11. Atlas - West Lynn Canal Avalanche Paths

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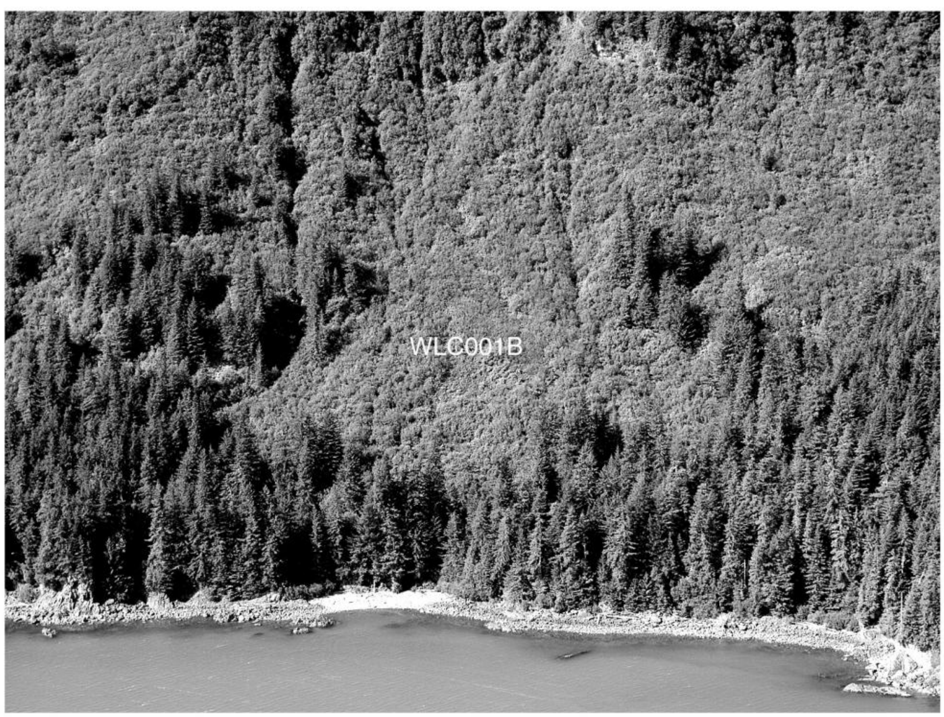
WLC001A
WLC001B


WLC001A

Path: WLC001A

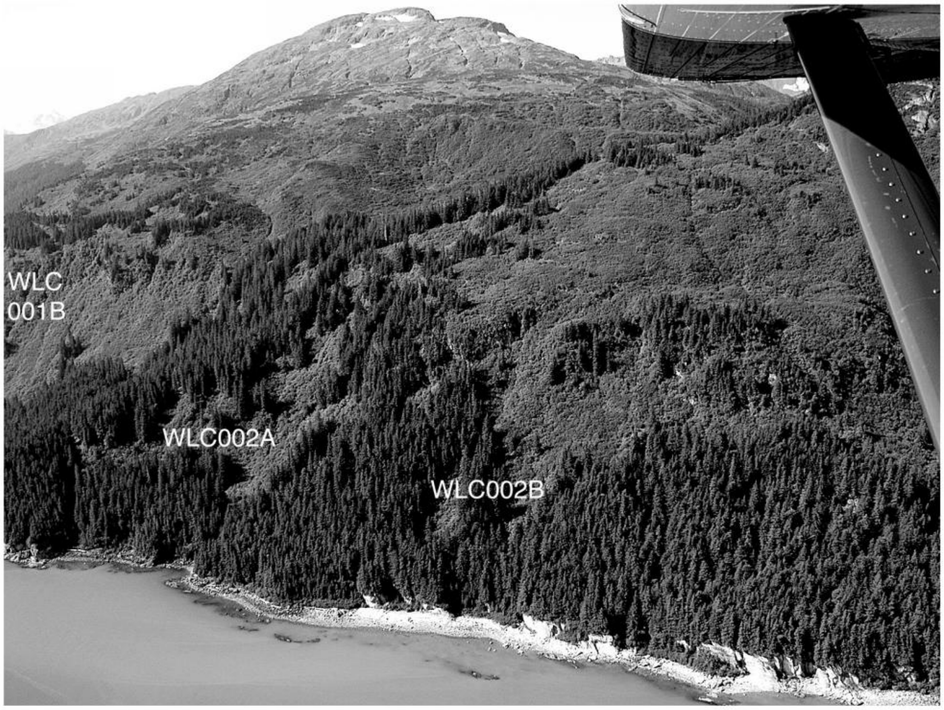
Path Group:	South Endicott
Latitude-Longitude:	59.084274 -135.281424
Max Width:	1000 feet / 305 meters
Typical Width:	175 feet / 53 meters
Starting Elevation:	1300 feet / 396 meters
Elevation Class:	medium low
Path Size:	medium
Starting Zone Characteristics:	open face
Start Aspect:	ENE
Path Type:	open face to thin forest
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.54
Structural Mitigation:	None
Structurally Mitigated AHI:	0.54
AHI with Forecasting and Exploders:	0.16

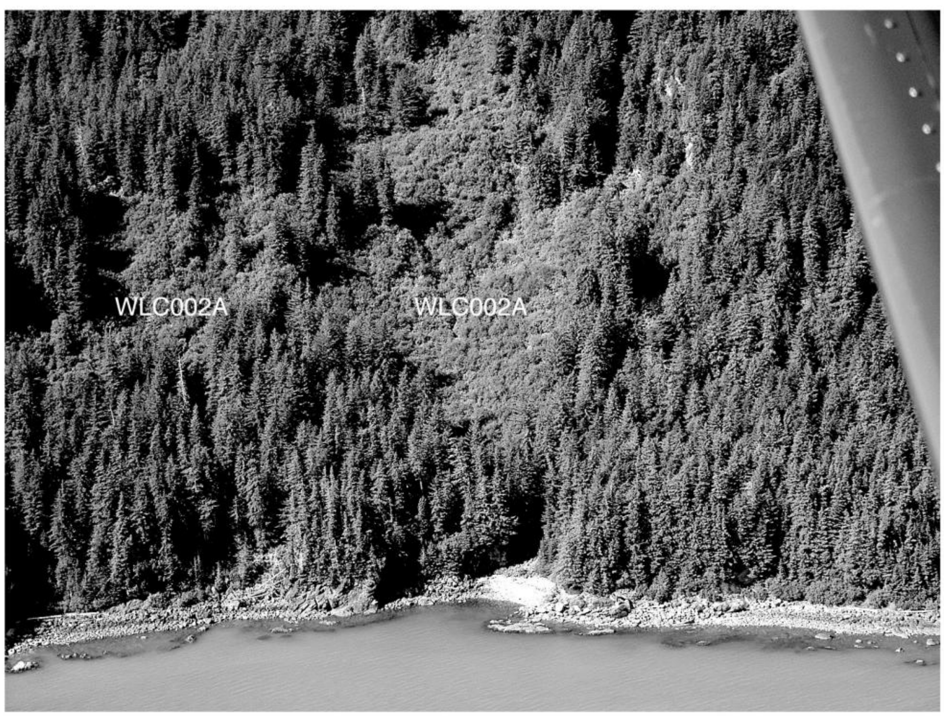

WLC001A
WLC001B


WLC001B

Path: WLC001B

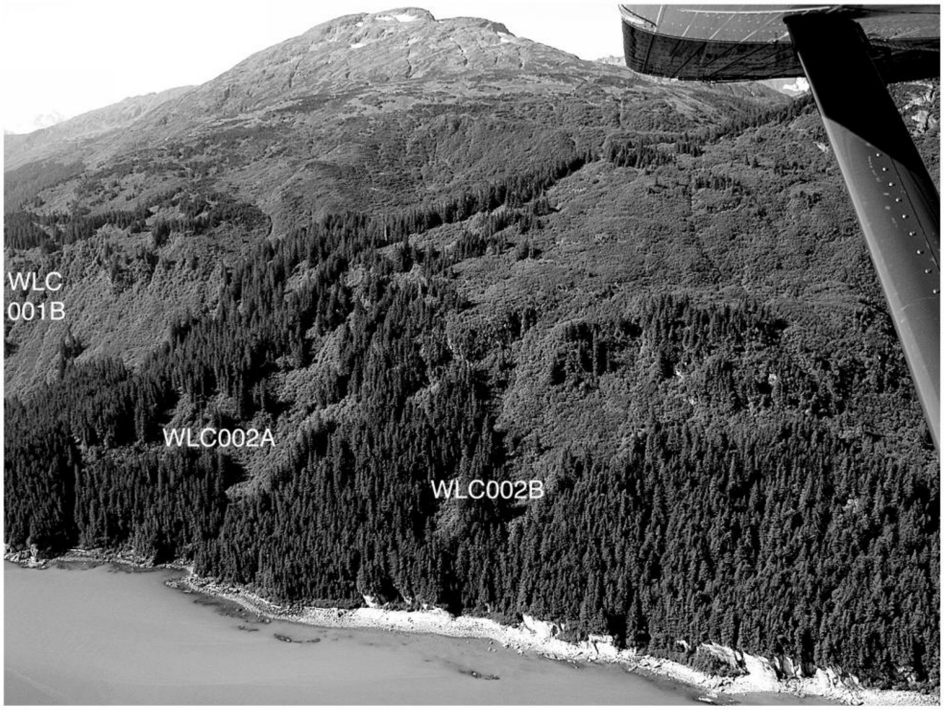
Path Group:	South Endicott
Latitude-Longitude:	59.084274 -135.281424
Max Width:	1000 feet / 305 meters
Typical Width:	125 feet / 38 meters
Starting Elevation:	1200 feet / 366 meters
Elevation Class:	medium low
Path Size:	medium
Starting Zone Characteristics:	open face
Start Aspect:	ENE
Path Type:	open face to thin forest
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.54
Structural Mitigation:	None
Structurally Mitigated AHI:	0.54
AHI with Forecasting and Exploders:	0.16


WLC
001B
WLC002A
WLC002B


WLC002A
WLC002A

Path: WLC002A

Path Group:	South Endicott
Latitude-Longitude:	58.453329 -135.142467
Max Width:	940 feet / 286 meters
Typical Width:	410 feet / 125 meters
Starting Elevation:	1000 feet / 305 meters
Elevation Class:	medium low
Path Size:	medium
Starting Zone Characteristics:	open face
Start Aspect:	ENE
Path Type:	open face to thin forest
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.51
Structural Mitigation:	None
Structurally Mitigated AHI:	0.51
AHI with Forecasting and Exploders:	0.15


WLC
001B
WLC002A
WLC002B


WLC002B

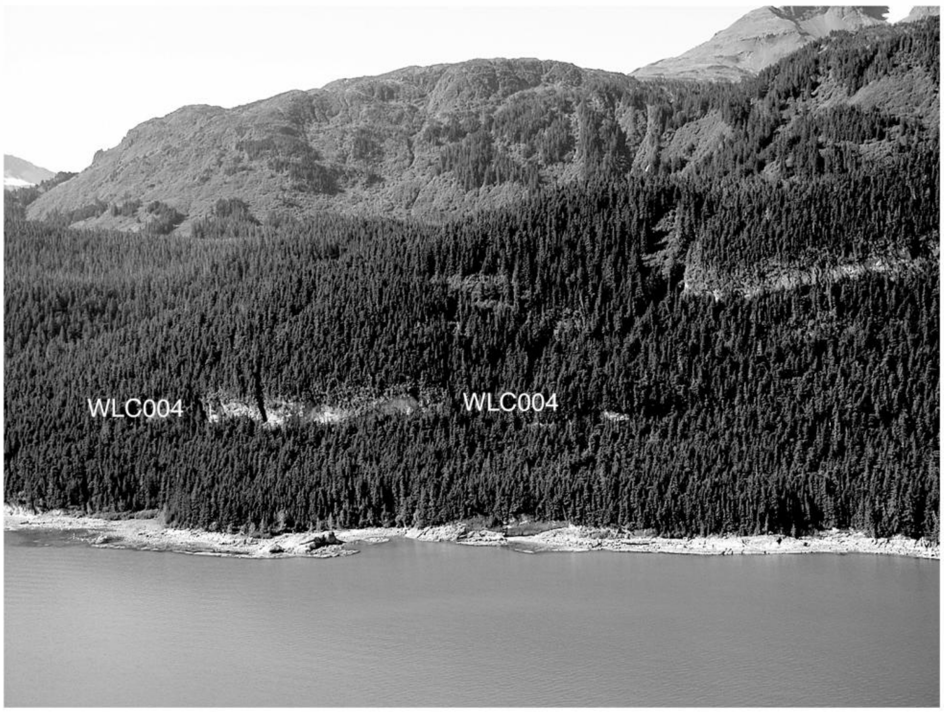
Path: WLC002B

Path Group:	South Endicott
Latitude-Longitude:	58.453329 -135.142467
Max Width:	590 feet / 180 meters
Typical Width:	350 feet / 107 meters
Starting Elevation:	1300 feet / 396 meters
Elevation Class:	medium low
Path Size:	medium
Starting Zone Characteristics:	open face
Start Aspect:	ENE
Path Type:	open face to thin forest
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.26
Structural Mitigation:	None
Structurally Mitigated AHI:	0.26
AHI with Forecasting and Exploders:	0.08


