Evolution of Avalanche Risk Reduction on the Alaska Railroad

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1. INTRODUCTION

The Alaska Railroad travels through the Chugach Mountains of Alaska for a distance of 190 km. With precipitous terrain and large snowfalls, numerous avalanches occur in the southern 108 km. of the rail line with 23 avalanche paths effecting 19.76 km. of track length. A total of 18% of the track can be impacted by avalanches in this area.

Since completion of the railroad in 1917, avalanches have played a significant and adverse role in the operation of the line. To date, avalanches have claimed a total of 8 lives with damage to equipment ranging well into the millions of dollars.

In the early days many snowsheds were constructed to protect against avalanches using local timbers, but all were gone by 1965. There were incidents of trains being derailed by avalanches in 1920, 1921, 1932, 1941, 1946, 1948, 1949, 1959, and 1961 (Fessler, personal com.) With the advent of the Alaska Pipeline project in the mid-1970's, traffic volumes on the line climbed dramatically with a corresponding increase in risk. A major accident in 1980 began the modern avalanche program. From 1980 until 1985, considerable effort was focused on slowing trains down when avalanche events might occur, and in acquiring the use of military artillery for avalanche control. From 1985 until 2000 a basic explosives mitigation program was undertaken which further reduced risk. A large post-control avalanche release in 2000 resulted in the death of a railroad operator while assisting the highway department in avalanche cleanup. After this incident, further efforts were undertaken to add improved forecasting and better facilities to the program. Traffic volumes also have increase substantially since 2000. Given the magnitude of the avalanche hazard, incidents continue to occur on a periodic basis. Another incident during the winter of 2009 has resulted in a new system analysis. This paper will summarize the analysis that went into each step of the avalanche program and the resulting reductions in risk and cost/benefits.

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2 DATA BASE AND ANALYSIS CONSIDERATIONS

For the purpose of analyzing risk in a recognizable format, the use of the Avalanche Hazard Index (AHI) (Schaerer 1989) has been adapted to a railroad setting. No significant adaptations are required to run the formula for trains, although there are substantial differences in speed and stopping distance. The equations used are not presented but are available by request. For those unfamiliar, a review of the original paper is in order. This index is widely used in highway applications, but has only rarely been used for railroads.

In using the AHI to define avalanche risk, it is worth noting that base values exceeding 40 typically result in implementation of a full time avalanche program. The more intensive programs with very high starting level AHI values (above 150), are typically faced with residual levels of 20 to 70 after mitigation efforts. Experience has shown that these residual levels still result in periodic close call incidents. For the purpose of comparison, Figure 1 shows the range of AHI values compared to hazard.

Figure 1- AHI Values

Hazard Catagory	AHI Value
Very Low	<1
Low	1 to 10
Moderate	10 to 40
High	40 to 150
Very High	>150

Figure 2 shows the range of unmitigated and mitigated AHI values for a few well known avalanche programs.(Stethem, 1993, pers com 2009; Glude, 2005; Comey, 2007)

Figure 2- AHI levels

Program	Unmitigated AHI	Mitigated AHI
Rogers Pass	1004	27
Little Cottonwood	1030	75
Red Mtn. Pass	335	70
Seward Highway	170	30
Alaska Railroad	213	29

The Alaska Railroad has meticulous records of natural avalanche occurrences to the railroad tracks between 1946 and 1986. This data base has been previously analyzed (Hamre, McCarty, 1996) for frequency/magnitude relationships with respect to runout distances. The avalanche program maintains occurrence records of both natural and artificial avalanches. Natural events that occur under “open” track conditions when people, vehicles, and trains could be in the location of the avalanche represent the residual avalanche risk. Avalanches that were artificially released or happened naturally onto a “closed” track represent the mitigated risk.

