HOW LITTLE COTTONWOOD CANYON GOT THIS WAY AND WHAT CAN BE DONE TO FIX IT INTERNATIONAL SNOW SCIENCE WORKSHOP 2018, INNSBRUCK, AUSTRIA

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ABSTRACT: To understand the distinct avalanche issues faced in Little Cottonwood Canyon today, it helps to look back at its history starting as a booming mining town. Beginning in the 1870s, the town of Alta was continually being destroyed by avalanches and rebuilt until the price of silver dropped in 1927 and the town was abandoned. The next era brought skiers and Monty Atwater, a 10th Mountain Division Veteran, Snow Ranger for the United States Forest Service (USFS), now considered the grandfather of the avalanche profession in the US. He was the first to use artillery to control avalanche danger. Fast-forward to now; much still is done the way that Monty did it in the 40s with artillery being the primary tool. What has changed is that Little Cottonwood is now home to Alta and Snowbird ski resorts and is situated next to over two million people along the Wasatch Front. On average over 1200 cm of annual snowfall mixes with nine hotels, 132 residential buildings, and a robust backcountry scene. This is all fed by a two lane 13 km long dead-end highway crossing 64 avalanche paths.
The Utah Department of Transportation (UDOT) is now tasked with managing the avalanche threat to the highway and by default, the Town of Alta and the Village of Snowbird. This case study examines UDOT's efforts to keep Utah State Hwy 210 and the canyon structures safe with two WWII era Howitzers, 550 rounds of artillery flying over many inhabited buildings, 21 Gazex® exploders, two O'Bellx® Exploders, a DaisyBell®, one Wyssen Tower®, six forecasters and a dog. Further, it explores plans for the Highway Avalanche Safety Program to evolve and better manage the avalanche problem into the future balancing the needs of the municipalities, multiple agencies, businesses, recreationists and residences.

KEYWORDS: avalanche, transportation, Alta, RACS, artillery, risk management, infrastructure

1.INTRODUCTION

1.1 Setting

Little Cottonwood Canyon (LCC) is located in the central portion of the Wasatch Mountains of northern Utah, USA. State Highway 210 (SR 210) runs up the canyon connecting the Salt Lake Valley to Snowbird and Alta ski resorts as well as the Town of Alta (Fig 1). It climbs from an elevation of 1646 m at the mouth of the canyon to 2650 m at its terminus at the base of Alta Ski Area. For the most part, the elevation of the ridgeline above SR 210 is between 3050 and 3350 meters. During times of peak traffic volume, nine to twelve thousand cars a day travel along SR 210 (F&P, 2018) carrying skiers to both the resorts and backcountry trail heads. 17km from Alta lies the heart of the Wasatch Front, home to over two million people. This access to world class mountain recreation is a major factor for people choosing to live in Utah and also one of the biggest factors contributing to UDOT's problem of people management. The highway has an Uncontrolled Avalanche Hazard Index (UAHI) of 6135, far greater than any major road in the world (Hendrikx and Jones, 2018).

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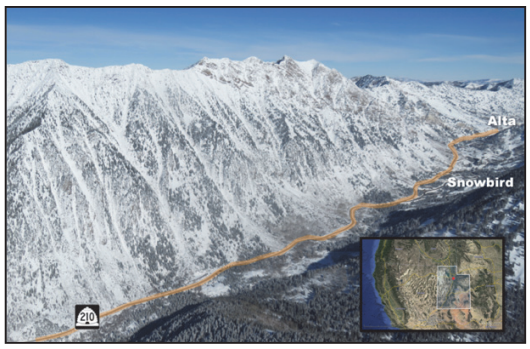

Fig. 1: LCC looking to the northeast with SR-210 highlighted in orange (UDOT photo).

The high traffic volume alone will cause traffic to back up the entire length of the canyon but when compounded by severe winter weather and challenging road conditions, the solid line of near-stationary cars drives the AHI through the roof. This traffic sits in the run out zones, and sometimes tracks, of the 64 paths that frequently cross the road each winter. Furthermore, because SR-210 is a dead end canyon they must cross these paths twice, both up and down. On top of the hazard to motorists, there are 54 inhabited buildings that are threatened by those same paths. Avalanche control

is conducted primarily with artillery and takes place on a frequent basis with the goal of producing smaller avalanches that don't reach infrastructure. Unfortunately, humans aren't always in charge of this. Mother Nature has the final say. Normal protocol has forecasters closing the road in the early morning hours in hopes to clean out the starting zones before the flood gates open and the canyon fills with resort and backcountry riders. Once this happens it becomes incredibly difficult to clear and reshoot most areas. Forecasters must decide how to live with any growing hazard until the end of the day when the masses clear out, or to trap them until areas can be cleared and shot, sometimes not until the next day.

