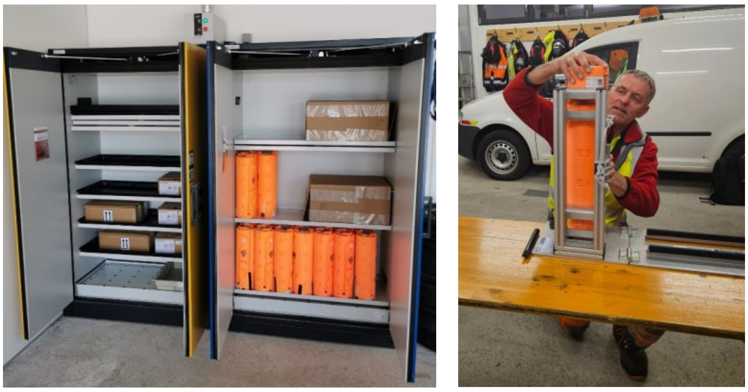

Figure 1: Left: Hazardous-goods cabinets at Road Maintenance Department Bruck for storing the two components of the Wyssen 2K charge – left: liquid component (nitromethane); right: solid component (ammonium nitrate). Right: Road Maintenance Department Bruck staff assembling a Wyssen 2K charge.

2.4 2025: Replacement of the Labeckbrunn GAZEX Installation

Since the problems with the existing GAZEX systems at the Labeckbrunn avalanche could not be solved, the LStrVw and the WLV put out a tender in the proven manner to replace the GAZEX in 2025. WAC won again the tender to replace the three original GAZEX installations with two LS12 Wyssen Avalanche Towers and the project was handled again analogously to the three preceding projects Bruderhof, Gadenstätt, and SSK. With this fifth construction phase, the RACS program on Pinzgau state roads has grown to a total of eight RACS across three municipalities securing three different state road sections.

3. PROJECT WORKFLOW: PLANNING, CONSTRUCTION AND OPERATION – USING THE EXAMPLE OF THE LABECKBRUNN AVALANCHE

The following sections illustrate the full project workflow – from hazard assessment through planning, construction and the safety concept to annual operation – using the most recent installation, protecting the state road B311 against the Labeckbrunn avalanche in the municipality of Saalfelden.

Every project begins with a community's desire to prevent prolonged road closures through controlled avalanche triggering. To assess the feasibility of avalanche blasting in specific avalanche paths, the WLV prepares a technical report (WLV, 2025a) to clarify if the avalanche problem could be solved with RACS and to estimate how many systems would be needed. Based on these results, a cost estimate for the installation and ongoing operation will then be prepared.

3.1 Hazard Assessment and Feasibility Study

The catchments of the Labeckbrunn avalanches lie on a south to south-west facing slope on the orographic right side of the Saalach valley, in the municipality of Saalfelden. The highest point of the starting zone is around 1950 m and avalanches could reach the valley floor at approximately 700 m (Figure 3). The Labeckbrunn avalanche paths has several partial starting zones, strongly differentiated by terrain chambers and rock bands, which are funneled together by a pronounced avalanche track. Before the RACS installations the starting zone was partly permanently secured by steel snow bridges, partly temporarily secured by the three GAZEX RACS and a catching dam with a deposition area at the valley floor. A nature protection area and the Natura 2000 site “Kalkhochalpen” overlap with the avalanche catchment (WLV, 2025a).

Figure 3: Starting zone (left) and runout area (right) of the Labeckbrunn avalanche with the protected state road B311.

The main hazard stems from large, dry powder avalanches. A release affects the main road network of Pinzgau, in particular the B311 and adjoining paths within the hazard area. Owing to the exposed location, artificial release is only possible by helicopter, and therefore only on days with favorable weather and wind conditions. Based on event documentation and the assessment of the local avalanche commission, spontaneous avalanches are estimated to reach the B311 roughly every 30 to 50 years, while a necessary closure of the road is estimated to occur every 5 to 10 years. Earlier avalanche events have repeatedly buried the road and have already caused damage to vehicles and their occupants.

Avalanche simulations carried out by the WLV showed that the existing catching dam at the Labeckbrunn avalanche, built in 1968/70, is far from sufficient to retain the snow masses of a powder avalanche, and that even for the flow avalanche, an extreme event would produce considerable avalanche pressures at the B311 despite the dam. Frequent, small-portion release of the starting zones throughout the winter season significantly reduces the probability of large-scale powder avalanches occurring. On the other hand the probability of a controlled avalanche hitting the road is very low. To keep this probability as low as possible, the safety concept requires artificial release in small portions, with blasting recommended already at new snow heights of 30 to 40 cm (WLV, 2025a). With regular blasting operations, there are no other objects besides the B311 in the danger zone of the Labeckbrunn avalanche.