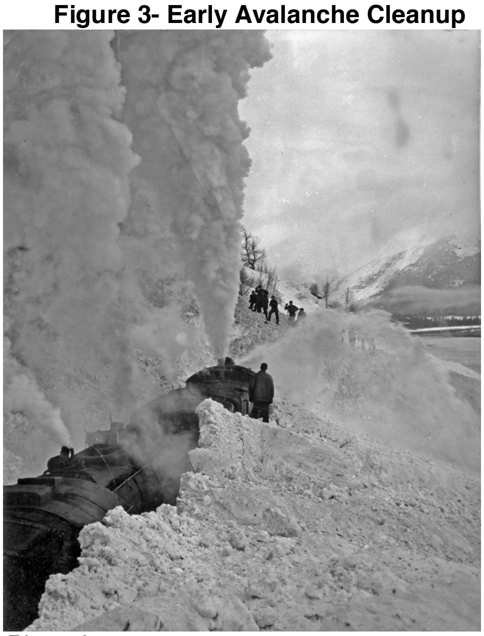
3 AVALANCHE PROGRAM EVOLUTION

A total of 4 distinctive time periods have been identified for analysis along with 2 potentially significant program changes. Each phase in the evolution of the avalanche program built on lessons learned from previous phases.

3.1 Pre-program 1917 to 1980

Little is known about avalanche effects on railroad operations before 1980 other than through newspaper accounts or daily train log sheets. Somewhere between 3 and 6 workers died on April 28, 1920 when they were swept into Turnagain Arm while cleaning up an avalanche near the town of Girdwood.

Figure 3- Early Avalanche Cleanup



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Another worker was killed in a train derailment due to avalanches on March 27, 1932. Buildings were destroyed and the caretaker lost during an avalanche on Dec. 13, 1948. There were numerous incidents of train derailments. The extent of damages cannot be quantified, but is likely significant.(Fesler, 1990)

Daily train sheets were kept noting train movements and unusual incidents during this time period. In 1984 these records were found dating back to 1946, noting all the avalanches that blocked the line by time, location, and size. This data base was adequate to compute the baseline, unmitigated AHI level.

Figure 4- Baseline AHI

Moving AHI	Waiting AHI	Total AHI
33	180	213

The moving AHI considers the probability of a moving train being hit by an avalanche. If a train is stopped by an avalanche that is already down, especially by running into the debris, it is subject to further avalanches in that path or adjacent paths it is exposed to. The AHI equations account for this separately as the waiting AHI. In this case, a waiting time of 4 hours was used.

3.2 Program Inception 1981 to 1986

On January 22, 1980, a freight train moving at 65km/hr. rounded a corner near the town of Girdwood and plowed into a large avalanche deposit that had previously released. A total of 4 locomotives and 13 train cars were derailed into Turnagain Arm during this event. This became the impetus for creating an avalanche program.

Figure 5- 1980 Train Derailment

Photo by D. Fesler

Efforts were made during this time period to quantify risk locations by examination of the data base, acquire the use of military artillery, and to mitigate with helicopter bombing when possible. The largest risk reduction was gained by implementing a “slide zone” policy. When there was a possibility of an avalanche reaching the railroad tracks, the slide zones were put into effect by orders to the trains. This required trains to operate at restricted speed in the slide zones. They were also given instructions to back out of slide zones if an avalanche had already occurred. While slowing the trains down increases the likelihood of them being impacted by a moving avalanche, it significantly decreases the risk of running into an avalanche that is already down and getting stuck. As a consequence, the waiting time calculations could be lowered to just one hour and stopping distances are substantially lowered. The resulting change in AHI is noted.

Figure 6- Slide Zones Implemented

Moving AHI	Waiting AHI	Total AHI
27	90	118

Given the high residual risk levels, further efforts were required to achieve suitable risk reduction.

3.3 Implement Explosives Mitigation

From 1986 until 2000, the use of military weapons for release of avalanches was heavily implemented into the avalanche program. Explosives mitigation was reasonably effective in some locations but not in others. In no cases was the risk reduction on a given path greater than 77%.There was little emphasis during this period on remote forecasting capabilities. As a consequence, approximately 75% of natural avalanches reaching the tracks during this time period were under open track conditions. In spite of this, progress was made on reducing the AHI levels as shown.