1.2. Motivation for Change

As both the resort and backcountry skiing populations increase, it has become clear that the status quo of artillery shells flying over inhabited buildings and producing shrapnel near their targets needs to change. Gone are the days where a few hardy mountaineers would access the steep terrain above SR-210. Easily accessible, deep powder skiing is enjoyed by many including those set on early morning "Dawn Patrol" touring in the exact locations targeted for artillery.
The US ARMY governs the use of military weapons for avalanche control. While patient for many years, they are again demanding an end to firing artillery over inhabited buildings, a practice normally allowed only during wartime.
It is for these reasons that UDOT is looking for alternatives to both artillery and sole reliance on active control measures.

2. HISTORY

2.1. Mining History

The first permanent settlement in LCC came in the late 1800's with the silver mining boom. By 1870 a town was built at Alta along with multiple mining rail lines. Aerial tramways were also constructed to move ore including one that spanned nearly 8km traversing the most active avalanche areas in the upper half of the canyon. All of this infrastructure was challenged by avalanches and general mountain defiance, fostering a cycle of destruction and reconstruction. In 1875 a narrow-gauge rail line was constructed well up onto the north slope, an alignment that was considered simpler to build. Avalanches and heavy snowfall soon became problematic and a snowshed was erected over this line all the way to Alta. It consisted of a stone wall on the uphill side of the track that supported heavy timbers and planks which matched the slope of the hill and was described as a never ending log cabin tunnel (Keller, 2001). Today's road alignment remains similar.

Fig. 2: Avalanche destroys Town of Alta 1885.

Between 1871 and 1893 at least 82 people died in avalanches in the canyon and the Town of Alta was hit by slides no less than six times, twice being totally destroyed. The end of this era saw George H. Watson buying up many mining claims that struggled to turn a profit. He later traded 1800 acres to the USFS in exchange for back taxes, an act that launched the birth of the ski industry.

2.2. Monty Era

The inception of the Alta Ski Area in 1938 brought a shift toward winter recreation and also the need to address the threat of avalanches both for the ski area and along the road. In 1945 the USFS hired an ex 10th Mountain Division Veteran, Monty Atwater, and together with Ed LaChapelle modern avalanche science in the US was born.

Fig. 3: Monty Atwater using explosives at Alta circa 1950. Utah Historical Society Photo

The two standardized recording methods and experimented with the use of explosives to trigger slides. At the urging of Swiss snow scientist Andre Roche, Monty pioneered the use of artillery for avalanche control while at the same time realizing it might some day need an alternative. Designing the avalauncher was one of his attempts at a replacement.

2.3. Skiing Booms

As skiing grew in popularity it brought more and more people into the relatively small Wasatch Mountains. Many resorts began popping up in Utah with the largest endeavor happening in 1971 and the birth of the then described "*Super-Resort",* Snowbird. Thousands of people flocked to LCC for these two famed resorts and the easily accessible backcountry. The lure of the untracked "*Greatest Snow on Earth*" has led to our current state. On every weekend, holiday, or big snow event there are large numbers of recreationists, residents and workers traveling a steep, two lane mountain highway that is at capacity at an ever increasing rate. When this bumper to bumper road mixes with severe winter weather, the scenario moves to the upper limit of acceptable risk regarding avalanche safety.

UDOT was handed the job of managing the threat of avalanches to the highway in 1983 when the USFS decided it didn't have the resources and that the task was outside of their general purveyance of managing forests. After being led by Ron Perla, then forecaster Binx Sandahl switched employers and became the first UDOT avalanche specialist. The program was last led by Liam Fitzgerald and has seen many changes but fundamentally the same tactics outlined by Monty and Ed continue to guide the program today.

3. ANALYSIS

3.1 UDOT Avalanche Safety

UDOT's team of four forecasters, one supervisor, one program manager and dog Elbert, monitor conditions closely with a wide array of tools including Infrasound, Radar, and Thermal Imaging to detect avalanches and people. Artillery at Alta and Snowbird resorts point across the canyon at 120 targets. 101 of those have a flight path that travel over buildings. In 2007 with the installation of the first two Gazex®, the number of targets with overhead trajectories began to drop. In that same year the ARMY demanded that the practice of overhead fire be stopped. After much negotiation UDOT was granted a conditional extension to the practice. First, a change in weapons systems from Recoilless Rifle to Howitzer was mandated. The ammunition for the M101 A1 105 mm Howitzer is more reliable and it is now the required weapon for all of the Avalanche Artillery Users of North America Committee (AAUNAC), the governing group formed to unify artillery for avalanche use. The second condition was that UDOT begin reducing the number of targets with overhead trajectories, the eventual goal being eliminating them entirely.