WLC003
WLC003

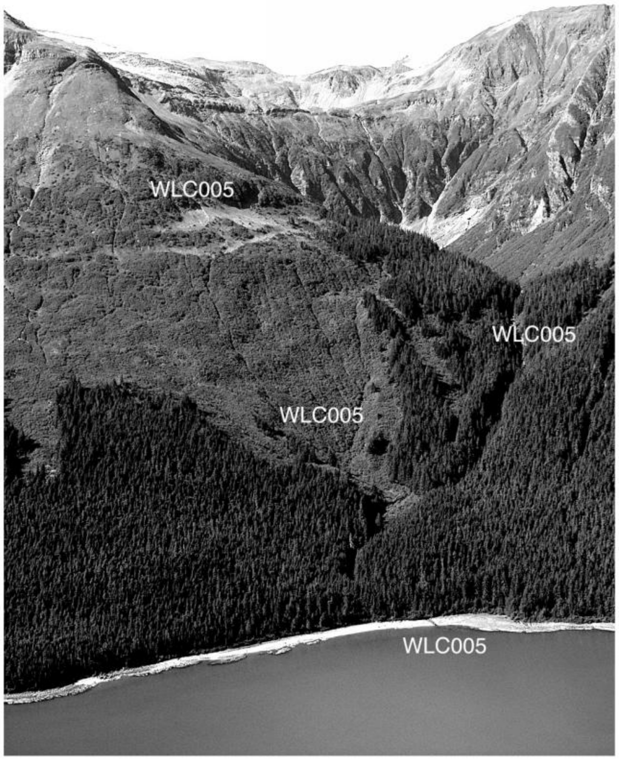
Path: WLC003

Path Group:	North Endicott
Latitude-Longitude:	58.46005 -135.143254
Max Width:	0.0 feet / 0.0 meters (stops above alignment)
Typical Width:	0.0 feet / 0.0 meters (stops above alignment)
Starting Elevation:	600 feet / 183 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	ENE
Path Type:	rock slabs and talus
Runout Angle:	decreases; usually stops above alignment
Unmitigated avalanche hazard index (AHI):	0.00
Structural Mitigation:	None
Structurally Mitigated AHI:	0.00
AHI with Forecasting and Exploders:	0.00


WLC004
WLC004

Path: WLC004

Path Group:	North Endicott
Latitude-Longitude:	58.481183 -135.160027
Max Width:	0.0 feet / 0.0 meters (stops above alignment)
Typical Width:	0.0 feet / 0.0 meters (stops above alignment)
Starting Elevation (ft):	1200 feet / 366 meters
Elevation Class:	low
Path Size:	small
Starting Zone Characteristics:	rock slabs and talus
Start Aspect:	ENE
Path Type:	rock slabs and talus
Runout Angle:	decreases; usually stops above alignment
Unmitigated avalanche hazard index (AHI):	0.00
Structural Mitigation:	None
Structurally Mitigated AHI:	0.00
AHI with Forecasting and Exploders:	0.00


WLC005
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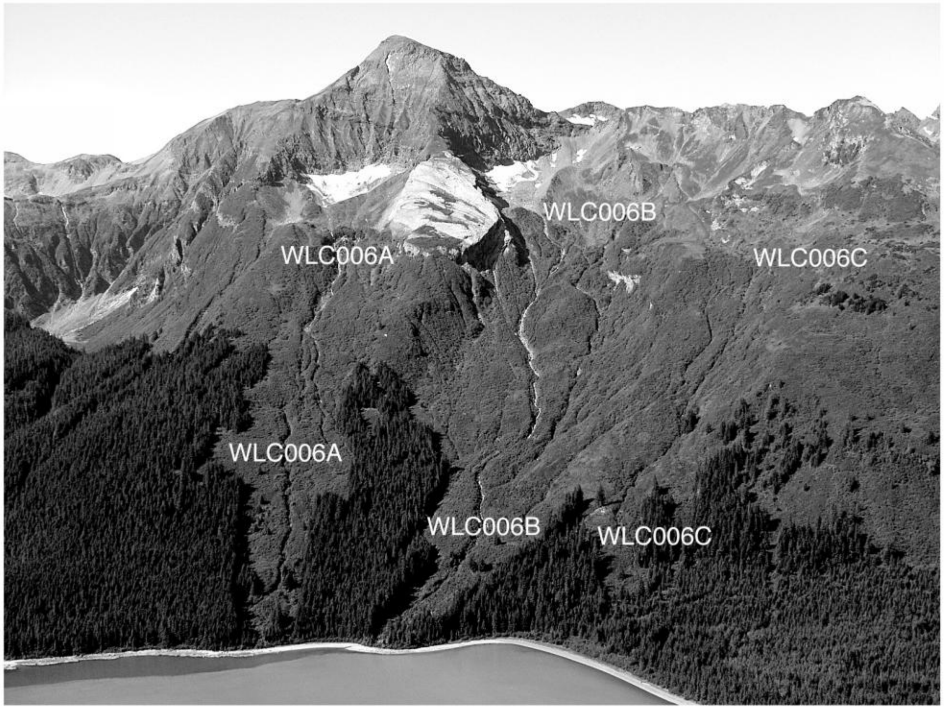
Path: WLC005

Path Group:	Sullivan
Latitude-Longitude:	58.500775 -135.175661
Max Width:	240 feet / 73 meters
Typical Width:	100 feet / 30 meters
Starting Elevation:	3300 feet / 1006 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	broad face and big bowl
Start Aspect:	NE
Path Type:	bowl and gullies
Runout Angle:	decreases abruptly
Unmitigated avalanche hazard index (AHI):	0.88
Structural Mitigation:	None
Structurally Mitigated AHI:	0.88
AHI with Forecasting and Exploders:	0.26


WLC006A
WLC006B
WLC006C
WLC006A
WLC006B
WLC006C


WLC006A
WLC
006B

Path: WLC006A

Path Group:	Sullivan
Latitude-Longitude:	58.573821-135.234129
Max Width:	960 feet / 293 meters
Typical Width:	580 feet / 177 meters
Starting Elevation:	4600 feet / 1402 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big bowl and big face
Start Aspect:	ENE
Path Type:	broad face with gullies
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	17.88
Structural Mitigation:	Elevated fill 0.5x
Structurally Mitigated AHI:	8.94
AHI with Forecasting and Exploders:	2.68


WLC006B
WLC006A
WLC006C
WLC006A
WLC006B
WLC006C


WLC006A
WLC006C
WLC006B

Path: WLC006B

Path Group:	Sullivan
Latitude-Longitude:	58.573821-135.234129
Max Width:	960 feet / 293 meters
Typical Width:	650 feet / 198 meters
Starting Elevation:	4400 feet / 1341 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big bowl and big face
Start Aspect:	ENE
Path Type:	broad bowl with gullies
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	17.88
Structural Mitigation:	Elevated fill 0.5x
Structurally Mitigated AHI:	8.94
AHI with Forecasting and Exploders:	2.68

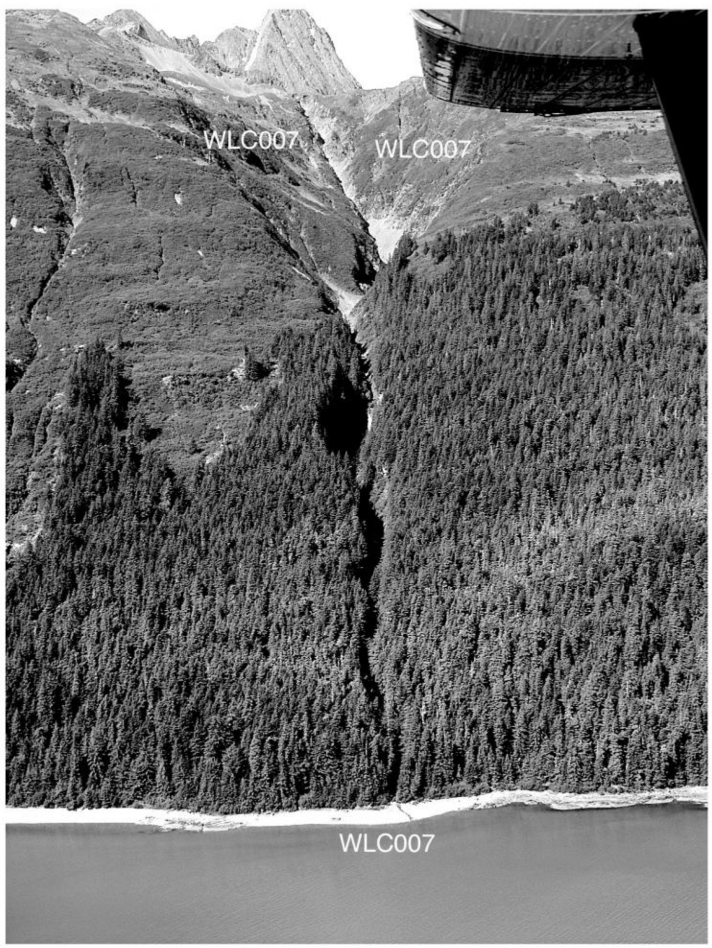

WLC006A
WLC006B
WLC006C
WLC006A
WLC006B
WLC006C


WLC006B
WLC006C

Path: WLC006C

Path Group:	Sullivan
Latitude-Longitude:	58.573821-135.234129
Max Width:	960 feet / 293 meters
Typical Width:	510 feet / 155 meters
Starting Elevation:	3500 feet / 1067 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big face
Start Aspect:	E
Path Type:	broad bowl with gullies
Runout Angle:	decreases; usually stops above alignment
Unmitigated avalanche hazard index (AHI):	17.88
Structural Mitigation:	None
Structurally Mitigated AHI:	17.88
AHI with Forecasting and Exploders:	5.36


WLC007
WLC007


WLC007
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WLC007

Path: WLC007

Path Group:	Sullivan
Latitude-Longitude:	58.581881 -135.241298
Max Width:	120 feet / 37 meters
Typical Width:	70 feet / 21 meters
Starting Elevation:	3500 feet / 1067 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	big bowl with gullies
Start Aspect:	E
Path Type:	deeply incised big gully
Runout Angle:	moderate decrease; high bridge crossing
Unmitigated avalanche hazard index (AHI):	2.50
Structural Mitigation:	Bridge 0.2x
Structurally Mitigated AHI:	0.50
AHI with Forecasting and Exploders:	0.15


WLC008
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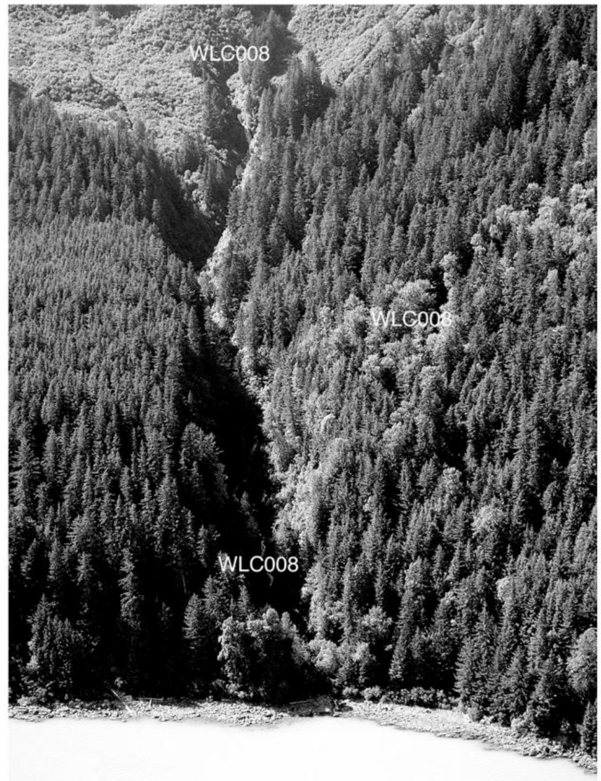
008
WLC008


WLC008
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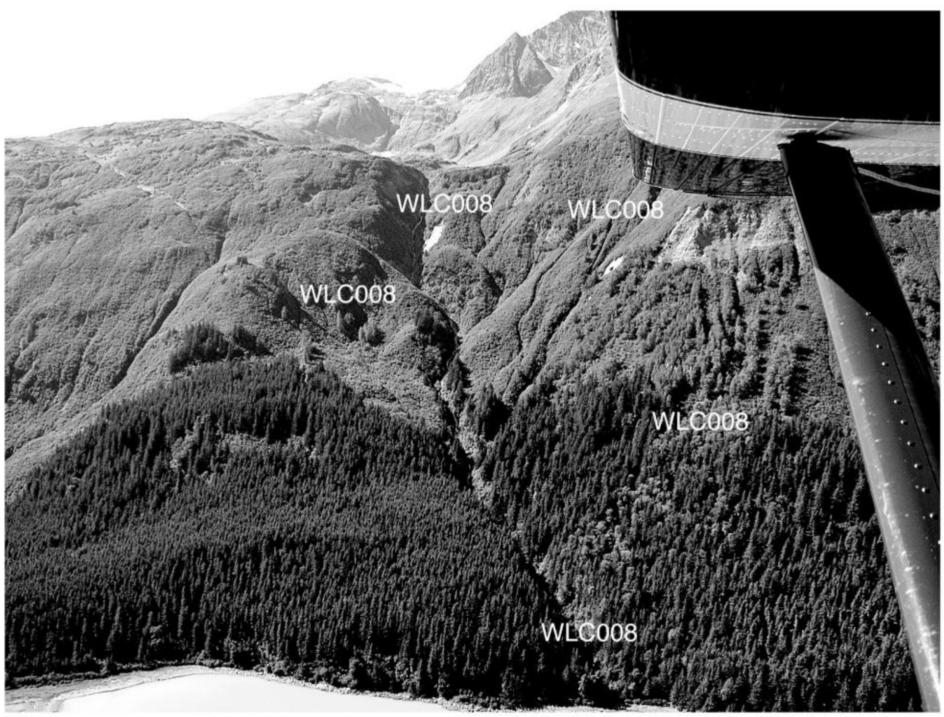
WLC008
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WLC008