Figure 7- Explosives Implemented

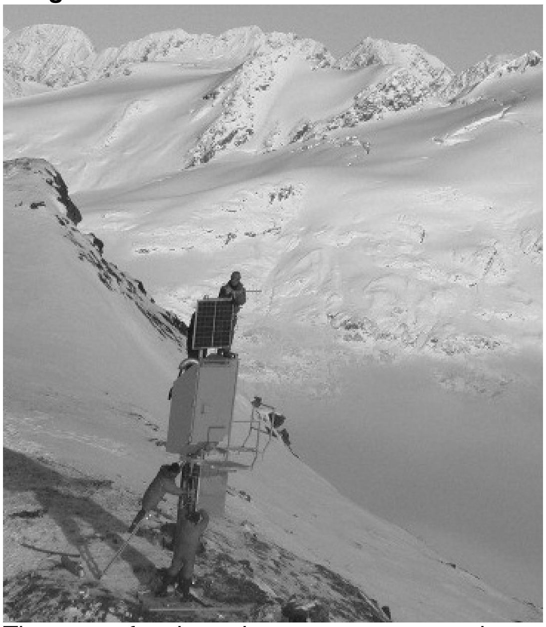
Moving AHI	Waiting AHI	Total AHI
10	31	41

Even with extensive use of explosives, close call incidents continued on a periodic basis, warranting further reduction efforts.

3.4 Integration of Advanced Systems

Improvements were made during this period to the capability of delivering explosives in a timely manner, avalanche detection, forecasting, weather stations, data base management, and hardening of snow clearing equipment (Hamre, 2006)

Figure 8- Avalanche Guard Installation



The costs for these improvements was significant at $1,500,000 USD of capital costs not including additional operations funding. This investment has reduced the residual AHI level further. Improvements in forecasting and data management have reduced the incidence of natural releases to open tracks from 75% to 50%. Partially offsetting these gains has been an increase in rail traffic. As a result, the current AHI is described.

Figure 9- Current AHI w/ 2008 traffic levels

Moving AHI	Waiting AHI	Total AHI
9	20	29

3.5 Further risk reductions

In spite of the efforts put forth, serious incidents continue to happen approximately once every ten years. This incident frequency is consistent with other programs with comparable residual AHI levels, but is bothersome.

The 49 Mile path is unique in that it has a high avalanche frequency, and is on a steep rail grade. The train handling problems associated with the grade compound the issues of avalanche management. Part of the avalanche path is subject to small, frequent sluffs which stop trains and leave them exposed to much larger but less frequent avalanches in a different portion of the avalanche path. Encounter probabilities show this path to be the most significant contributor to avalanche risk in spite of explosives mitigation. The top five paths by encounter probability are listed.

Figure 10- Encounter Probability

Path Name	Annual Probability
49 Mile	0.257
Kern	0.130
43 Mile	0.084
Door 4	0.040
Bird Flats	0.031

Opportunity exists to significantly effect the AHI by singular focus on this avalanche path. The option exists to excavate into the uphill bank 25 meters laterally, creating a catchment ditch 3 meters deeper than the tracks. This would catch approximately 80% of the total avalanche activity on this path. By implementing this strategy the AHI would be further reduced to approximately 2/3 of the current risk level.

Figure 11- Earthworks at 49 Mile

Moving AHI	Waiting AHI	Total AHI
8	13	21

Further reductions would focus on the Kern and Centerline paths where snowsheds would be required in order to mitigate the risk. The Kern path would yield a larger drop in AHI.

Figure 12- Snowshed at 2 paths

Moving AHI	Waiting AHI	Total AHI
7	8	15

4 ALTERNATIVE CONSIDERATIONS

4.1. Cost effectiveness

Measuring the cost versus risk benefit is difficult. In this review, to the calculated losses we have added the annual cost of the avalanche program including both operations and capital costs to derive a total cost.

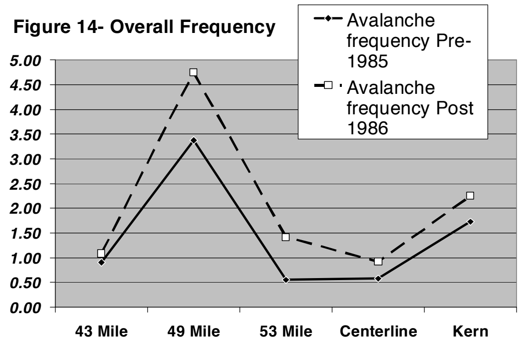
Figure 13- Total Program Costs

Method	Loss $	Annual $	Total $
Baseline	$580,427	$0	$580,427
Slidezones	$378,279	$10,000	$388,279
Explosives	$129,360	$155,000	$284,360
Current	$77,643	$357,212	$434,855
Dirt@49	$56,660	$389,496	$446,156
Sheds	$46,417	$849,068	$895,485

