Addendum to Appendix J

Snow Avalanche Report

Prepared by

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TABLES

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ERRATA SHEET

OCTOBER 2004 SNOW AVALANCHE REPORT

1. Page 35, Table 5: Elevated Fills, Conversion. The wrong conversion factor was used for the metric units of thrust. Using the conversion 1 Kpa = 20.9 pounds per square foot (psf), the parenthetical value on the first line of the thrust column for ELC002 should be 201 Kpa and the parenthetical value on the second line for ELC 014 should be 321 Kpa.

2. Page 98, Page Number. A typographical error resulted in this page being numbered as 998.

3. Page 277, Juneau Area Avalanche History Analysis Table. The second page of the table, provided below, is missing and should be inserted as page 278.

Table E-1
Juneau Area Avalanche History Analysis

Avalanche season from…	To…	Number of avalanches	Largest size avalanche	Avg. Annual # of avalanches for period	Average size avalanche for period	Period type
1949	1950	0.0				
1950	1951	1.0	3.0			
1951	1952	1.0	4.0			
1952	1953	1.0	3.0	1.0	3.3	Warm period
1953	1954	0.0				
1954	1955	7.0	3.0			
1955	1956	2.0	3.0			
1956	1957	0.0				
1957	1958	0.0				
1958	1959	1.0	3.0			
1959	1960	0.0				
1960	1961	0.0				
1961	1962	5.0	3.0			
1962	1963	0.0				
1963	1964	4.0	4.0			
1964	1965	1.0	3.0			
1965	1966	8.0	3.0			
1966	1967	1.0	3.0			
1967	1968	0.0				
1968	1969	0.0				
1969	1970	0.0				
1970	1971	9.0	3.0			
1971	1972	6.0	5.0			
1972	1973	1.0	3.0			
1973	1974	6.0	4.0			
1974	1975	3.0	4.0			
1975	1976	11.0	4.0	2.8	3.4	Cold period
1976	1977	0.0				
1977	1978	0.0				
1978	1979	0.0				
1979	1980	1.0	3.0			
1980	1981	0.0				
1981	1982	1.0	3.0			
1982	1983	0.0				
1983	1984	0.0				

Table E-1 (continued)
Juneau Area Avalanche History Analysis

Avalanche season from…	To…	Number of avalanches	Largest size avalanche	Avg. Annual # of avalanches for period	Average size avalanche for period	Period type
1984	1985	8.0	4.0			
1985	1986	0.0				
1986	1987	0.0				
1987	1988	0.0				
1988	1989	6.0	4.0			
1989	1990	0.0				
1990	1991	2.0	3.0			
1991	1992	0.0				
1992	1993	0.0				
1993	1994	0.0				
1994	1995	0.0				
1995	1996	1.0	3.0			
1996	1997	2.0	3.0			
1997	1998	1.0	3.0			
1998	1999	0.0		1.0	3.3	Warm period
1999	2000	4.0	3.0			
2000	2001	0.0				
2001	2002	7.0	3.0			
2002	2003	0.0		2.8	3.0	Cold period
Cold period average				2.1	3.5	
Warm period average				0.8	3.4	
Warm to cold multiplier				2.6	1.0	

1.0 ADDITIONS TO THE OCTOBER 2004 SNOW AVALANCHE REPORT

1. Page 13. Table 1. Avalanche Hazard Index (AHI) Comparison – The following table has been updated by listing Alternative 2B and adding Thane Road.

Table 1
AHI Comparison

Highway	Unmitigated AHI	Daily Observations & Forecasts	Forecasting, Closure, & Explosives	Structural Mitigation	Special Explosives Methods
Rogers Pass, BC	1004	x	x	x	X
Red Mtn. Pass, CO	335	x	x	x	
* Seward Highway, AK (Anchorage-Seward, old alignment)	331	x	x	x	
* Seward Highway, AK (Anchorage-Girdwood, old alignment)	188	x	x	x	
East Lynn Alt 2B, AK	186	x	x	x	
Coal Bank/Molas, CO	108	x	x		
West Lynn, AK	100	x	x	x	
Berthoud Pass, CO	93	x	x		
Coquihalla, BC	90	x	x	x	x
Loveland Pass, CO	80	x	x		
Wolf Creek Pass, CO	54	x	x	x	
Silverton-Gladstone, CO	49	x	x		
Teton Pass, WY	47	x	x		x
Lizard Head Pass, CO	39	x	x		
I-70 Tunnel Approaches, CO	27	x	x	x	
Thane Road, AK	21		x	x	

Note: * Historical data for AHI calculation is only available for the pre-1998 Seward Highway alignment.