Path: WLC008

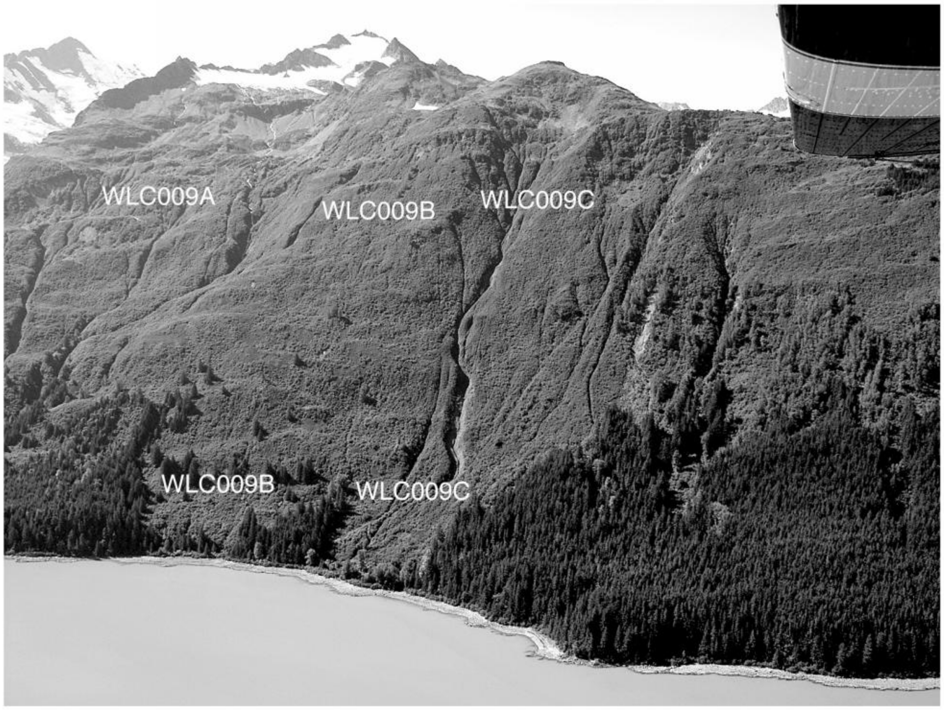
Path Group:	Rainbow
Latitude-Longitude:	59.070038 -135.264214
Max Width:	260 feet / 79 meters
Typical Width:	150 feet / 46 meters
Starting Elevation:	4000 feet / 1219 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	big broad face and medium gullied bowl
Start Aspect:	ENE
Path Type:	gullied bowl into deeply incised big gully
Runout Angle:	decrease; high bridge crossing
Unmitigated avalanche hazard index (AHI):	2.09
Structural Mitigation:	Bridge 0.2x
Structurally Mitigated AHI:	0.42
AHI with Forecasting and Exploders:	0.13


WLC009A
WLC009A
WLC009B
WLC009C
WLC009A
WLC009B
WLC009C


WLC009A

Path: WLC009A

Path Group:	Rainbow
Latitude-Longitude:	59.000429-135.241143
Max Width:	1433 feet / 437 meters
Typical Width:	1420 feet / 433 meters
Starting Elevation:	5000 feet / 1524 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big bowl
Start Aspect:	ENE
Path Type:	gullied bowl into broad gullied unconfined
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	11.84
Structural Mitigation:	Elevated fill 0.5x
Structurally Mitigated AHI:	5.92
AHI with Forecasting and Exploders:	1.78


WLC009A
WLC009B
WLC009C
WLC009B
WLC009C


WLC009B
WLC009C

Path: WLC009B

Path Group:	Rainbow
Latitude-Longitude:	59.000429-135.241143
Max Width:	1433 feet / 437 meters
Typical Width:	1080 feet / 329 meters
Starting Elevation:	3400 feet / 1036 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	big broad face
Start Aspect:	ENE
Path Type:	big broad face into broad unconfined runout
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	11.84
Structural Mitigation:	Elevated fill 0.5x
Structurally Mitigated AHI:	5.92
AHI with Forecasting and Exploders:	1.78


WLC009A
WLC009B
WLC009C
WLC009B
WLC009C


WLC009B
WLC009C

Path: WLC009C

Path Group:	Rainbow
Latitude-Longitude:	59.000429-135.241143
Max Width:	1433 feet / 437 meters
Typical Width:	890 feet / 271 meters
Starting Elevation:	3400 feet / 1036 meters
Elevation Class:	high
Path Size:	very large
Starting Zone Characteristics:	medium bowls
Start Aspect:	ENE
Path Type:	broad unconfined track and runout with gullies
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	11.84
Structural Mitigation:	Elevated fill 0.5x
Structurally Mitigated AHI:	5.92
AHI with Forecasting and Exploders:	1.78


WLC010D
WLC
010C
WLC010D
WLC010B
WLC010A
WLC010A
WLC
010B
WLC
010C
WLC010D


WLC010A
WLC010B

Path: WLC010A

Path Group:	Pyramid
Latitude-Longitude:	59.105158-135.29264
Max Width:	630 feet . 192 meters
Typical Width:	100 feet / 30 meters
Starting Elevation:	3800 feet / 1158 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	big bowl and big broad face
Start Aspect:	ENE
Path Type:	broad bowl into broad unconfined with gullies
Runout Angle:	moderate decrease; alignment out on flats
Unmitigated avalanche hazard index (AHI):	1.20
Structural Mitigation:	Elevated fill 0.5x
Structurally Mitigated AHI:	0.60
AHI with Forecasting and Exploders:	0.18


WLC
010C
WLC010D
WLC010D
WLC010B
WLC010A
WLC010A
WLC
010B
WLC
010C
WLC010D


WLC010C
WLC010B
WLC010D

Path: WLC010B

Path Group:	Pyramid
Latitude-Longitude:	59.105158-135.29264
Max Width:	630 feet / 192 meters
Typical Width:	340 feet / 104 meters
Starting Elevation:	3100 feet / 945 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	small bowls and gullies
Start Aspect:	ENE
Path Type:	broad gully to unconfined gullied runout
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	1.20
Structural Mitigation:	Elevated fill 0.5x
Structurally Mitigated AHI:	0.60
AHI with Forecasting and Exploders:	0.18


WLC
010C
WLC010D
WLC010D
WLC010B
WLC010A
WLC010A
WLC
010B
WLC
010C
WLC010D


WLC010C
WLC010B
WLC010D

Path: WLC010C

Path Group:	Pyramid
Latitude-Longitude:	59.105158-135.29264
Max Width:	630 feet / 192 meters
Typical Width:	380 feet / 116 meters
Starting Elevation:	3700 feet / 1128 meters
Elevation Class:	high
Path Size:	medium
Starting Zone Characteristics:	big gully
Start Aspect:	ENE
Path Type:	broad gully to unconfined gullied runout
Runout Angle:	moderate decrease
Unmitigated avalanche hazard index (AHI):	1.20
Structural Mitigation:	Elevated fill 0.5x
Structurally Mitigated AHI:	0.60
AHI with Forecasting and Exploders:	0.18


WLC010D
WLC
010D
WLC010D


WLC010C
WLC010B
WLC010D

Path: WLC010D

Path Group:	Pyramid
Latitude-Longitude:	59.105158-135.29264
Max Width:	630 feet / 192 meters
Typical Width:	340 feet / 104 meters
Starting Elevation:	4200 feet / 1280 meters
Elevation Class:	high
Path Size:	large
Starting Zone Characteristics:	medium bowl, medium face, big gullied bowl
Start Aspect:	ENE
Path Type:	gullies and face to broad unconfined runout
Runout Angle:	decreases; usually stops above alignment
Unmitigated avalanche hazard index (AHI):	1.20
Structural Mitigation:	Elevated fill 0.5x
Structurally Mitigated AHI:	0.60
AHI with Forecasting and Exploders:	0.18

12. Technical Appendices

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12.1. *APPENDIX 1: Avalanche Hazard Index (AHI) Calculation*

Introduction

The avalanche hazard index (AHI) is a dimensionless numerical expression representing damage and loss potential as the result of an interaction between snow avalanches and vehicles on a highway (Schaerer, 1989). The concept was first developed in Canada (Avalanche task force, 1974), and has been applied at various locations in North America and New Zealand (Fitzharris and Owens, 1980; Armstrong, 1981; Mears, 1993; Mears and Newcomb (unpublished); Fesler, Mears and Fredston, 1990; Mears, 1995.

Avalanche hazard on a highway contains two elements: (a) the frequency (or probability) of an encounter, and (b) the nature, magnitude, and severity of the resulting damage from the avalanche.

Damage Potential and Weighting the Consequences

The severity of the potential damage is used to define three idealized types of avalanches as follows:

1. Light snow avalanches. Flowing avalanches of light snow cross and block the highway, deposit snow approximately one to three feet (0.3 to 1.0m) deep, and could push a car off the highway but not bury it. **Light snow avalanches are assigned a weighting factor of 3.**

2. Deep snow avalanches. Flowing avalanches of deep snow deposit snow to a depth of more than 3 feet (1.0m) could bury or push vehicles off the highway and could severely damage a vehicle and injure or kill occupants. **Deep snow avalanches are assigned a weighting factor of 10.**

3. Plunging snow avalanches. Plunging snow avalanches fall onto a highway at high speeds after descending steep terrain *or* tumble vehicles off the highway down a steep slope or into the water. **Plunging snow avalanches are assigned a weighting factor of 12.** Many of the avalanche paths considered on East and West Lynn Canal and the Seward Highway produce avalanches that at times must be considered the plunging-snow type.

Avalanche Frequency and Width

Avalanche frequency and width (length of highway covered) must be estimated for each path for light snow, deep snow, and plunging snow avalanche types. Frequency, F, is expressed as the average number or occurrences of a given class of avalanche (light, deep, or plunging) in each path per year. F is computed as the reciprocal of the average return period, P, thus $F = 1/P$. For example, an avalanche (light, deep, or plunging type) with a return period of 10 years has an annual frequency of 0.10.

Calculating the AHI

The AHI is calculated by multiplying the damage-weighting factor (discussed above) by the frequencies of moving and stationary vehicles in avalanche paths. The encounter probability, P, is calculated

$P = P_M + P_W$,

where (1) P_M is the probability of a moving vehicles being hit by an avalanche and P_W is the probability of a waiting vehicle being hit by a second avalanche in the same path or by adjacent avalanches. When avalanches are closely spaced, as they are in the avalanche terrain of both the East and West Lynn Canal alignment alternatives, P increases because the P_W term is large. Even if traffic is light, a long queue of traffic can back up below avalanche paths.

The moving vehicle encounter probability, P_M is calculated $P_M = f(N,L,D,F,V)$, where (2) N = average daily winter traffic (460 vehicles per day on the East Lynn Canal route and 365 vehicles per day on the West Lynn Canal route, using projected year 2050 traffic counts), L = average highway length covered by avalanches of a given class, D = vehicle stopping distance (a function of speed and driver reaction time), F = frequency of avalanches of a given class, in years, and V = average vehicle speed (which also controls D). The calculation in (2) is repeated for each avalanche path and each class of avalanche in that path. The term P_M becomes an important factor only if traffic volume is very high (generally in excess of 10,000 vehicles per day) and is therefore not an important term on the Juneau access alternatives.

The waiting vehicle encounter probability P_W is calculated

$P_W = f(p_s,N,F) + 0.5\ f(p'_s, N,F)$,

where (3) p_s = probability of an avalanche in an adjacent path hitting traffic that is backed up until emergency response arrives (assumed one hour response time due to the remoteness of the route). The length of a queue of vehicles stopped on the highway depends on traffic volume and response time. When avalanche paths are closely spaced and of relatively high frequency the probability p_s of vehicles in the queue being hit by an avalanche increases. In equation (3), N is the number of vehicles exposed in avalanche terrain, F is the avalanche frequency in years, and p'_s is the probability of a second avalanche in the path that caused the traffic blockage.

The AHI is calculated for *each path, i,* as follows:

$AHI_i = \Sigma\ W_j\ (P_{mj} + P_{wj})$,

where (4) the subscript j refers to the three classes of avalanches (light, deep, and plunging).

Finally, a cumulative AHI_H was calculated for the entire East and West Lynn Canal routes, based on current proposed alignments as follows:

$AHI_H = \Sigma\ AHI_i$, where (5) $1 \leq i \leq n$ and n is the number of paths on each highway alignment considered.

As discussed by Schaerer (1989), each avalanche path (together with its neighboring paths) was assumed to be independent of other paths on the highway. Therefore, the same avalanche was assumed capable of hitting both moving and waiting traffic each time it occurred after another avalanche had blocked the highway. It could be argued that the AHI could be made more realistic by taking into account that traffic stops after one avalanche occurrence and that each avalanche can strike vehicles only once. However, this “more realistic” assumption would not allow a comparison between individual avalanche paths that is one of the primary objectives of this analysis. Therefore, the simpler approach was used to calculate the index. Furthermore, the AHI calculation assumes a uniform flow of traffic regardless of conditions. In fact, traffic would certainly be heavier on some days and would probably decrease during severe conditions. Both would change vehicle exposure to avalanches.

The standard AHI calculating procedure was applied because (a) it enables comparison between different paths, (b) it enables “problem areas” to be quantified, and (c) it enables the East and West Lynn Canal routes to be compared to each other and to other highways in the United States and Canada that have AHI values calculated.

12.2. *APPENDIX 2: AHI Data Collection and Reliability*

The results of the analysis are only as reliable as the data used. Where available, actual avalanche sizes and return intervals were used, with correction factors applied to normalize the figures to consistency with longterm climate and avalanche records.

Where there were no avalanche occurrences within the period of observation, the return period of the missing avalanche types was estimated to the nearest "half-order of magnitude" or approximately to within a factor of 3. The half-order of magnitude steps used have return periods of 1.000 (1 year); 0.333 (3 years); 0.100 (10 years); 0.033 (30 years); 0.010 (100 years); 0.003 (300 years).

Avalanche types that did not occur during the six years of field observations were given a minimum return interval of 10 years, the next half-order of magnitude step up from six years.

The longer return interval estimates were determined in part by comparison with other paths in the region for which frequency data was available, and in part by path characteristics and vegetation patterns. Air photos and detailed laser-surveyed topographic maps allowed thorough study of vegetation patterns and terrain features that indicate path boundaries.

In northern Southeast Alaska, the limit of the most recent 30-year avalanche cycle on many paths is clearly visible as a sharp difference in the age of the trees where they have regrown since they were last destroyed in the early 1970s. This boundary yields good information for 30-year avalanche events on those paths.

Vegetation damage from the most recent 100-year to 300-year cycle is also visible on many paths. Some paths produced 200 year avalanches in the early 1970s cycle (Fesler, November 2003 note) and others show trimlines from earlier cycles in the 1920s or 1930s. Paths with no evidence of 100-year or more-frequent events fall into the 300-year return interval category, unless the characteristics of the path are such that the avalanche type in question does not occur at all.

The precision of these estimates is greatest for the shortest return interval events, which are the ones that have the greatest influence on the avalanche hazard index. Paths with longer than 30-year return intervals, which have the least reliable data, also have minimal impact on the AHI results.

Actual avalanche frequency data has been used wherever it is available. No observations are available for the West Lynn Canal alternative, but fixed-wing aerial observations were conducted along the East Lynn Canal route for six of the eight avalanche seasons since the original 1995 study. In four of these winters (1995-96, 1997-98, 2000-01, and 2001-02), flights were made on a regular basis throughout the winter, and frequencies can be reliably determined from the observations.