3.2 Financing, Tendering and Construction

Based on the WLV's technical report and their cost estimate for the project the LStrVw negotiates the cost-sharing key for construction, material costs and the ongoing operation with the federal government, the province, and the affected municipalities. Once the financing of the project has been clarified, the LStrVw prepares the tender for the RACS installation in close cooperation with the WLV. After the contract is awarded, WLV and the manufacturer jointly finalize the positioning of the RACS. At the Labeckbrunn avalanche WAC first computes GIS-based effect-range analyses for the locations specified in the tender and for alternative locations with better coverage of the potential starting zones, followed by a joint site visit involving WLV, LStrVw and the local avalanche commission to fix the final tower positions in the field (Figure 4). WAC then recomputes the effect-range analysis for the definitive locations so that the areas affected and above all, the areas not affected are clear to everyone involved. If the coverage of the starting areas is deemed sufficient, WAC determines the design forces from snow, avalanche and wind loading on the five ground anchors of each tower (four vertical anchors and one shear-relief anchor, Figure 5), and provides these, together with the foundation and installation instructions, to the WLV, which dimensions the anchors and plans the construction for each site.

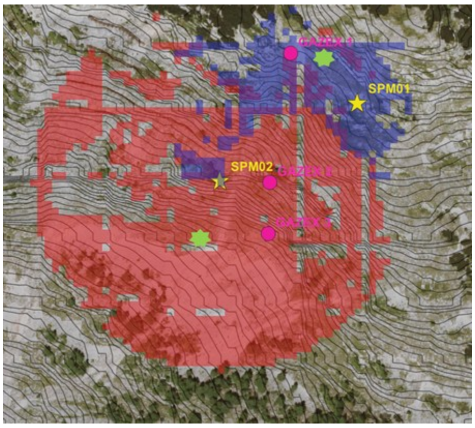

Figure 4: Effect-range analysis for the two new Wyssen avalanche towers in the catchment of the Labeckbrunn avalanche. Assumed effective range of 130m for a 5kg charge detonating 8m above the surface (Amt der Tiroler Landesregierung, 2022).

The WLV then carries out the construction: site setup, drilling of the ground anchors, casting of the concrete foundations and mounting of the towers, following the detailed foundation and installation instructions provided by WAC (Figure 5). WAC subsequently inspects and accepts the foundations and mounted towers together with the WLV in the field.

Figure 5: Tower foundation before pouring the concrete (left), after concreting (middle) and with the tower installed (right).

Once the towers are accepted, WAC commissions the deployment boxes of the new RACS at the Road Maintenance Department Bruck depot and trains the operating staff in charge assembly and in operating the Wyssen Avalanche Towers LS12 through the WAC.3 platform. Each operator has to hold a valid qualification for controlled avalanche blasting and must also complete the manufacturer's training program.

3.3 Safety Concept

In parallel, the WLV and the LStrVw develop the safety concept for the operational running of the RACS for each side. It comprises an organizational chart setting out all stakeholders involved together with their respective responsibilities and tasks. A closure plan designating the hazard area, the endangered objects and infrastructure and the closure points (Figure 6). Furthermore, dedicated checklists for each actor in the operation has been developed. The checklist for the local avalanche commission structures the situation assessment, the recommendation to blast and the documentation of the decision process and of how the decision is communicated. On the other hand the checklist for the road maintenance authority structures the recording of the blasting order, the coordination of road closures and blasting time and the documentation of closures, blast success and communication (WLV, 2025b).

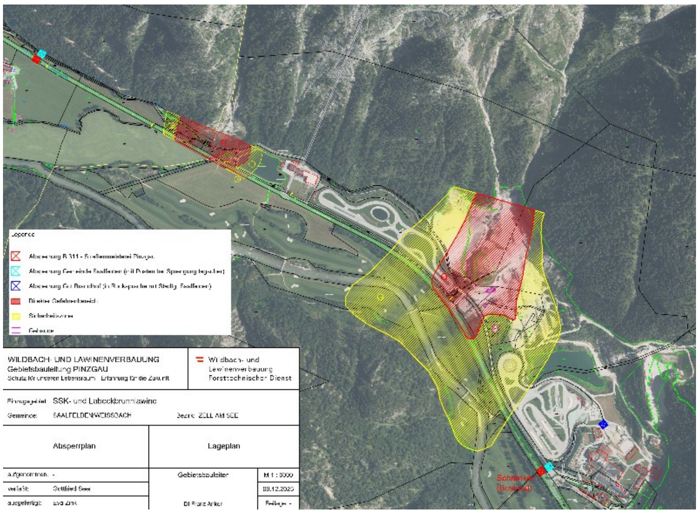

Figure 6: Closure plan for the Labeckbrunn (left) and SSK avalanches (right), showing the direct hazard area, endangered infrastructure and the closure points on the B311 and adjoining roads.