2. Page 16. The following subsection should be added to findings following Lynn Canal Mitigation Options – Explosive Delivery

   Forest Service Permits for Avalanche Program

   U.S. Forest Service and any other land use permits for highway alternatives must include provisions for the avalanche program, including access, explosive use, any installations in the avalanche paths, and permits for the weather station sites.

3. Page 33. Add the following subsections to Avalanche Mitigation following Table 4, Highway Residual AHI Comparison

   Mitigated AHI Target Value

   Like most avalanche standards, acceptable mitigated AHI values are not absolutes, but are established by industry practice. The target residual AHI of 30 or less was chosen because it is accepted as an adequate level of mitigation for similar highways in North America. Tables 4A and 4B detail the level of avalanche mitigation on the North American highways for which figures are available. For most highways in the tables, unmitigated AHI multiplied by 0.21 is used to calculate Residual AHI, using the average residual risk as calculated in Table 4. A Residual AHI factor of 0.04 is used for Rogers Pass based on the reduction calculated for its intensive mitigation program in the Five Mountain Parks Highway Avalanche Study. The Lynn Canal routes listed here have a Residual AHI factor of 0.15 multiplied by the structurally mitigated AHI value. These East Lynn Canal values are for the option without snowsheds and use conservative criteria for extended closures as detailed under Risk Management, Avalanche Forecasting, and Highway Closures in this section.

Table 4A
Residual AHI Comparison

AHI Category	Highway	Unmitigated AHI	Residual AHI
Very High AHI Highways	Rogers Pass, BC	1004	40
	Red Mtn. Pass, CO	335	70
	* Seward Highway, AK (Anchorage-Seward, old alignment)	331	70
	* Seward Highway, AK (Anchorage-Girdwood, old alignment)	188	39
	Coal Bank/Molas, CO	108	23
	Average, Very High AHI highways	**393**	**48**
High AHI Highways	Berthoud Pass, CO	93	20
	Coquihalla, BC	90	19
	Loveland Pass, CO	80	17
	Wolf Creek Pass, CO	54	11
	Silverton-Gladstone, CO	49	10
	Teton Pass, WY	47	10
	Average, High & Very High AHI highways	**216**	**30**
Moderate AHI Highways	Lizard Head Pass, CO	39	8
	I-70 Tunnel Approaches, CO	27	6
	Thane Road, AK	21	4
	Average, all listed highways	**176**	**25**
Lynn Canal	East Lynn Alt 2B, AK (very high)	186	27
	West Lynn, AK (high)	100	15

Note: *Historical data for AHI calculation is only available for the pre-1998 Seward Highway alignment.

Table 4A compares the unmitigated and the mitigated, or residual, AHI levels for highways grouped by AHI range. The average residual AHI for Very High unmitigated AHI category highways is 48. The unmitigated AHI values for the East Lynn Canal, Alternative 2B route is in the Very High category. The chosen target residual AHI of 30 is the average for the highways in the next lower AHI category, High and Very High, giving a safety margin of one full step on the chart. The other highways on the chart are considered to have adequate operational safety margins. The target figure of AHI 30 for the East Lynn Canal route, Alternative 2B allows an additional margin of 38 percent. The unmitigated AHI for the West Lynn Canal route, Alternative 3, is at the very top of its High category, bordering on Very High. The target AHI 30 meets the average residual AHI standard for highways in both the High and Very High categories, yielding a similar margin to that for the East Lynn Canal route.

Table 4B
Mitigated AHI Per Unit Distance Comparison

AHI Category	Highway	Unmitigated AHI	Avalanche Zone, Miles	Residual AHI/Mile	Avalanche Zone, Km	Residual AHI/Km
Very High AHI Highways	Rogers Pass, BC	1004	24.8	1.6	40.0	1.0
	Red Mtn. Pass, CO	335	17.4	4.1	28.0	2.5
	* Seward Highway, AK (Anchorage-Seward, old alignment)	331	88.9	0.8	143.1	0.5
	* Seward Highway, AK (Anchorage-Girdwood, old alignment)	188	16.5	2.4	26.6	1.5
	Coal Bank/Molas, CO	108	34.0	0.7	54.7	0.4
	Average, Very High AHI highways	**393**	**36.3**	**1.9**	**58.5**	**1.2**
High AHI Highways	Berthoud Pass, CO	93	16.0	1.2	25.7	0.8
	Coquihalla, BC	90	12.4	1.5	20.0	0.9
	Loveland Pass, CO	80	8.0	2.1	12.9	1.3
	Wolf Creek Pass, CO	54	18.4	0.6	29.6	0.4
	Silverton-Gladstone, CO	49	6.5	1.6	10.5	1.0
	Teton Pass, WY	47	13.8	0.7	22.2	0.4
	Average, High & Very High AHI highways	**216**	**23.3**	**1.6**	**37.6**	**1.0**
Moderate AHI Highways	Lizard Head Pass, CO	39	21.0	0.4	33.8	0.2
	I-70 Tunnel Approaches, CO	27	15.0	0.4	24.1	0.2
	Thane Road, AK	21	2.9	1.5	4.6	1.0
	Average, all listed highways	**176**	**21.1**	**1.4**	**34.0**	**0.9**
Lynn Canal	East Lynn Alt 2B, AK (very high)	186	50.5	0.5	81.3	0.3
	West Lynn, AK (high)	100	33.3	0.4	53.7	0.3