In 1996-97 and 1999-2000, flights were made only at the end of the season. Debris piles indicated which paths had produced large avalanches in those seasons, but the number of slides contributing to the piles could not be determined. Avalanche frequency was estimated for these two seasons by assuming that the paths that slid had as many avalanches as their average in the other years of observation.

While the observations data are very useful, six years is a short period of record for climate-related phenomena. The sample has been evaluated to determine how representative it is, and corrected for bias with regard to known climate cycles. The route was re-flown in 2012 and the mapping was updated to reflect new and expanded paths. Activity was consistent with this earlier analysis.

The key to this analysis is determining how the period of study fits into long-term climate patterns. While there is no guarantee that past climate patterns will continue into the future, climate history is the best tool available for predicting future trends.

Robert Kanan, a recently retired National Weather Service meteorologist and climatologist with long experience studying the climate of northern Southeast Alaska, analyzed long-term weather patterns and climate trends in the region for this study, and a correction factor was used to increase the frequencies to be consistent with the calculated long-term averages.

12.3. ***APPENDIX 3: AHI Input Data Analysis***

Long- term Climatology: Tropical Pacific Ocean El Niño-Southern Oscillation (ENSO), and Effects on Southeast Alaska Snowfall

Robert A. Kanan

Juneau, Alaska, August, 2003

1. Brief overview of ENSO.

El Niño-Southern Oscillation (ENSO) is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales. It has a strong influence on seasonal snowfall totals at Juneau and northern Southeast Alaska. ENSO is a 2- to 6-year cycle of warmer and colder sea surface temperatures, and tilting of the near-surface thermocline along the equator from 150 degrees west to the date line. More details are available on many Internet web sites, such as the NOAA/NWS Climate Diagnostic Center: and the Climate Prediction Center at:

2. How ENSO is measured.

The standard monitoring of ENSO is the Multivariate ENSO Index (MEI). The MEI uses the six main observed variables over the tropical Pacific: sea level pressure (Darwin to Tahiti), zonal and meridional components of the surface wind, sea surface temperature, surface air temperature, and total cloudiness fraction of the sky. Complete data are available from 1950 to present. Another, less complete measure of ENSO is the Southern Oscillation Index (SOI), the single-variable Darwin-to-Tahiti surface pressure difference. Except for a few missing years, data go back to 1882.

Other variables, such as precipitation and temperature climate, exhibit time-dependent behavior that is sensitive to some aspect of ENSO. Long-term records on the periphery of the Indian and Pacific Oceans have been constructed from historical sources, tree-ring reconstructions (summer temperature and winter rainfall), and annual record of oxygen isotope composition for a high-elevation glacier in Peru. ENSO estimates can be made back to the late 16th century, and at least a portion of the Medieval Warm Period (~A.D. 950-1250). In general, spectral power on time scales of about two to six years is statistically significant and persists throughout most of the time intervals sampled. Assuming that the ENSO phenomenon is the source of much of the variability at these time scales, this indicates that ENSO has been an important part of interannual climatic variations over broad areas of the circum-Pacific region throughout the last millennium. Significant correlations were found between El Niño and reconstructed Sierra Nevada winter precipitation at about two to four years throughout much of their common record (late 16th century to present), and between six and seven years from the mid-18th to early 20th century.

3. ENSO life cycle, and the longer decadal oscillations.

The ENSO cycle of two to four years also has a longer (~20 years) oscillation of prevailing warm and cold events. The prevailing very cold La Niña period from 1954-1976 had only three seasonal warm events greater than one standardized departure (1958,1966, and 1973). That cold period was followed by a very warm prevailing El Niño from 1977-1998 with only one cold departure (1988). Extending this longer decadal ENSO oscillation back farther in time becomes much less exact. The MEI data date back only to 1950, so the less useful SOI must be used to reconstruct earlier periods. There is at least some indication the decadal oscillation of about 20 years continues with an overall warm El Niño from about 1934-1954, prevailing cold La Niña from about 1915-1933, warm from 1894?-1914, and perhaps a weak prevailing cold period prior to about 1893.

Besides the lack of MEI data, the difficulty in accurately extending the decadal ENSO oscillation to the first half of the last century and earlier is that the magnitude of the ENSO events was much weaker than those in modern time (since about 1950). There are other much longer period oscillations that may reinforce or reduce the magnitude, and/or alter the length of some of the shorter-period ENSO decadal oscillations.

4. ENSO effects on winter weather in Southeast Alaska

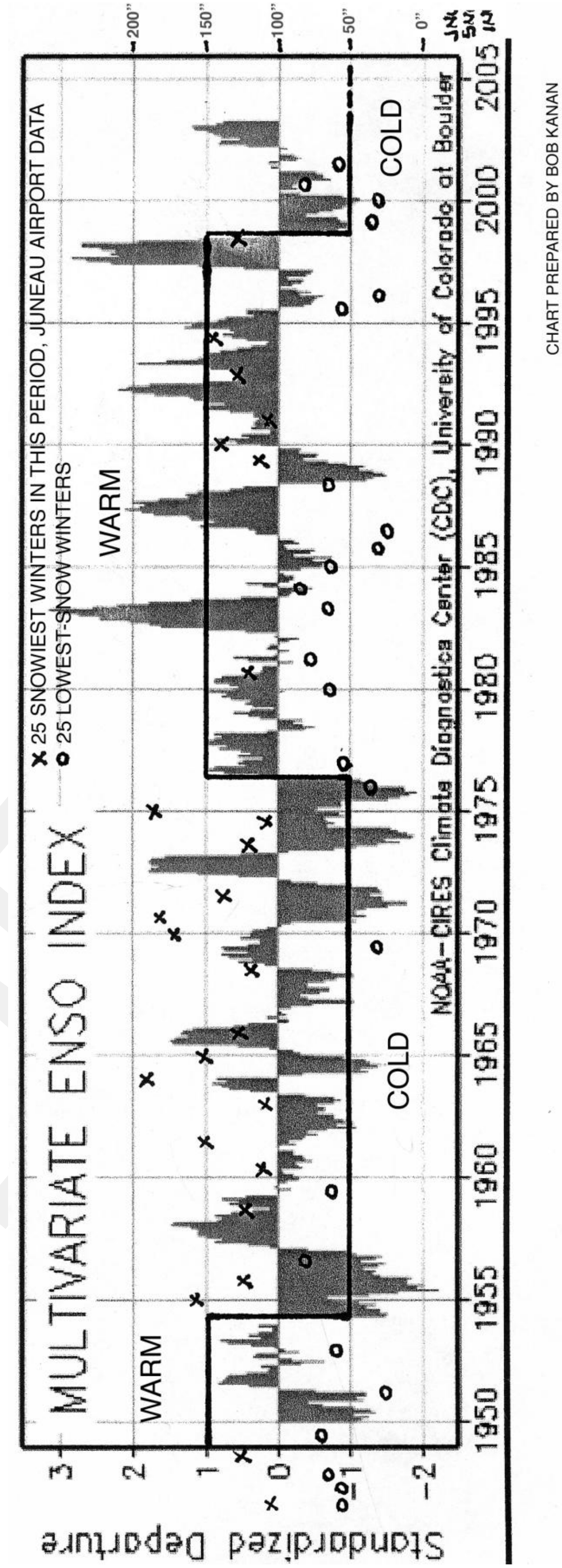
Juneau winter temperature and snowfall data show a strong correlation to ENSO. This is also the case for northern Southeast Alaska, especially north of the average position of the quasi-stationary Arctic front (a discontinuous line from Cape Spencer to Cape Fanshaw) after intense cold air outbreaks from Canada. The average position of the 500MB ridgeline is normally along the west coast of North America. But during warm El Niño events this average ridgeline position is displaced about 500 miles eastward into Canada. This allows a more frequent southwesterly flow aloft over Southeast Alaska, with the storm track across the north Pacific bringing warm, moist tropical source air onshore over the Southeast Alaska panhandle. Conditions are warmer and wetter, with less of the precipitation in the form of snow at sea level. Then, during cold La Niña conditions, the 500MB ridge line is displaced about 1000 miles westward to the eastern Aleutian Islands and the eastern Bering Sea. This pattern blocks storms from moving into the eastern Gulf of Alaska and allows Arctic high pressure to build over northwestern Canada. This is the prerequisite for outbreaks of cold air over northern Southeast Alaska so that the next southwesterly warm air overrunning flow produces both longer duration and larger amounts of snowfall before the snow changes to rain as the Arctic air is mixed with the warmer maritime-source air.

5. ENSO plot and Juneau snowfall

The longer-term shifts of the decadal oscillation are outlined on a plot of ENSO (using the MEI) from 1950 to the present. Then the seasonal (October 1 through –April 30) 25 years of highest and lowest snowfall at Juneau International Airport are plotted. The connection between snowfall and ENSO is very strong. La Niña (cold) events have the highest snowfall seasons, and El Niño (warm) has the lowest snowfall. The La Niña period from 1954 to 1977 had 16 of the 25 greatest seasonal snowfalls during the last 60 years in Juneau, and only four of the lowest snowfalls. The seasonal snowfall anomalies often are near the transition of brief ENSO shifts from the prevailing longer term decadal condition, or where shorter periods (one month or so) displacement of the 500MB ridge-line altered prevailing conditions.

Another way to look at the ENSO impact on the average (96.2 inches, or 2.44m) seasonal snowfall at Juneau airport during the last 60 years is to consider only the 20 greatest and 20 lowest snowfall totals. The following chart plots these differences, and the standard departure from normal temperatures. Seventeen of 40 years fell during cold La Niña conditions for an average of 126.2 inches, or 3.21m (or 131 percent of all seasons). Twenty-three seasons occurred during warm El Niño conditions with an average of 76.0 inches, or 1.93m (79 percent of all seasons). The average variability between El Niño and La Niña years is 50.2 inches, or 1.28m.

The chart shows standardized departure from normal winter temperatures.


MULTIVARIATE ENSO INDEX
× 25 SNOWIEST WINTERS IN THIS PERIOD, JUNEAU AIRPORT DATA
o 25 LOWEST-SNOW WINTERS
WARM
COLD
WARM
COLD
Standardized Departure
3
2
1
0
-1
-2
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
200"
150"
100"
50"
0"
NOAA–CIRES Climate Diagnostics Center (CDC), University of Colorado at Boulder
CHART PREPARED BY BOB KANAN

6. Looking ahead from the present (2003)

The ENSO – PDO decadal oscillation most likely made a shift in 1998 from the strong prevailing warm (El Niño) conditions entered into during 1977 that lasted about 21 years. This shift to another long-term cold (La Niña) cycle in 1998 was confirmed in a 1999 conversation with Dr. Aants Leetmaa, director of the NWS Climate Prediction Center. If that is the case, the prevailing ENSO condition should be a series of cold La Niña events through the year 2018 or so. The major shift to colder La Niña conditions in 1998 initially lasted only through 2001, and then went to warm El Niño levels in 2002. That is not unlike how the cold 1954-1976 ENSO period started. The present 2003 status of ENSO is neutral, with no strong indications of warm or cold trends. The highest probability remains that the next 15 years will be mostly La Niña conditions. If the cold La Niña prevails, the average seasonal snowfall in northern Southeast Alaska will be significantly above average during the period.

Observations since the 2004 and 2005 reports indicate that the climate in the region has indeed shifted to the cold half of the PDO cycle.

Discussion of AHI Input Data

There has been no need to update the corrections based on Kanan's 2003 study:

Given Robert Kanan's long-term analysis, the question is where in the ENSO – PDO cycle the six years of study fall. It happens there were three years nominally in the warm half of the cycle (1995-96, 1996-97, and 1997-98) and three years nominally in the cold half (1999-00, 2000-01, and 2001-02). If they were representative years, it would be a simple matter to average them directly. Are they?

The warm-cycle winters appear to be representative of their warm cycle, which ran from 1976-77 through 1998-99. Comparison of winter (November through April) Juneau Airport National Weather Service Data available online for the winters of study with the 1976-99 warm period winters shows that the winters of study had sea-level snowfall 70 percent of the warm period average, precipitation 120 percent of the warm period average, and temperature 0.3°F (0.17°C) below the warm period average. This is a reasonable match, well within the standard deviation. In comparison with the long-term Juneau Airport averages, the sea-level snowfall was 60 percent of normal, the precipitation 80 percent of normal, and the temperature 1.6°F (0.89°C) above normal, about as expected for warm cycle years.

The cold-cycle winters are more problematic. They do not yet have the rest of their cycle for comparison, but Juneau Airport data shows sea-level snowfall at 50 percent of the long-term winter average, precipitation at 70 percent of average, and temperature 1.9°F (1.06°C) above normal. The temperature has obviously not dropped to what would be expected in a cold cycle. It appears that some correction for the last three years' data may be necessary.

What about avalanche activity?

A key to the analysis is the strong correlation Kanan demonstrated between weather in northern Southeast Alaska and the 20-year El Niño–Southern Oscillation (ENSO) and the related Pacific Decadal Oscillation (PDO) warm and cold cycles. Winters in northern Southeast Alaska show a bimodal pattern; they tend to be either cold and snowy, or warm and rainy, without much in-between.

Kanan extended the ENSO and Pacific Decadal Oscillation cycles back far enough to compare with the available recorded Juneau-area avalanche history, going back to 1890. The ENSO PDO cycle was extended using Kanan's analysis of pressure gradients in the South Pacific Ocean, not as accurate as the multivariate index (MEI) used in modern climatology, but the best available parameter for historical data.

The avalanche record was compiled by Bill Glude from the historical records available at the time of this study. Those included Doug Fesler and Jill Fredston's reports for the City & Borough of Juneau in 1992, for the A-J Mine in 1989, and for a DOT&PF Thane Road study in 1990. Fesler and Fredston's data came from historical newspaper articles, mining records, and highway records. Recent observations for the Lynn Canal and A-J Mine studies by Bill Glude were also incorporated.

This long-term avalanche history consists of slides big enough to have been recorded in the newspapers, by highway crews, or by other sources. Because the concern is slides large enough to reach a highway at low elevation, the bias of the data set is consistent with our interest. It is an incomplete record by people who were for the most part untrained in avalanche observation, but it is the most accurate long-term data set available.