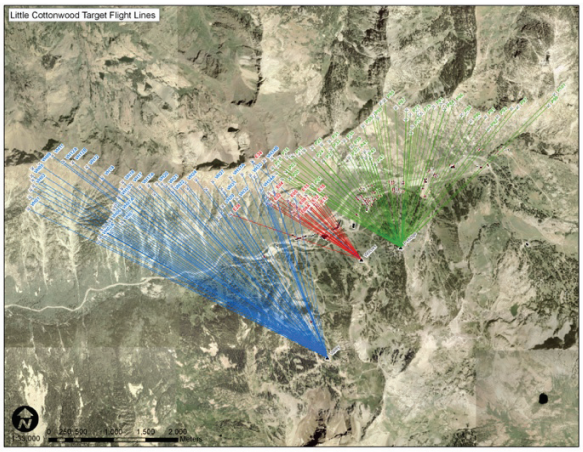

Fig. 4 LCC Artillery Target Flight Lines pre 2006

This is no easy task given UDOT's level of dependency on an inexpensive, reliable, safe and efficient means of triggering avalanches on a broad scale. An analysis was done comparing costs of different avalanche control methods, both their initial capital investment and cost per shot (Yount and Gorsage, 2016) and it was reconfirmed that artillery is by far the least expensive tool overall. When considering metrics such as annual artillery membership dues, maintenance, army fees, and training, UDOT's cost per artillery shell is $132. Alternative explosive delivery devices like the Avalauncher and Avalanche Pipe® aren't viable due to their shorter range. Remote avalanche control systems (RACS) have therefore been incorporated. By winter 2018-2019 UDOT will have 21 Gazex®, two O'Bellx®, one DaisyBell®, and one Wyssen Tower® operational in LCC. Initial capital investment is also a huge factor when considering types of active control methods. Each type of RACS comes with different costs for the equipment and installation. Gazex® has lower equipment and higher installation costs and O'Bellx® and Wyssen® are easier to install and more expensive to purchase. In the end it all evens out, and the cost per RACS is approximately $220K. UDOT has invested over $6 million on its 24 RACS and is planning for 12 more in 2019 and possibly another 10 in 2021 which would mark a

milestone; eliminating overhead fire in LCC. While costs and maintenance have increased, greater efficiency and increased safety have been realized.

3.2 Avalanche Hazard Index (AHI)

It is difficult to quantify the risk of a motorist-avalanche encounter on any given highway, but one of the best tools used is the AHI. The standard formula used considers factors such as avalanche size and frequency, number of paths and distance between them, traffic volume and speed, and length of highway exposed. Another factor that greatly influences the risk is the waiting traffic encounter probability, or if after an avalanche blocks the road, the risk to the backup of traffic exposed to other avalanche paths. In LCC this factor causes the number to skyrocket. The AHI hazard categories go from Low <1, to Very High >150. In 2006 the AHI was calculated at 1045 using the standard formula by Schaerer (F&P,2006). The waiting traffic factor used was 3 paths on either side. This is likely far too few given today's current traffic that creates a "Red Snake" of brake lights the entire length of the canyon. In July 2018 the AHI was recalculated using updated traffic numbers and avalanche occurrences and the waiting traffic component was adjusted to up to 20 paths for some locations (Hendrikx and Jones 2018). The new number of 6135 better reflects the true risk during peak traffic high hazard days.
But what does a program do with such a number? It should be noted that these numbers are for an uncontrolled avalanche hazard, which is not the current state of affairs. With the hazard reduction measures of the UDOT Avalanche Safety Program the residual hazard (RAHI), after closures and control work, is brought down to 71, still in the High category. The goal of the program is to reduce the RAHI to below 40, in the Moderate category. It is clear however that such a reduction cannot be achieved by active control measures alone. Some form of passive measures must be incorporated or the number of vehicles using the road must be significantly reduced.

4. FINDINGS AND RECOMMENDATIONS

4.1 Alta through Snowbird

It is useful to break the canyon up into different zones to better reflect their individual characteristics and challenges. From Alta through the Snowbird Village lie almost all of the infrastructure of importance in the canyon. With this it becomes clear that certain types of passive control measures are not appropriate. Snowsheds in this zone for instance, might protect the highway but largely would just divert the problem toward another piece of infrastructure or building. Supporting structures are not viable due to terrain limitations and multiple recreational use. The plan calls for continued artillery use and additional RACS along the Emma Ridge above Alta. Installation of seven more Gazex® and one O'Bellx® will be completed in Hellgate this fall allowing for more options to conduct control missions outside of peak busy hours and further reducing overhead fire by 33% (see Table 1).