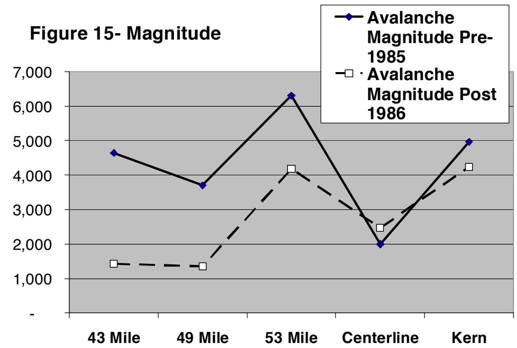
The most effective program would lower the risk to an acceptable level, and have the least total cost. The explosives only program stands out in this analysis, but with a residual AHI of 41, was deemed too risky.

4.2 Alteration of avalanche characteristics by mitigation work

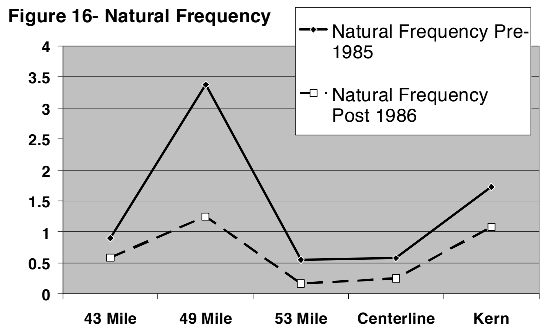
There has been much speculation on the effects an active explosives program has on avalanche characteristics. Analysis of the five major paths that receive frequent explosives risk reduction shows that overall avalanche frequency to the tracks has increased.



However, the magnitude of avalanches as measured by the depth of burial and length on the tracks has decreased.



Additionally, the frequency of natural events to the tracks has decreased substantially as well.



Taken in the aggregate, these statistics show a marked decrease in risk. If we take these trends to be true, than we can re-run the

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AHI calculations using current traffic levels, and modified frequency and magnitude statistics.

Figure 17- New Frequency & Magnitude

Moving AHI	Waiting AHI	Total AHI
19.76	**22.08**	**41.83**

This method of calculating AHI shows a higher moving level and overall level than shown in Figure 9. In the Figure 9 calculations a 50% reduction was taken for natural avalanches happening during closures. In this case, no reduction is taken, which likely overstates the AHi somewhat.

4.3 Comparison to Actual Losses

In spite of the best efforts of the mitigation program, serious incidents continue to occasionally occur. These have resulted in losses since the avalanche programs inception. Values have been assigned to these losses in order to compare actual losses against calculated losses, normalized to 2009 U.S. dollars. This helps to verify whether the calculations are valid enough to base major capital project costs on.

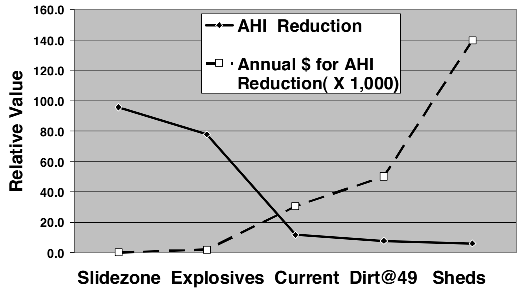
Figure 18- Actual vs. Calculated Losses

Year	Actual losses in 2009$ USD	Calculated Loss
1985	$ 139,400	
1989	$196,384	
1993	$204,450	Explosives
1997	$490,773	Only for 15
2000	$1,878,858	Years, current
2009	$500,000	program for
Total	$3,409,866	10 years
Avg.	**$136,395**	**$108,673**

4.4 Reduction cost per AHI Unit.

The following graph illustrates the cost per unit at each phase of avalanche risk reduction, and is illustrative of the difficulty of decisions later in the cycle of program development.

Figure 19- Cost of Risk Reduction



5. Conclusions

Provided an adequate data set exists, objective analysis of risk reduction and cost/benefit considerations can be gained through careful use of the Avalanche Hazard Index.

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