Other data sets were considered, but rejected as unsuitable. The Juneau Icefield Research Project has records dating back to the 1940s, but they are primarily glacial mass balance and summertime climate records, and are not currently available in a usable format. There is avalanche data from the avalanche program on Bear Pass on the Stewart-Hyder highway northeast of Ketchikan, but that is 300 miles (480km) away, on a pass rather than along a fjord, in an area with roughly twice the precipitation on the coastal side of the mountains, in a much milder climate, and far from the influence of the arctic front which is key to northern Southeast Alaska winter weather patterns. There is avalanche data from the Seward Highway, but that is 700 miles (1130km) away, in a cooler area where the dynamics of the interplay between the arctic front and coastal storms from the Gulf of Alaska are much different.

The historical record below lists the total number of recorded slides by winter, broken into cold and warm ENSO – PDO periods. The avalanche rating is the highest rating assigned to a slide in that season. Because the cycles differ in length, the average number of slides per winter is calculated for each period. Finally a ratio, or multiplier, is calculated at the bottom of the spreadsheet comparing avalanche frequency between the warm and cold ENSO – PDO periods.

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
1889	1890	0.0				
1890	1891	3.0	5.0			
1891	1892	0.0				
1892	1893	1.0				
1893	1894	2.0	3.0	1.2	4.0	cold period
1894	1895	5.0	4.0			
1895	1896	0.0				
1896	1897	0.0				
1897	1898	0.0				
1898	1899	1.0				
1899	1900	0.0				
1900	1901	0.0				
1901	1902	0.0				
1902	1903	1.0	3.0			
1903	1904	0.0				
1904	1905	0.0				
1905	1906	0.0				
1906	1907	0.0				
1907	1908	0.0				
1908	1909	0.0				
1909	1910	1.0	4.0			
1910	1911	0.0				
1911	1912	0.0				
1912	1913	0.0				
1913	1914	0.0				
1914	1915	0.0		0.4	3.7	warm period
1915	1916	6.0	3.0			
1916	1917	4.0	5.0			
1917	1918	1.0	3.0			
1918	1919	1.0	3.0			
1919	1920	1.0	3.0			
1920	1921	2.0	4.0			
1921	1922	1.0	4.0			
1922	1923	3.0	4.0			
1923	1924	2.0	4.0			
1924	1925	0.0				
1925	1926	1.0	4.0			
1926	1927	0.0				
1927	1928	1.0	3.0			
1928	1929	1.0	5.0			
1929	1930	0.0				
1930	1931	0.0				
1931	1932	3.0	4.0	1.6	3.8	cold period
1932	1933	0.0				
1933	1934	2.0	3.0			
1934	1935	1.0	4.0			
1935	1936	1.0	3.0			
1936	1937	0.0				
1937	1938	0.0				
1938	1939	7.0	4.0			
1939	1940	0.0				
1940	1941	0.0				
1941	1942	0.0				
1942	1943	0.0				
1943	1944	0.0				
1944	1945	1.0	3.0			
1945	1946	1.0	3.0			
1946	1947	3.0	3.0			
1947	1948	1.0	3.0			
1948	1949	2.0	4.0			

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				
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	

Avalanche frequency in the historical data set for the Juneau area shows a strong correlation with the 20-year El Niño – Southern Oscillation and Pacific Decadal Oscillation (ENSO – PDO) cycles, with 2.6 times as many slides recorded during cold cycles as in warm cycles.

Avalanche size does not show a correlation.

If the cold cycle years in the period of study were consistent with the long-term averages, there should be 2.6 times as many slides as in the warm cycle years. The records show 2.2 times as many observed hits to the alignment, a significant increase in avalanche frequency from the warm cycle winters, but lower than the long-term figure of 2.6.

The figures for cold cycle frequencies were corrected to eliminate the sample bias and normalize them to the long-term average multiplier of 2.6. The warm and cold cycle years' data were then averaged to calculate the frequencies for the avalanche hazard index.

For AHI calculation purposes, a standard relationship between total path width and the widths of plunging, deep, and light avalanches is often assumed. For these calculations, width ratios for each type of avalanche were derived based on field observations in the Lynn Canal terrain and snow climate, and applied those locally-derived ratios for greater accuracy.

There is one other correction to the data. The data set did not include any of the rare but very large avalanche cycles, and so an estimate was made to determine how significant that absence would be to the average frequencies used for the AHI calculations.

It has been demonstrated (Birkeland and Landry, 2002) that the size-frequency relationship of avalanches follows a power law, as do many other natural phenomena. That means that the number of events increases logarithmically as the size decreases, or that large events are much more rare than moderate or small events. A straight line with a characteristic slope can be fitted to the data for a given locality and used to characterize its avalanche behavior as a system.

This power-law relationship can be a useful tool, but no existing data sets for northern Southeast Alaska are complete enough to use it. The observation flight data is unsuitable because the observations are not daily, because the primary concern is large slides, and because the small slides are difficult to record accurately from the air. No daily records including the full range of sizes exist in the region.

A similar principle was used to determine the influence of very large but rare events on a frequency average. The following theoretical spreadsheet of relative avalanche size (on a scale of one to 5, relative to path capability) in relation to return interval and frequency was constructed. Avalanche size as listed in the spreadsheet over the full 300-year return period was averaged and compared that to a three-year sample, the closest half-order of magnitude step to the six years of record. Relative size three and larger slides, which are the ones that will reach a low-elevation highway, were the focus. The difference in the averages was only 0.5 percent.

Although the difference is negligible, a factor of +0.005L was applied as a size-correction multiplier to the AHI factor L for avalanche width, expressed in the AHI calculations as length of the slide on the highway.

12.4. *APPENDIX 4: Highway Closures*

Closure periods were calculated using the weather logs and avalanche observations from the same six years of field studies as were used in the AHI calculations, with the same correction factors applied.

Each avalanche cycle was evaluated to determine how long the highway would have been closed, and what level of explosive work would have been conducted. Weather events that would have been forecast as avalanche cycles but turned out to be false alarms are also tallied, but given lower figures for closure time and explosive operations, as would have occurred once forecasters realized the expected activity was not materializing.

Highways with mitigated AHIs comparable to the East and West Lynn Canal route are left open at night at "low" through "considerable" hazard levels, unless natural avalanches are forecast to reach low elevations. If avalanches are likely to reach low elevations, and explosive work is not completed, the highway would be closed at night. Night closures were tallied for the major avalanche cycles.

Because howitzer use allows closure section by section as explosive work proceeds, the West Lynn Canal alternative uses spot closures in daytime for explosive work when the danger level is increasing but instability is limited. The highway is closed when the instability is increasing more rapidly than explosive work can proceed. Prolonged closures were tallied under these conditions.

Limitations of darkness and storm conditions were factored into the initial tallies for all options. Corrections are added as follows:

a. An additional 20 percent was taken from the explosive delivery mission tally for helicopter-based programs, because many days that appear suitable based only on the weather records would in fact be too windy, foggy, or stormy. The mission tally was simply reduced, as the window of opportunity would pass and the snowpack would either slide or stabilize on its own.
b. All blaster box figures were reduced 30 percent because the raw mission tally reflects only their capability for being fired in storm conditions. Operations using blaster boxes report that the high cost of ammunition and its delivery by helicopter necessitate using them conservatively.
c. Howitzer use figures for the West Lynn Canal WLC1 option were only reduced ten percent, as weather would not have much effect on transporting a trailered howitzer on the highway.

The tallies for missions and highway closure times under all options were further adjusted by 20 percent for crew limitations. It is often impossible to conduct explosive operations because the entire maintenance crew is tied up with other urgent work, or is working far enough away that they cannot get back in time, or because conditions develop too rapidly to respond, or because of budget and workforce limitations. Some other highway operations reported even greater limitations due to crew factors, but it is assumed here that safety and reliability of this highway would be a high enough priority to merit adequate funding. Short funding would increase closure time.

13. *APPENDIX 5: Transportation Avalanche Danger Scale*

LOW (green)

Natural and human-triggered avalanches unlikely.

Destructive avalanches unlikely to come near developed areas.

Normal caution.

MODERATE (yellow)

Natural avalanches unlikely; human-triggered avalanches possible.

Destructive avalanches possible but unlikely to come near developed areas.

Normal caution.

CONSIDERABLE (orange)

Natural avalanches possible; human-triggered avalanches likely.

Destructive avalanches may come near or reach developed areas.

Increasing caution in or under steeper terrain and in avalanche zones. Monitor forecasts.

HIGH (red)

Natural avalanches likely; human-triggered avalanches very likely.

Destructive avalanches likely to come near or reach developed areas.

Minimize exposure in avalanche zones. Monitor avalanche forecasts.

EXTREME (black)

Natural and human-triggered avalanches certain.

Destructive avalanches likely to reach developed areas.

Eliminate exposure to avalanche zones. Monitor avalanche forecasts.

13.1. *APPENDIX 6: Highway Closure and Operation Criteria*

These guidelines are a sample of the kind of material that is part of a project-specific operational avalanche plan and are not a substitute for such a detailed plan. A project-specific plan is required under Alaska case law for worker safety before construction or operation of an avalanche-exposed facility may proceed. Planning at that level is beyond the scope of this report.

LOW (green)

- Generally stable snowpack; avalanche activity unlikely.
- Highway open.
- Normal highway plowing operations are not required to call in their locations.
- Stationary snow removal operations, clearing avalanche debris or collection areas, must have approval of avalanche forecaster in charge, report to dispatch every 30 minutes, and have a spotter.

MODERATE (yellow)

- If natural avalanches are possible, but are not forecast to reach lower elevations, the highway is open. Areas of unstable snow exist, but are not widespread. Large avalanches are unlikely.
- Normal highway plowing operations call in their location every 30 minutes.
- Stationary snow removal operations must have approval of avalanche forecaster in charge, report to dispatch every 30 minutes, and have a spotter. No clearing of avalanche debris or collection areas.
- Workers must stay inside vehicles when working in avalanche areas.
- Crews should alert the avalanche forecaster in charge to any observations or changes in the weather that may affect avalanche activity.
- If status is Moderate without avalanches to lower elevations, but trend is toward increasing avalanche danger, crews prepare for possible sweep and closure. Preventive explosive work and spot closures initiated if danger level is increasing but instability is limited. Highway can open if explosive work is completed on all paths threatening highway, danger from ongoing conditions is minimal, and the danger level for the paths affecting the highway can be lowered to Moderate with no slides forecast to reach low elevations.
- If danger level is Moderate but natural avalanches may reach lower elevations, highway is swept and closed to all but DOT&PF and law enforcement use. Entry into closed area requires specific permission from the avalanche forecaster in charge. Crew precautions for Considerable danger level are in effect. Explosive work initiated if possible. Highway can reopen if explosive work is completed on all paths threatening highway, danger from ongoing conditions is minimal, and the danger level for the paths affecting the highway can be lowered to Moderate with no slides forecast to reach low elevations.

CONSIDERABLE (orange)

- Natural avalanches are possible. Instability more widespread.
- Highway closed to all but DOT&PF and law enforcement use. Entry into closed area requires specific permission from the avalanche forecaster in charge.

- Workers must stay inside vehicles when working in avalanche areas, and remain on the main highway and shoulders.
- Crews plowing or sweeping call in when entering and leaving every avalanche path, identifying their location to dispatch. No stationary equipment within avalanche areas.
- Crews should alert the avalanche forecaster in charge to any observations or changes in the weather that may affect avalanche activity, and should contact the forecaster immediately if there is any new avalanche activity.
- Explosive work initiated or continued if possible.
- Highway can be reopened with careful monitoring only after explosive work is completed on all paths threatening highway, danger from ongoing conditions is minimal, and the danger level for the paths affecting the highway can be lowered to Moderate with no slides forecast to reach low elevations.

HIGH (red)

- Generally unstable snowpack. Widespread avalanche activity has not yet begun, or is ending, but slides may reach the highway.
- Highway closed to all but DOT&PF and law enforcement use. Entry into closed area requires specific permission from the avalanche forecaster in charge.
- Explosive work initiated only if practical. Forecaster in charge may permit explosives work with strict precautions. Crews passing through avalanche zones must be spotted and must maintain constant communications.
- Plowing operations are allowed only in support of explosives missions, under the same rules. Workers must stay inside vehicles when working in avalanche areas, keep moving within avalanche areas, and remain on the main highway and shoulders.
- Highway can be reopened with careful monitoring only after explosive work is completed on all paths threatening highway, danger from ongoing conditions is minimal, and the danger level for the paths affecting the highway can be lowered to Moderate with no slides forecast to reach low elevations.
- These criteria would generally be difficult to meet during high danger level periods. The highway must remain closed if there is any doubt.

EXTREME (black)

- Widespread avalanche cycle reaching low elevations is imminent or in progress.
- Highway closed to all traffic. No exceptions.
- The forecaster in charge, as always, has the discretion to reduce the danger level when appropriate.

13.2. *APPENDIX 7: Explosive Calculations*

The explosives calculation worksheets have been updated to reflect the current alignment and recalculated AHI numbers, targeting mitigation measures to the paths where they are most needed.

The number of shots for each delivery method was calculated by studying each path from the air and on oblique and vertical airphotos, as well as on detailed topographic maps, to determine how many target areas are needed to ensure release.

The frequency weighting corrected for how often a particular path would be part of an explosive delivery mission. The greatest-threat, most-active paths are part of every mission, so their frequency weighting is one. Paths that would need explosive work on half the missions have a frequency weighting of 0.5, those that would need work on one third of the missions have a weighting of 0.3, and so on.

The "weighted average shots per mission" is the total number of shots multiplied by the frequency weighting, and the "weighted shots per year" is the weighted shots per mission multiplied by the number of missions per year, which is calculated separately based on the weather and highway closure analysis.

Charge sizes are 50lb (23kg) ammonium nitrate – fuel oil (ANFO) bags for helicopter placement, 8-pound (3kg) high explosive for howitzer rounds, and 6-pound (3kg) mortar rounds for the blaster boxes. One alternative would be to use 25 lb (12.5 kg) ANFO charges as appropriate.

For options with howitzers, the firing location is an open pad for sites the gun could be trailered to, or a secure garage at remote sites where the gun must be left between missions. Access to the firing location is a highwayside turnout where the site is along the highway, a pad on a spur road (approximate spur road length given) if it is near the highway, or helicopter access if it is a remote site. For the howitzer option for the East Lynn alternative, three howitzers would be located at remote sites and one howitzer would be trailered to one of several locations for firing from an open pad.

The field of fire for a howitzer is the total side-to-side, or horizontal, angle between the farthest left and farthest right shot from that location. It is listed because howitzer capabilities vary, and repositioning may be required with some models to cover the full width of the field of fire.