3.4 Operations and Division of Responsibilities

When flying conditions are good, authorized blaster at the SMB staff prepare the 2K charges for the eight Wyssen Avalanche Towers in the morning at the depot and deliver them, along with the deployment boxes, to the three launch sites in the municipalities Rauris, Maishofen and Saalfelden. On site, the rounds are primed, the deployment boxes are loaded and everything is prepared for flight.

Figure 7: A fully loaded deployment box of a Wyssen LS12 avalanche tower with an additional signal horn installed to warn people and animals in the avalanche's path.

Thanks to the 2K charge, it takes only about 30 minutes per magazine on site, so the eight RACS units at the three different locations can be prepared simultaneously by the three blasting officers from the road maintenance department and then deployed one after another onto the masts by the same helicopter. The Wyssen Avalanche Towers are then ready for use and remain armed on the towers throughout the winter (Figure 8).

Figure 8: Wyssen avalanche towers without (left) and with the deployment box mounted (right); helicopter transport of a loaded deployment box (middle) to the Labeckbrunn avalanche towers in Saalfelden.

During the winter, the local avalanche commissions assess the current avalanche danger daily and following significant snowfall or wind drift, recommend to the LStrVw that the relevant avalanche path be released by controlled blasting. In this context, the advantages of the LIA laser scanner are particularly noteworthy, as they allow avalanche commissions to determine exactly how much snow is in the avalanche starting zone and how much has been added by snowfall or wind-driven snow.

Police and SMB then close the hazard area according to the closure plan and verify that no persons or animals remain within it. Signal horns mounted on the deployment box sound a warning before blasting for any persons who may be present in the starting zones and information boards at access points to the starting zones show the hazard area and explain the blasting signals. After the cordoning off and inspecting of the area of risk the authorized blaster of SMB triggers the avalanche towers by smartphone directly on site and documents the blast, its success and the resulting avalanche. SMB subsequently clears any remaining snow from the road. Because regular blasting of smaller snow volumes prevents most avalanches from reaching the road at all, this is rarely necessary. If the situation allows, blasting operations are usually carried out very early in the morning so as not to disrupt commuter and tourist traffic. Even during the day, delays are minimal, as the entire operation typically takes no longer than 20 minutes.

At the end of the winter season, the helicopter flies the deployment boxes back to the valley, where SMB disassembles the charges on site. The two components of the Wyssen 2K charges and the ignition cord are stored separately from one another in their respective storage locations. SMB returns the deployment boxes to the depot for the summer, where WAC carries out the annual inspection of the boxes. Over the summer SMB also hikes to each tower in the terrain to carry out a visual inspection and re-grease the mounting pin, ensuring the deployment box can again be safely mounted the following autumn.

4. CONCLUSION

The experience gained from four construction phases and several winters of operation of the Pinzgau RACS program shows that specialized partners and a clear division of responsibilities during planning, construction and operation is key and keeps the complexity manageable even if 8 RACS distributed across several municipalities are operated by one single centralized road maintenance department. Combined with a defined cost-sharing framework for both construction and ongoing operation and with a jointly developed, regularly updated safety concept makes projects of this kind feasible and implementable for all stakeholders. The Wyssen Avalanche Tower has proven to be an extremely reliable system and the excellent cooperation of Wyssen employees throughout all phases of the projects has contributed to their successful implementation. The switch to the Wyssen 2K charge has also further simplified the operation of the RACS and significantly improved the safety of the operating personnel. After several winters of operation all parties involved report high satisfaction with both the organizational model and the technical performance of the RACS program. This model - collaborative planning and implementation, decentralized hazard assessment by local avalanche commissions, centralized operation by one single road maintenance department, cost allocation among all beneficiaries - may be transferable to similar road protection projects in other alpine communities.

References

Amt der Tiroler Landesregierung, Abt. Zivil- und Katastrophenschutz, Lawinenkommissionsangelegenheiten (Hrsg.): Ausbildungshandbuch der Tiroler Lawinenkommissionen, 6. Edition, 2022.

WLV Gebietsbauleitung Pinzgau, 2025a. Labeckbrunnlawine 2025 – Abtrag Gaz Ex Anlage und Errichtung Sprengmasten, Technischer Bericht. Wildbach- und Lawinenverbauung, Gebietsbauleitung Pinzgau, Zell am See, Austria, 14 pp.

WLV Gebietsbauleitung Pinzgau, 2025b. Sicherheitskonzept Labeckbrunn-Lawine: Organigramm, Absperrplan, and operational checklists for the local avalanche commission and Straßenmeisterei Pinzgau. Wildbach- und Lawinenverbauung, Gebietsbauleitung Pinzgau, Saalfelden, Austria.