Notes: *Historical data for AHI calculation is only available for the pre – 1998 Seward Highway alignment.
Km = kilometers

Another way to compare residual AHI is to look at AHI per unit distance as shown in Table 4B. This method factors in the length of the route, allowing fair comparison between long and short routes. Alternative 2B and Alternative 3, have values below the average for the highways in the next lower AHI category, High and Very High, giving a safety margin of one full step on the chart. The East Lynn Canal segment from paths ELC 002 – 030 has the highest number of large avalanche paths per unit distance of any portion of the route, with an AHI of 185 over 17.4 miles (28.0 kilometers [km]), yielding values of 1.5 AHI/mile (0.9 AHI/Km). These values are lower than the average for the High and Very High residual AHI categories, yielding a safety margin of more than one full step on the chart.

AHI Values and Risk to Travelers and Workers

The AHI numbers commonly used in avalanche hazard evaluation do not express the probability of death, damage, or injury per unit time or per thousand travelers, as do studies in some other fields like medicine. The AHI is used for comparing the hazard rather than evaluating the level of risk. It is a relative index, as noted in AHI Overview on pages 25 through 27 and in Appendix 1: AHI Calculation on pages 265 through 267 of the 2004 *Snow Avalanche Report*. Many avalanche-exposed highways have not had their AHI values determined because it is an involved, time-consuming calculation, but the AHI has been calculated for enough avalanche-exposed highways in North America to make it the most useful available method for avalanche hazard comparison. The AHI numbers cannot be translated directly into probability of adverse encounters and there is no compilation of figures available from which to determine absolute probabilities.

Risk Management Records of Three Very High AHI Highways

The three highways with the highest AHI values listed in this report are Rogers Pass at 1004 (mitigated to 40), Red Mountain Pass at 335 (mitigated to 70), and the old alignment of the Seward Highway from Anchorage to Seward at 331 (mitigated to 70). The Trans-Canada Highway over Rogers Pass in British Columbia has operated for the 42 years since 1962 with a state-of-the-art avalanche program. There have been no deaths to the traveling public on the Rogers Pass highway, but there have been two highway worker deaths. The same secondary avalanche killed both workers in 1966 while they were clearing debris from an earlier slide. The highway was closed to the public at the time. There have been 33 avalanche involvements, 8 of which resulted in vehicle or building damage and 3 in injury or death.

Red Mountain Pass in Colorado has had a full avalanche program for the 11 years since the winter of 1992-93. During that time, there have been no deaths, damaged vehicles, or injuries. There was one involvement. A Colorado DOT&PF truck was hit by an intentionally triggered slide but was undamaged.

Figures for the Seward Highway are available for the 23 years since 1981, during which there has been a full avalanche program. There were no deaths to the traveling public. There was one highway worker killed by a secondary avalanche in 2000 while clearing debris from an earlier slide. The highway was closed to the public at the time. There were 12 avalanche involvements, spanning a range from dust clouds causing loss of control to avalanches striking vehicles, but a breakdown of the involvements was not available in the records. One of the 12 incidents was the 2000 fatality.

Table 4C
Avalanche Risk Summary, Three Very High AHI Highways

Category	Events Per Year
All Avalanche Involvements	0.61
Avalanche Involvements, Damage to Vehicles or Buildings	0.15
Avalanche Involvements, Injuries or Deaths	0.04
Avalanche Deaths, Highway Workers	0.04
Avalanche Deaths, Traveling Public	<0.01

The history of the three Very High AHI highways totals 76 years of combined operational records, summarized in Table 4C. There have been no deaths to the traveling public, or less than 0.01 deaths per operational year. There have been three deaths to highway workers, or 0.04 per operational year. The higher risk to highway workers underscores the need for strict adherence to the avalanche program and risk management protocols presented in this study, particularly when reopening the highway after avalanches have occurred. There have been 46 avalanche involvements, or 0.61 per operational year. A complete breakdown is only available for 53 of those operational years, but those records show 0.15 incidents with vehicle or building damage per operational year and 0.04 with injuries or deaths per operational year.