The longest howitzer shot is listed because range is a concern. 105mm howitzers are routinely used up to 3 to 3.5 miles (4800-5600m) range, and can hit targets at over five miles (8000m) with good accuracy. All targets listed in the options are within howitzer range.

The elevation of the highest howitzer shot is listed because elevation and distance determine the necessary trajectory. All shot points could be hit with relatively flat trajectories that stay below 10,000' (3050m). No shots have trajectories where overshooting would target inhabited areas.

Airspace must be closed in the vicinity of howitzer explosive delivery operations to avoid risk to aircraft. These closures are coordinated through the Federal Aviation Administration.

For options with blaster boxes, the width of the starting zone in meters is calculated as "start zone (m)", and is divided by the 300m range of a mast with two cabinets mounted on it to arrive at the number of masts. Determination of individual mast locations is a design-level choice that is beyond the scope of this study.

13.3. *APPENDIX 8: Explosive Calculation and Operations Worksheets*

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ELC A & B Explosive Quantities and Locations

(East Lynn Canal Option A: Helicopter Only, Option B: Daisy Bell)

path	number of shots	frequency weighting	weighted average shots per mission	weighted average shots per year
LC001	5.0	0.5	2.5	6.3
LC002	8.0	1.0	8.0	20.2
LC003	3.0	0.2	0.6	1.5
LC003-1	2.0	0.1	0.1	0.3
LC004	1.0	0.1	0.1	0.1
LC005	15.0	0.5	7.5	18.9
LC005-1	2.0	0.5	1.0	2.5
LC006	15.0	1.0	15.0	37.8
LC007	2.0	0.5	1.0	2.5
LC008	4.0	0.8	3.0	7.6
LC009	4.0	1.0	4.0	10.1
LC010	2.0	1.0	2.0	5.0
LC011	3.0	1.0	3.0	7.6
LC012	15.0	0.7	10.5	26.5
LC013	15.0	0.8	12.0	30.3
LC014	10.0	1.0	10.0	25.2
LC015	1.0	0.1	0.1	0.3
LC016	5.0	0.1	0.3	0.6
LC017	4.0	0.3	1.2	3.0
LC018	6.0	1.0	6.0	15.1
LC019	0.0	0.0	0.0	0.0
LC019-1	2.0	0.3	0.6	1.5
LC020	0.0	0.0	0.0	0.0
LC021	0.0	0.0	0.0	0.0
LC022	1.0	0.2	0.2	0.5
LC023	1.0	0.8	0.8	1.9
LC024	10.0	1.0	10.0	25.2
LC025	4.0	1.0	4.0	10.1
LC026	6.0	1.0	6.0	15.1
LC026-1	1.0	1.0	1.0	2.5
LC027	1.0	0.5	0.5	1.3
LC028	2.0	0.8	1.6	4.0
LC028-1	1.0	0.1	0.1	0.1
LC028-2	2.0	0.1	0.1	0.3
LC029	2.0	0.5	1.0	2.5
LC030	1.0	0.1	0.1	0.1
LC031	1.0	0.1	0.1	0.1
ELC031-1	3.0	0.5	1.5	3.8
ELC031-2	3.0	0.5	1.5	3.8
LC032	1.0	0.1	0.1	0.1
LC033	1.0	0.1	0.1	0.1
LC034	1.0	0.1	0.1	0.1
LC035	5.0	0.5	2.5	6.3
TOTAL	171.0		119.4	301.0

ELC C Howitzer Operations

(Howitzer-helicopter-blaster box explosive delivery)

path	Howitzer firing location	explosive delivery?	field of fire	longest shot (m)	longest shot (mi)	highest shot (m)	highest shot (ft)
LC001	Berners	howitzer	25°	2600	1.6	1371.5	4500
LC002	none	blaster boxes		300	0.2	1798.2	5900
LC003	none	helicopter			0.0	0.0	
LC003-1	none	helicopter			0.0	0.0	
LC004	none	helicopter			0.0	0.0	
LC005	Eldred Rock	howitzer	80°	5600	3.5	1645.8	5400
LC005-1	Eldred Rock	howitzer	80°	4100	2.5	1280.1	4200
LC006	Eldred Rock	howitzer	80°	4500	2.8	1554.4	5100
LC007	Eldred Rock	howitzer	80°	3500	2.2	762.0	2500
LC008	Eldred Rock	howitzer	80°	4100	2.5	1219.1	4000
LC009	Eldred Rock	howitzer	80°	3100	1.9	396.2	1300
LC010	Eldred Rock	howitzer	80°	3300	2.0	457.2	1500
LC011	Eldred Rock	howitzer	80°	3400	2.1	487.7	1600
LC012	Eldred Rock	howitzer	80°	5600	3.5	1798.2	5900
LC013	Eldred Rock	howitzer	80°	5400	3.4	1615.4	5300
LC014	Eldred Rock	howitzer	80°	6500	4.0	1310.6	4300
LC015	none	helicopter			0.0	0.0	
LC016	none	helicopter			0.0	0.0	
LC017	Anyaka Isl.	howitzer	40°	6700	4.2	1615.4	5300
LC018	Anyaka Isl.	howitzer	40°	6900	4.3	1676.3	5500
LC019	Anyaka Isl.	snowshed	40°	7100	4.4	1798.2	5900
LC019-1	Anyaka Isl.	howitzer	40°	4400	2.7	1036.3	3400
LC020	Anyaka Isl.	snowshed	40°	5700	3.5	1219.1	4000
LC021	Anyaka Isl.	snowshed	40°	6300	3.9	1463.0	4800
LC022	Anyaka Isl.	howitzer	40°	4900	3.0	274.3	900
LC023	Anyaka Isl.	howitzer	40°	5700	3.5	1066.7	3500
LC024	Anyaka Isl.	howitzer	40°	5900	3.7	1097.2	3600
LC025	Chilkat Pen.	howitzer	30°	6500	4.0	1341.1	4400
LC026	Chilkat Pen.	howitzer	30°	6500	4.0	1341.1	4400
LC026-1	Chilkat Pen.	howitzer	30°	5300	3.3	335.3	1100
LC027	Chilkat Pen.	howitzer	30°	5600	3.5	640.0	2100
LC028	Chilkat Pen.	howitzer	30°	5700	3.5	670.5	2200
LC028-1	Chilkat Pen.	howitzer	30°	5600	3.5	548.6	1800
LC028-2	Chilkat Pen.	howitzer	30°	5600	3.5	518.1	1700
LC029	Chilkat Pen.	howitzer	30°	6300	3.9	914.4	3000
LC030	Chilkat Pen.	howitzer	30°	5600	3.5	396.2	1300
LC031	none	helicopter			0.0	0.0	
ELC031-1	none	helicopter			0.0	0.0	
ELC031-2	none	helicopter			0.0	0.0	
LC032	none	helicopter			0.0	0.0	
LC033	none	helicopter			0.0	0.0	
LC034	none	helicopter			0.0	0.0	
LC035	none	helicopter			0.0	0.0	

ELC C Explosive Quantities and Locations

(East Lynn Canal Option C: Howitzer-blaster box-helicopter)

path	explosive delivery?	start zone (m)	# masts	# Howitzer shots	# blaster box shots	# heli shots	freq. weighting	weighted Howitzer shots/yr	weighted blaster shots/yr	weighted heli shots/yr
LC001	howitzer			12.0	0.0	0.0	0.5	57.6	0.0	0.0
LC002	blaster box	1600	5.3	0.0	15.0	0.0	1.0	0.0	148.5	0.0
LC003	helicopter		0.0	0.0	0.0	3.0	0.2	0.0	0.0	1.1
LC003-1	helicopter		0.0	0.0	0.0	2.0	0.1	0.0	0.0	0.2
LC004	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
LC005	howitzer		0.0	15.0	0.0	0.0	0.5	72.0	0.0	0.0
LC005-1	howitzer		0.0	2.0	0.0	0.0	0.5	9.6	0.0	0.0
LC006	howitzer		0.0	15.0	0.0	0.0	1.0	144.0	0.0	0.0
LC007	howitzer		0.0	2.0	0.0	0.0	0.8	14.4	0.0	0.0
LC008	howitzer		0.0	6.0	0.0	0.0	0.5	28.8	0.0	0.0
LC009	howitzer		0.0	5.0	0.0	0.0	1.0	48.0	0.0	0.0
LC010	howitzer		0.0	4.0	0.0	0.0	1.0	38.4	0.0	0.0
LC011	howitzer		0.0	3.0	0.0	0.0	1.0	28.8	0.0	0.0
LC012	howitzer		0.0	15.0	0.0	0.0	0.7	100.8	0.0	0.0
LC013	howitzer		0.0	20.0	0.0	0.0	0.8	153.6	0.0	0.0
LC014	howitzer		0.0	15.0	0.0	0.0	1.0	144.0	0.0	0.0
LC015	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.2
LC016	helicopter		0.0	0.0	0.0	5.0	0.1	0.0	0.0	0.5
LC017	howitzer		0.0	7.0	0.0	0.0	0.3	20.2	0.0	0.0
LC018	howitzer		0.0	10.0	0.0	0.0	1.0	96.0	0.0	0.0
LC019	snowshed		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LC019-1	howitzer		0.0	3.0	0.0	0.0	0.3	8.6	0.0	0.0
LC020	snowshed		0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
LC021	snowshed		0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
LC022	howitzer		0.0	2.0	0.0	0.0	0.2	3.8	0.0	0.0
LC023	howitzer		0.0	3.0	0.0	0.0	0.8	21.6	0.0	0.0
LC024	howitzer		0.0	12.0	0.0	0.0	1.0	115.2	0.0	0.0
LC025	howitzer		0.0	6.0	0.0	0.0	1.0	57.6	0.0	0.0
LC026	howitzer		0.0	7.0	0.0	0.0	1.0	67.2	0.0	0.0
LC026-1	howitzer		0.0	1.0	0.0	0.0	1.0	9.6	0.0	0.0
LC027	howitzer		0.0	2.0	0.0	0.0	0.5	9.6	0.0	0.0
LC028	howitzer		0.0	4.0	0.0	0.0	0.8	30.7	0.0	0.0
LC028-1	howitzer		0.0	1.0	0.0	0.0	0.1	0.5	0.0	0.0
LC028-2	howitzer		0.0	4.0	0.0	0.0	0.1	1.9	0.0	0.0
LC029	howitzer		0.0	4.0	0.0	0.0	0.5	19.2	0.0	0.0
LC030	howitzer		0.0	2.0	0.0	0.0	0.1	1.0	0.0	0.0
LC031	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
ELC031-1	helicopter		0.0	0.0	0.0	3.0	0.5	1.5	0.0	2.7
ELC031-2	helicopter		0.0	0.0	0.0	3.0	0.5	1.5	0.0	2.7
LC032	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
LC033	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
LC034	helicopter		0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1
LC035	helicopter		0.0	0.0	0.0	5.0	0.5	0.0	0.0	4.6
			5.3	182.0	15.0	27.0		1305.6	148.5	12.4

ELC D Operations and Explosives										
(East Lynn Canal option D: Blaster Boxes on Major Paths (Mitigated AHI > 1.75), Heli Backup)										
path	explosive delivery	start zone (m)	# blast masts	# blast shots	# heli shots	freq. weighting	weighted avg. heli shots/ mission	weighted blaster shots/ mission	weighted blaster shots/yr	weighted heli shots/ yr
LC001	helicopter			0.0	5.0	0.5	2.5	0.0	0.0	4.6
LC002	blaster box	1600	5.3	15.0	0.0	1.0	0.0	15.0	148.5	0.0
LC003	helicopter			0.0	3.0	0.2	0.6	0.0	0.0	1.1
LC003-1	helicopter			0.0	2.0	0.1	0.1	0.0	0.0	0.2
LC004	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC005	helicopter			0.0	10.0	0.5	5.0	0.0	0.0	9.1
LC005-1	helicopter			0.0	2.0	0.5	1.0	0.0	0.0	1.8
LC006	blaster box	1100	3.7	15.0	0.0	1.0	0.0	15.0	148.5	0.0
LC007	helicopter			0.0	2.0	0.5	1.0	0.0	0.0	1.8
LC008	helicopter			0.0	4.0	0.8	3.0	0.0	0.0	5.5
LC009	blaster box	100	1.0	5.0	0.0	1.0	0.0	5.0	49.5	0.0
LC010	blaster box	100	1.0	4.0	0.0	1.0	0.0	4.0	39.6	0.0
LC011	blaster box	100	1.0	4.0	0.0	1.0	0.0	4.0	39.6	0.0
LC012	helicopter			0.0	15.0	0.7	10.5	0.0	0.0	19.2
LC013	helicopter			0.0	15.0	0.8	12.0	0.0	0.0	21.9
LC014	blaster box	500	1.7	15.0	0.0	1.0	0.0	15.0	148.5	0.0
LC015	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.2
LC016	helicopter			0.0	5.0	0.1	0.3	0.0	0.0	0.5
LC017	helicopter			0.0	4.0	0.3	1.2	0.0	0.0	2.2
LC018	blaster box	900	3.0	10.0	0.0	1.0	0.0	10.0	99.0	0.0
LC019	snowshed			0.0	0.0	0.0	0.0	0.0	0.0	0.0
LC019-1	helicopter			0.0	2.0	0.3	0.6	0.0	0.0	1.1
LC020	snowshed			0.0	0.0	0.0	0.0	0.0	0.0	0.0
LC021	snowshed			0.0	0.0	0.0	0.0	0.0	0.0	0.0
LC022	helicopter			0.0	1.0	0.2	0.2	0.0	0.0	0.4
LC023	blaster box	300	1.0	2.0	0.0	0.8	0.0	1.5	14.9	0.0
LC024	blaster box	800	2.7	12.0	0.0	1.0	0.0	12.0	118.8	0.0
LC025	blaster box	800	2.7	6.0	0.0	1.0	0.0	6.0	59.4	0.0
LC026	blaster box	1100	3.7	7.0	0.0	1.0	0.0	7.0	69.3	0.0
LC026-1	blaster box	100	1.0	1.0	0.0	1.0	0.0	1.0	9.9	0.0
LC027	blaster box	100	1.0	1.0	0.0	0.5	0.0	0.5	5.0	0.0
LC028	helicopter			0.0	2.0	0.8	1.6	0.0	0.0	2.9
LC028-1	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC028-2	helicopter			0.0	2.0	0.1	0.1	0.0	0.0	0.2
LC029	helicopter			0.0	2.0	0.5	1.0	0.0	0.0	1.8
LC030	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC031	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC031-1	blaster box	300	1.0	3.0	0.0	0.5	0.0	1.5	14.9	0.0
ELC031-2	blaster box	200	0.7	3.0	0.0	0.5	0.0	1.5	14.9	0.0
LC032	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC033	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC034	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC035	helicopter			0.0	5.0	0.5	2.5	0.0	0.0	4.6