Tbl. 1: UDOT Artillery Fire Over Buildings

UDOT Overhead Fire	Pre 2006	2013	2018	2019
Buildings with Overhead Fire	76	73	60	28
Artillery Shots go over Buildings	101	84	68	32
Reduction in # of Buildings	-	3 = 14%	16 = 21%	48 = 64%
Reduction in Overhead Fire Shots	-	17 = 17%	33 = 33%	69 = 70%

In fall of 2017 UDOT installed the first Wyssen Tower in the US in Cardiff Bowl. The benefits of its ease of installation, small footprint, large area of influence, and low environmental impact have led to a plan for the next 12 towers to be installed along the Emma Ridge in summer 2019. Figure 3 shows the flight lines of artillery shots from the Peruvian Ridge Howitzer at Alta and the reduction of overhead fire with the use of Gazex. This analysis was completed by Dynamic Avalanche Consulting (Jones et al. 2016) before Wyssen was approved in the US by the ATF. It does still show the dramatic reduction in overhead fire targets. With this stage of the avalanche safety improvement plan (F&P, 2016) there will be a 70% reduction, leaving the last 30% with the targets on Mt. Superior. These changes also vastly improve the ability to manage the hazard at more appropriate times of day without the risk of shrapnel in high traffic areas.

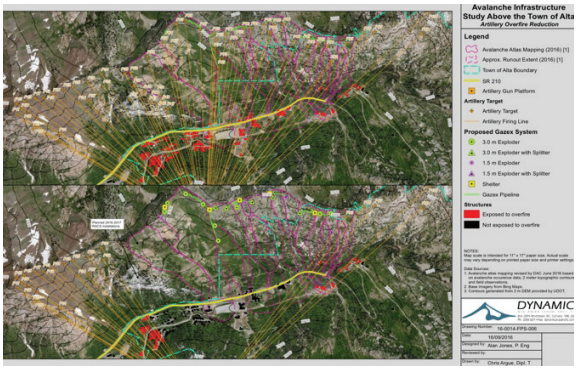

Fig.3 Overhead Fire Reduction in the Town of Alta

4.2 Mid and Lower Canyon

Below Snowbird there is a near continuous threat with paths stacked up closely for the next 4km. The zone with the biggest threat and that with the most

close calls is White Pine. It consists of two, 1000m vertical paths with multiple starting zones that can affect the road independently and four slightly smaller paths stacked up in succession. Here the road also travels through the lower part of the tracks of the paths making even smaller avalanches a threat. Most of this terrain is located in a Wilderness Area prohibiting any permanent structures. Making the argument for a variance to the restrictions was considered but ultimately it was decided that even the best form of active avalanche control still leaves open the possibility for a post control release. In the past, passive measures have been proposed but the high cost has been prohibitive. Currently two snowsheds, ~300m and ~700m, are being proposed as part of an Environmental Impact Statement (EIS) aimed at creating long term solutions to the transportation and avalanche problems. The cost of these sheds is estimated at near $50million and there is promising support. They represent a potential reduction in control efforts below Snowbird of up to 75%.

4.3 Transportation Solutions

Part of the EIS is focused on how best to deal with a demand that is larger than the current two lane road can supply. Many options are being considered including better bus service with larger transit hubs, adding additional lanes for public transit and carpooling, road tolling, cog railway, aerial tram, improved information systems creating a "*smart roadway*", traffic signaling to meter the afternoon exodus, and others. The goal of all of them is to reduce single occupancy vehicles and incentivize public transport to relieve the gridlock that at it's worst can last for over three hours.

5. CONCLUSIONS

The challenges faced today in LCC are not new. They have existed to some degree for over 100 years and are simply occurring much more frequently. Many places in our modern world face the issue of a rapidly growing population fighting for limited resources. The real challenge lies in how to find a balance and uncover ways to stop loving our sacred places to death. The UDOT team is trying to come to the solutions holistically, finding ways to both increase the efficiency and effectiveness in avalanche control and finding better, innovative ways to move people through the mountains safely.

CONFLICT OF INTEREST

Neither TAS and its parent company MND, nor Wyssen supported this study financially or materially. The products referred to in this study and those purchased by UDOT were acquired at fair market price through normal distribution channels and were evaluated objectively regarding the benefits offered to each situation. The authors have not benefitted financially from the production or installation of any said products.

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We also must acknowledge our team of UDOT avalanche forecasters especially the most sleep deprived of the group in LCC. Thanks for all your hard work and tireless dedication.

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