Table 4D
Effectiveness of Avalanche Programs on Two Very High-AHI Transportation Corridors

Death Rate Without Avalanche Programs	1.55
Death Rate With Avalanche Programs	0.04
Improvement Factor	39.24

Effectiveness of avalanche programs on Very High-AHI highways is best evaluated where death rates per year can be compared for periods with and without avalanche programs. Before the Trans-Canada Highway was opened over Rogers Pass, the Canadian Pacific Railroad operated for the 76 years from 1885 to 1962 with only flimsy wooden snowsheds for avalanche defense. Records for these early years are incomplete, but the best available references state that "more than 200 people died in avalanches" there. Red Mountain Pass has been plowed throughout each winter since 1935. In the 57 years of operation until the modern avalanche program began in 1992-93, six people were killed. The history of these two routes totals 133 years of combined operational records before modern avalanche programs. At least 206 people died, or greater than 1.55 deaths per operational year. The death rate without modern avalanche programs is almost 39 times the death rate of 0.04 per year for high AHI highways with them. This large difference suggests that avalanche programs are an effective and necessary means of reducing risk to travelers and highway workers.

Table 4E
Comparison of Risks to Alaskans with Highway Avalanche Risk

Category	Deaths Per Year
Alaska, All Motor Vehicles	102.00
Alaska, Highways	95.00
Alaska, Other Accidental	51.00
Alaska, Poisonings	51.00
Alaska, Other Transport Accidents	48.00
Alaska, Drownings & Submersions	25.00
Alaska, Falls	18.00
Alaska, Smoke, Fire, and Flames	15.00
Alaska, Firearms, Accidental	5.00
Alaska Highways, Avalanches, Highway Workers	0.06
High AHI Highways, Avalanches, Highway Workers	0.04
Alaska Highways, Avalanches, Traveling Public	<0.03
High AHI Highways, Avalanches, Traveling Public	<0.01

Table 4E compares a number of risks to Alaskans with highway avalanche risk in terms of deaths per year. Among Alaska highways, only the Seward and the Richardson Highways have full modern avalanche programs. There are limited programs on the Dalton Highway, the Copper River Highway, and Thane Road. The Parks Highway, the Haines Highway, the Alaskan portion of the Klondike Highway, and several other less-traveled roads in Alaska have avalanche issues but no avalanche programs.

Alaska has had no highway avalanche deaths to the traveling public in the 35 years since 1969, and two highway worker avalanche deaths. Both were clearing debris from previous avalanches while the highway was closed to the public. One death was in Southeast Alaska, on Thane Road in 1974. There have been no highway avalanche deaths to the traveling public in Alaska during this period, or less than 0.03 deaths per year, and there have been 0.06 deaths per year to highway workers. In contrast, the total traffic death rate for Alaska over the most recent ten-year period for which figures are available is 95.

For comparison with non-highway risks, the total Alaska motor vehicle accident death rate for the most recent ten-year period for which figures are available, including off-road accidents, is 102 deaths per year. The rate for poisonings is 51 deaths per year, for other transport accidents it is 48 deaths per year, for drowning and submersion it is 25 per year, for falls it is 18 per year, for exposure to smoke, fire, and flame it is 15 per year, and for accidental discharge of firearms it is 5 per year. For other accidental deaths, it is 51 deaths per year.

4. Page 337. Appendix 13. References. The following references were used for this addendum in the discussions of residual risk and should be added to the references appendix:

Goodrich, J. 2005. Personal communication on accident figures, Parks Canada avalanche forecaster for Rogers Pass, BC. Summer 2005.

Marshall, J. and Roberts, J. 1993. Vol. 1 Living (and dying) in Avalanche Country, Simpler Way Book Company, PO Box 556, Silverton, CO 81433.

Matthews, M. 2005. Personal communication on Alaska accidental death figures, from Alaska Department of Health and Social Services vital statistics. Summer 2005.

National Highway Transportation Safety Administration 2003. State Traffic Safety Information for Year 2003, Alaska Toll of Motor Vehicle Crashes. http://www.nhtsa.dot.gov/STSI/State_Info.cfm?year=2003&State=AK&Accessibl e=0

Onslow, T. 2005. Personal communication on accident figures, Alaska DOT&PF avalanche forecaster for the Seward Highway. Summer 2005.

Roberts, J. 2005. Personal communication on accident figures, Colorado Avalanche Information Center highway avalanche forecaster for Colorado Department of Transportation on Red Mountain Pass. Summer 2005.

5. Page 339. Appendices. Add Appendix 14: Peer Review. This study was peer reviewed at the draft stage by three nationally prominent avalanche specialists: Dr. Edward LaChappelle of McCarthy, Alaska, Doug Fesler of Anchorage, Alaska, and Dr. Chris Landry of Silverton, Colorado. Their recommendations were incorporated to the extent possible into the final study.