Totals		8100	27.0	103.0	89.0		43.6	99.0	980.4	79.7

ELC E Operations and Explosives

(East Lynn Canal Option E: Blaster Boxes Top Paths (Mitigated AHI > 4), Heli. Elsewhere)

path	explosive delivery	start zone (m)	# blast masts	# blast shots	# heli shots	freq. weighting	weighted avg. heli shots/ mission	weighted blast shots/ mission	weighted blast shots/yr	weighted heli shots/ yr
LC001	helicopter			0.0	5.0	0.5	2.5	0.0	0.0	4.2
LC002	blaster box	1600	5.3	15.0	0.0	1.0	0.0	15.0	148.5	0.0
LC003	helicopter			0.0	3.0	0.2	0.6	0.0	0.0	1.0
LC003-1	helicopter			0.0	2.0	0.1	0.1	0.0	0.0	0.2
LC004	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC005	helicopter			0.0	15.0	0.5	7.5	0.0	0.0	12.6
LC005-1	helicopter			0.0	2.0	0.5	1.0	0.0	0.0	1.7
LC006	blaster box	1100	3.7	15.0	0.0	1.0	0.0	15.0	148.5	0.0
LC007	helicopter			0.0	2.0	0.5	1.0	0.0	0.0	1.7
LC008	helicopter			0.0	4.0	0.8	3.0	0.0	0.0	5.1
LC009	blaster box	100	1.0	0.0	4.0	1.0	4.0	0.0	0.0	6.7
LC010	helicopter			0.0	2.0	1.0	2.0	0.0	0.0	3.4
LC011	helicopter			0.0	3.0	1.0	3.0	0.0	0.0	5.1
LC012	helicopter			0.0	15.0	0.7	10.5	0.0	0.0	17.7
LC013	helicopter			0.0	15.0	0.8	12.0	0.0	0.0	20.2
LC014	blaster box	500	1.7	15.0	0.0	1.0	0.0	15.0	148.5	0.0
LC015	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.2
LC016	helicopter			0.0	5.0	0.1	0.3	0.0	0.0	0.4
LC017	helicopter			0.0	4.0	0.3	1.2	0.0	0.0	2.0
LC018	helicopter			0.0	6.0	1.0	6.0	0.0	0.0	10.1
LC019	snowshed			0.0	0.0	0.0	0.0	0.0	0.0	0.0
LC019-1	helicopter			0.0	2.0	0.3	0.6	0.0	0.0	1.0
LC020	snowshed			0.0	0.0	0.0	0.0	0.0	0.0	0.0
LC021	snowshed			0.0	0.0	0.0	0.0	0.0	0.0	0.0
LC022	helicopter			0.0	1.0	0.2	0.2	0.0	0.0	0.3
LC023	blaster box	300	1.0	2.0	0.0	0.8	0.0	1.5	14.9	0.0
LC024	blaster box	800	2.7	0.0	0.0	1.0	0.0	10.0	99.0	0.0
LC025	blaster box	800	2.7	6.0	0.0	1.0	0.0	6.0	59.4	0.0
LC026	helicopter			0.0	7.0	1.0	7.0	0.0	0.0	11.8
LC026-1	blaster box	100	1.0	1.0	0.0	1.0	0.0	1.0	9.9	0.0
LC027	helicopter			0.0	1.0	0.5	0.5	0.0	0.0	0.8
LC028	helicopter			0.0	2.0	0.8	1.6	0.0	0.0	2.7
LC028-1	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC028-2	helicopter			0.0	2.0	0.1	0.1	0.0	0.0	0.2
LC029	helicopter			0.0	8.0	0.5	4.0	0.0	0.0	6.7
LC030	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC031	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
ELC031-1	helicopter			0.0	3.0	0.5	1.5	0.0	0.0	2.5
ELC031-2	helicopter			0.0	3.0	0.5	1.5	0.0	0.0	2.5
LC032	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC033	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1
LC034	helicopter			0.0	1.0	0.1	0.1	0.0	0.0	0.1

LC035	helicopter			0.0	5.0	0.5	2.5	0.0	0.0	4.2
Totals		5,300	17.7	54.0	129.0		74.6	63.5	628.8	125.6

WLC F Howitzer Operations

(Howitzer explosive delivery)

path	firing location	type	access	spur road length (m)	spur road length (mi)	field of fire	longest shot (m)	longest shot (mi)	highest shot (m)	highest shot (ft)
WLC001A & B	Endicott R.	open pad	spur road	800	0.5	30°	3000	1.9	396	1300
WLC002 A & B	Endicott R.	open pad	spur road	800	0.5	"	1900	1.2	488	1600
WLC003	*none*	*avoids path*								
WLC004	*none*	*avoids path*								
WLC005	Sullivan	open pad	spur road	500	0.3	70° (in 1st position)	3700	2.3	1311	4300
WLC006 A-C	Sullivan	open pad	spur road	500	0.3	"	3100	1.9	1402	4600
WLC007	Sullivan	open pad	spur road	500	0.3	10° (in 2nd position)	2900	1.8	1036	3400
WLC008	S. Rainbow	open pad	spur road	500	0.3	25° (in 1st position)	4000	2.5	1402	4600
WLC009 A-C	S. Rainbow	open pad	spur road	500	0.3	20° (in 2nd position)	4900	3.0	1219	4000
WLC009 A-C	Rainbow-Pyramid	open pad	spur road	400	0.2	25° (in 1st position)	4800	3.0	1219	4000
WLC010 A-D	Rainbow-Pyramid	open pad	spur road	400	0.2	40° (in 2nd position)	2900	1.8	1128	3700
WLC010 A-D	Chilkat Crossing	open pad	roadside turnout	0	0.0	depends on loc'n	depends on loc'n	depends on loc'n		3700
	Total spur road length (approx.)			4900	3.0					

WLC F Explosive Quantities and Locations				
(West Lynn Canal option F: Howitzer Only)				
path	**# shots**	**frequency weighting**	**weighted average shots/ mission**	**weighted average shots/ year**
WLC001 A & B	6.0	1.0	6.0	64.8
WLC00 2A & B	6.0	1.0	6.0	64.8
WLC003	0.0	0.0	0.0	0.0
WLC004	0.0	0.0	0.0	0.0
WLC005	8.0	0.5	4.0	43.2
WLC006 A-C	20.0	1.0	20.0	216.0
WLC007	10.0	0.1	1.0	10.8
WLC008	20.0	0.3	6.0	64.8
WLC009 A-C	20.0	1.0	20.0	216.0
WLC010 A-D	15.0	1.0	15.0	162.0
Totals	105.0		78.0	842.3

WLC G Explosive Quantities and Locations

(West Lynn Canal Option G: Howitzer-Blaster Box)

path	explosive delivery	start zone (m)	# blaster box masts	# how. shots	# blaster box shots	freq. weighting	weighted avg. how. shots/ mission	weighted avg. how. shots/ yr	weighted average blaster shots/ mission	weighted average blaster shots/ yr
WLC001 A & B	blaster boxes	700	2.3	0	6	1.0	0.0	0.0	6.0	50.4
WLC002 A & B	blaster boxes	700	2.3	0	6	1.0	0.0	0.0	6.0	50.4
WLC003	*avoids path*									
WLC004	*avoids path*									
WLC005	howitzer			8	0	0.5	4.0	33.6	0.0	0.0
WLC006 A-C	blaster boxes	2200	7.3	0	20	1.0	0.0	0.0	20.0	168.0
WLC007	howitzer			10	0	0.1	1.0	8.4	0.0	0.0
WLC008	howitzer			20	0	0.3	6.0	50.4	0.0	0.0
WLC009 A-C	blaster boxes	2800	9.3	0	20	1.0	0.0	0.0	20.0	168.0
WLC010 A-D	blaster boxes	1600	5.3	0	15	1.0	0.0	0.0	15.0	126.0
Totals		8000	26.7	38	67		11.0	92.4	67.0	562.7

13.4. *APPENDIX 9: Avalanche Program Budget Discussion*

The budget spreadsheets reflect efforts to catalog and price all components related to a viable avalanche program. Whenever possible, cost estimates from DOT&PF or other state employees most knowledgeable about the particular item or service in question were used. The source of each estimate is given on the spreadsheets.

Following are some of the assumptions used:

Helicopter ferry time from Juneau to the Lynn Canal area is estimated to be 1.2 hours round-trip for a typical mission, the average of 0.8 hours roundtrip from the helicopter bases to the southern end of either the East or West Lynn Canal highway, and flight time to the north end of 1.6 hours roundtrip. Since all destinations would be between these points, the ferry time used here is the average of 1.2 hours.

Standby time and additional flying time based on distance and typical rate of climb and travel were added to the ferry time in accordance with the type of mission; e.g., explosives work, weather station maintenance, blaster box reloading.

Monthly operating and replacement costs for DOT&PF heavy equipment are as supplied by DOT&PF staff.

Annual replacement costs for equipment are figured based on the following formula: new cost adjusted for inflation divided by useful life in years. This methodology is the same basic methodology DOT&PF uses to calculate monthly replacement costs for heavy equipment. Including replacement costs in the annual operating budget is meant to amortize the cost of recapitalization, so that there would not be a need for extra funds when equipment reaches the end of its useful life.

Labor costs were calculated based on current wages.

The time for temporary flaggers is estimated based on highway closure times during explosive delivery and snow removal time. While there would be gates to keep travelers out of avalanche zones during highway closures, highway flaggers would be needed in certain circumstances, such as when the highway is partially closed but one lane of traffic has been opened.

13.5. ***APPENDIX 10: Avalanche Program Options Comparison***

Explosive Delivery Option	Capital Budget	Operating Budget	Average Closure Time/yr (days)	Average Number of Closures/yr	Range of Closure Length (days)	Residual AHI
A E Lynn, DOTPF, Helicopter Only,	$3,742,743	$1,426,952	25.9	12.4	0.8-8.0	27.7
B E Lynn, DOTPF, Daisy Bell only	$3,892,743	$1,398,947	22.4	12.4	0.8-8.0	27.7
C E Lynn, DOTPF, Howitzer, plus Blaster Boxes & Helicopter	$22,480,784	$1,570,028	15.8	11.6	0.6-4.1	27.7
D E Lynn, DOTPF, Blaster Boxes, plus Helicopter	$8,603,893	$1,665,746	12.1	9.9	0.8-2.2	27.7
E E Lynn , DOTPF, Limited Blaster Boxes, plus Helicopter	$6,983,893	$1,591,346	22.4	12.4	0.8-6.1	27.7
F W Lynn, DOTPF, Howitzer Only	$3,152,833	$1,446,176	6.4	10.8	0.4-0.9	17.9
G W Lynn, DOTPF, Howitzer plus Blaster Boxes	$8,025,234	$1,384,025	5.5	8.4	0.4-1.0	17.9

13.6. *APPENDIX 11: Operating Budget Spreadsheets*

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Operating Budget - East Lynn Canal Option A: Helicopter Only

							Total annual cost	**Information source**	**Notes**
Explosives		Equipment		Cost per shot		Annual number of shots	Annual cost		
		Heli explosives		$99		301	$29,757	Austin Powder Ketchikan Alaska	includes ANFO, boosters, cap and fuse, igniters, sandbag, tape, shipping, and RECCO reflectors
		RECCO detector rental					$700	RECCO AB, Sweden	
Helicopter time		(A-Star)	Hours per mission	Hourly rate	Number of missions	Total annual hours	Annual cost		
	Explosive delivery	flight time		$1,760		17.0	$29,920	Coastal Helicopters	
		standby		$880		4.0	$3,520	Coastal Helicopters	
	Weather station maintenance	flight time	2	$1,760	16	32	$56,320	Coastal Helicopters	
		standby	4	$880	16	64	$56,320	Coastal Helicopters	
	Snow study	flight time	2.5	$1,760	8	20	$35,200	Coastal Helicopters	
		standby	2	$880	8	16	$14,080	Coastal Helicopters	
Vehicles/ heavy equipment			Number of vehicles	Monthly cost per vehicle	Monthly cost	Number of months	Annual cost		
Debris removal equipment	Operating rate	Cat 988G loader	2	$1,128	$2,256	12	$27,072	G. Patz	includes repair and maintenance
Debris removal equipment	Replacement rate	Cat 988G loader	2	$3,092	$6,184	12	$74,208	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	Cat 988G loader	2	$1,008	$2,016	12	$24,192	G. Patz	4 gal/hr burn rate; 6 hrs/day; 10 days/month
Debris removal equipment	Operating rate	D9R dozer	2	$1,250	$2,500	12	$30,000	G. Patz	includes repair and maintenance
Debris removal equipment	Replacement rate	D9R dozer	2	$5,160	$10,320	12	$123,840	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	D9R dozer	2	$1,260	$2,520	12	$30,240	G. Patz	5 gal/hr burn rate; 6 hrs/day; 10 days/month
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	3	$277	$831	12	$9,972	G. Patz	1-forecasters, 2-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	3	$250	$750	12	$9,000	G. Patz	includes payments to credit bank to replace at end of service life
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	3	$280	$840	12	$10,080	G. Patz	1000 miles per mo. @ $0.25/mi
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years, averaged)	Annual replacement cost		replacement figured with 3% inflation
	Chains for loaders		2	$10,500	$21,000	3	$7,210		
	Avalanche caches		2	$18,744	$37,487	5	$7,722		see budget detail spreadsheet
	Vehicle caches		4	$5,445	$21,780	5	$4,487		see budget detail spreadsheet
	Forecasting office equipment		1	$23,300	$23,300	4	$6,000		see budget detail spreadsheet
	Forecasting field equipment		1	$17,172	$17,172	5.1875	$3,410		see budget detail spreadsheet
	Signage	avalanche zone signs	196	$100	$19,600	8	$2,524		
		highway entry signs	2	$500	$1,000	8	$129		
		trailhead warning signs	40	$20	$800	8	$103		

	Weather station maintenance	replacement parts					$51,000	Mark Moore, NWAC	15% of equipment cost annually
Forecasting office operations			Number	Unit cost	Monthly cost	Number of months	Annual cost		
	Telephones		4	$35	$140	12	$1,680	DOA	
	Long distance				$150	12	$1,800	AAS	
	Networking charge	monthly charge per employee		$60		30	$1,800	DOA	30 is the number of employee-months per year
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		All wages multiplied by 1.63 per N. Slagle
	Forecasting staff	Equipment Operator	WG 52, Full Time	1	$190,702	1.00	$190,702	G Patz, DOT	
		Equipment Operator	WG 53, Full Time	1	$174,242	1.00	$174,242	G Patz, DOT	
		Equipment Operator	WG 53, Seasonal	1	$106,232	0.50	$53,116	G Patz, DOT	
		administrative overhead	15% of personnel costs				$62,709	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	4	$280,960	1.7	$280,960	G. Patz	
	Avalanche-related operators	Seasonal operators for explosives makeup	Wage group 53D		$2,451		$2,451		
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		temp. flagger	Wage group 56 (hourly)	2	$117.87	50.8	$5,988	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		forecasters	3	$1,500	$4,500	annually	$4,500	G Patz, DOT	avalanche mitigation training
Total Annual Operating Budget							**$1,426,952**		

Operating Budget - East Lynn Canal Option B: Daisy Bell Only

							Total annual cost	**Information source**	**Notes**
Explosives		Equipment		Cost per shot		Annual number of shots	Annual cost		
		Daisy Bell gas		$3.00		301	$903	AEL&P	Hydrogen & oxygen
		Daisy Bell maintenance					$2,000	AEL&P	Hydrogen & oxygen
Helicopter time		(A-Star)	Hours per mission	Hourly rate	Number of missions	Total annual hours	Annual cost		
	Explosive delivery	flight time		$1,760		14.5	$29,920	Coastal Helicopters	
		standby		$880		1.2	$3,520	Coastal Helicopters	
	Weather station maintenance	flight time	2	$1,760	16	32.0	$56,320	Coastal Helicopters	
		standby	4	$880	16	64.0	$56,320	Coastal Helicopters	
	Snow study	flight time	2.5	$1,760	8	20.0	$35,200	Coastal Helicopters	
		standby	2	$880	8	16.0	$14,080	Coastal Helicopters	
Vehicles/ heavy equipment			Number of vehicles	Monthly cost per vehicle	Monthly cost	Number of months	Annual cost		
Debris removal equipment	Operating rate	Cat 988G loader	2	$1,128	$2,256	12	$27,072	G. Patz	includes repair and maintenance
Debris removal equipment	Replacement rate	Cat 988G loader	2	$3,092	$6,184	12	$74,208	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	Cat 988G loader	2	$1,008	$2,016	12	$24,192	G. Patz	4 gal/hr burn rate; 6 hrs/day; 10 days/month
Debris removal equipment	Operating rate	D9R dozer	2	$1,250	$2,500	12	$30,000	G. Patz	includes repair and maintenance

Debris removal equipment	Replacement rate	D9R dozer	2	$5,160	$10,320	12	$123,840	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	D9R dozer	2	$1,260	$2,520	12	$30,240	G. Patz	5 gal/hr burn rate; 6 hrs/day; 10 days/month
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	3	$277	$831	12	$9,972	G. Patz	1-forecasters, 2-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	3	$250	$750	12	$9,000	G. Patz	includes payments to credit bank to replace at end of service life
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	3	$280	$840	12	$10,080	G. Patz	1000 miles per mo. @ $0.25/mi
Daisy Bell	annual maintenance		1	$2,000	$2,000		$2,000	Mike Janes, AEL&P	TAS; Daisy Bell exploder;
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years, averaged)	Annual replacement cost		replacement figured with 3% inflation
	Chains for loaders		2	$10,500	$21,000	3	$7,210		
	Avalanche caches		2	$18,744	$37,487	5	$7,722		see budget detail spreadsheet
	Vehicle caches		4	$5,445	$21,780	5	$4,487		see budget detail spreadsheet
	Forecasting office equipment		1	$23,300	$23,300	4	$6,000		see budget detail spreadsheet
	Forecasting field equipment		1	$17,172	$17,172	5	$3,410		see budget detail spreadsheet
	Signage	avalanche zone signs	196	$100	$19,600	8	$2,524		
		highway entry signs	2	$500	$1,000	8	$129		
		trailhead warning signs	40	$20	$800	8	$103		
	Weather station maintenance	replacement parts					$51,000	Mark Moore, NWAC	15% of equipment cost annually
Forecasting office operations			Number	Unit cost	Monthly cost	Number of months	Annual cost		
	Telephones		4	$35.00	$140	12	$1,680	DOA	
	Long distance				$150	12	$1,800	AAS	
	Networking charge	monthly charge per employee		$60.00		30	$1,800	DOA	30 is the number of employee-months per year
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		All wages multiplied by 1.63 per N. Slagle
	Forecasting staff	Equipment Operator	WG 52, Full Time	1	$190,702	1.00	$190,702	G Patz, DOT	
		Equipment Operator	WG 53, Full Time	1	$174,242	1.00	$174,242	G Patz, DOT	
		Equipment Operator	WG 53, Seasonal	1	$106,232	0.50	$53,116	G Patz, DOT	
		administrative overhead	15% of personnel costs				$62,709	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	4	$280,960	1.7	$280,960	G. Patz	
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		temp. flagger	Wage group 56 (hourly)	2	$117.87	50.8	$5,988	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		forecasters	3	$1,500	$4,500	annually	$4,500	AAS	professional development
Total Annual Operating Budget							**$1,398,947**		

Operating budget - East Lynn Canal Option C: Howitzer-blaster box-helicopter

							Total annual cost	**Information source**	**Notes**
Explosive delivery		Equipment	Number	Cost			**Annual cost**		
	Annual lease of 105mm Howitzer	available model	3	$100			$300	T. Onslow	
Explosives				Cost per round		Number of rounds	Annual cost		Annual number of rounds
	Howitzer			$113		1306	$147,970	G. Patz	per round cost w/shipping plus 10 percent for emergency shipments
	Blaster boxes			$192		149	$28,657	CIL Orion	2012 prices plus 15% for shipping and expected cost increases. Cost per round includes RECCO reflectors
	Heli explosives			$99		12	$1,186	Austin Powder Ketchikan Alaska	includes ANFO, boosters, cap and fuse, igniters, sandbag, tape, shipping, and RECCO reflectors
		RECCO detector rental					$700	RECCO AB, Sweden	
Helicopter time		(A-Star)	Hours per mission	Hourly rate	Number of missions	Total annual hours	Annual cost		

	Explosive delivery	flight time		$1,760		10	$17,600	Coastal Helicopters	includes time to access Howitzer sites
		standby		$880		12	$10,560	Coastal Helicopters	
	Weather station maintenance	flight time	2	$1,760	16	32	$56,320	Coastal Helicopters	includes two trips annually for blaster box loading/ unloading
		standby	4	$880	16	64	$56,320	Coastal Helicopters	
	Snow study	flight time	2.5	$1,760	8	20	$35,200	Coastal Helicopters	
		standby	2	$880	8	16	$14,080	Coastal Helicopters	
Vehicles/heavy equipment			Number of vehicles	Monthly cost per vehicle	Monthly cost	Number of months	Annual cost		
Debris removal equipment	Operating rate	Cat 988G loader	2	$1,128	$2,256	12	$27,072	G. Patz	includes repair and maintenance
Debris removal equipment	Replacement rate	Cat 988G loader	2	$3,092	$6,184	12	$74,208	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	Cat 988G loader	2	$1,008	$2,016	12	$24,192	G. Patz	4 gal/hr burn rate; 6 hrs/day; 10 days/month
Debris removal equipment	Operating rate	D9R dozer	2	$1,250	$2,500	12	$30,000	G. Patz	includes repair and maintenance
Debris removal equipment	Replacement rate	D9R dozer	2	$5,160	$10,320	12	$123,840	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	D9R dozer	2	$1,260	$2,520	12	$30,240	G. Patz	5 gal/hr burn rate; 6 hrs/day; 10 days/month
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	3	$277	$831	12	$9,972	G. Patz	1-forecasters, 2-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	3	$250	$750	12	$9,000	G. Patz	includes payments to credit bank to replace at end of service life
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	3	$280	$840	12	$10,080	G. Patz	1000 miles per mo. @ $0.25/mi
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost		Replacement figured with 3% inflation
	Chains for loaders		2	$10,500	$21,000	3	$7,210		
	Avalanche caches		2	$18,744	$37,487	5	$7,722		see budget detail spreadsheet
	Vehicle caches		4	$5,445	$21,780	5	$4,487		see budget detail spreadsheet
	Forecasting office equipment			$23,300	$23,300	4	$6,000		see budget detail spreadsheet
	Forecasting field equipment			$17,172	$17,172	5	$3,410		see budget detail spreadsheet
	Signage	avalanche zone signs	196	$100	$19,600	8	$2,524		
		highway entry signs	2	$500	$1,000	8	$129		
		trailhead warning signs	40	$20	$800	8	$103		
	Weather station maintenance	replacement parts					$51,000	Mark Moore, NWAC	15% of equipment cost annually
Forecasting office operations			Number	Unit cost	Monthly cost	Number of months	Annual cost		
	Telephones		4	$35	$140	12	$1,680	DOA	
	Long distance				$150	12	$1,800	AAS	
	Networking charge	monthly charge per employee		$60		30	$1,800	DOA	30 is the number of employee-months per year
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		All wages multiplied by 1.63 per N. Slagle
	Forecasting staff	Equipment Operator	WG 52, Full Time	$1	$190,702	1.00	$190,702	G Patz, DOT	
		Equipment Operator	WG 53, Full Time	$1	$174,242	1.00	$174,242	G Patz, DOT	
		Equipment Operator	WG 53, Seasonal	$1	$106,232	0.50	$53,116	G Patz, DOT	
		administrative overhead	15% of personnel costs				$62,709	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	4	$280,960	1.7	$280,960	G. Patz	
	Avalanche-related operators	Seasonal operators for explosives makeup	Wage group 53D	0	$2,451	0	$2,451		
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		temp. flagger	Wage group 56 (hourly)	$2	$117.87	50.8	$5,988	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		forecasters	3	$1,500	$4,500	annually	$4,500	G Patz, DOT	avalanche mitigation training

Total Annual Operating Budget							**$1,570,028**		

Operating Budget - East Lynn Canal option D: Blaster Boxes on Major Paths, Heli Backup									
							Total annual cost	**Information source**	**Notes**
Explosives				Cost per round		Number of rounds	Annual cost		Annual number of rounds.
	Blaster boxes			$192		980	$188,482	ARR	2012 prices plus 15% for shipping and expected cost increases. Cost per round includes $2.00 per round for RECCO reflectors
	Heli explosives			$99		80	$7,909	Austin Powder Ketchikan Alaska	includes ANFO, boosters, cap and fuse, igniters, sandbag, tape, shipping, and RECCO reflectors
		RECCO detector rental					$700	RECCO AB, Sweden	
Helicopter time		(A-Star)	Hours per mission	Hourly rate	Number of missions	Total annual hours	Annual Cost		
	Explosive delivery	flight time		$1,760		35	$61,600	Coastal Helicopters	
		standby		$880		50.0	$44,000	Coastal Helicopters	
	Weather station maintenance	flight time	2	$1,760	16	32	$56,320	Coastal Helicopters	includes two trips annually for blaster box loading and unloading
		standby	4	$880	16	64	$56,320	Coastal Helicopters	
	Snow study	flight time	2.5	$1,760	8	20	$35,200	Coastal Helicopters	
		standby	2	$880	8	16	$14,080	Coastal Helicopters	
Vehicles/heavy equipment			Number of vehicles	Monthly cost per vehicle	Monthly cost	Number of months	Annual cost		
Debris removal equipment	Monthly rate	Cat 988G loader	2	$1,128	$2,256	12	$27,072	G. Darling costs, G. Patz specs.	includes replacement, maintenance, fuel
Debris removal equipment	Replacement rate	Cat 988G loader	2	$3,092	$6,184	12	$74,208	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	Cat 988G loader	2	$1,008	$2,016	12	$24,192	G. Patz	4 gal/hr burn rate; 6 hrs/day; 10 days/month
Debris removal equipment	Operating rate	D9R dozer	2	$1,250	$2,500	12	$30,000	G. Patz	includes repair and maintenance
Debris removal equipment	Replacement rate	D9R dozer	2	$5,160	$10,320	12	$123,840	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	D9R dozer	2	$1,260	$2,520	12	$30,240	G. Patz	5 gal/hr burn rate; 6 hrs/day; 10 days/month
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	3	$277	$831	12	$9,972	G. Darling costs, G. Patz specs.	1-forecasters, 2-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	3	$250	$750	12	$9,000	G. Darling costs, G. Patz specs.	
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	3	$280	$840	12	$10,080	G. Patz	1000 miles per mo. @ $0.25/mi
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost		Replacement figured with 3% inflation
	Chains for loaders		2	$10,500	$21,000	3	$7,210		
	Avalanche caches		2	$18,744	$37,487	5	$7,722		
	Vehicle caches		4	$5,445	$21,780	5	$4,487		see budget detail spreadsheet
	Forecasting office equipment			$23,300	$23,300	4	$6,000		see budget detail spreadsheet
	Forecasting field equipment			$17,172	$17,172	5	$3,410		see budget detail spreadsheet
	Signage	avalanche zone signs	196	$100	$19,600	8	$2,524		
		highway entry signs	2	$500	$1,000	8	$129		
		trailhead warning signs	40	$20	$800	8	$103		
	Weather station maintenance	replacement parts					$51,000	Mark Moore, NWAC	15% of equipment cost annually
Forecasting office operations			Number	Unit cost	Monthly cost	Number of months	Annual cost		
	Telephones		4	$35	$140	12	$1,680	DOA	
	Long distance				$150	12	$1,800	AAS	
	Networking charge	monthly charge per employee		$60		30	$1,800	DOA	30 is the number of employee-months per year
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		All wages multiplied by 1.63 per N. Slagle
	Forecasting staff	Equipment Operator	WG 52, Full Time	$1	$190,702	1.00	$190,702	G Patz, DOT	
		Equipment Operator	WG 53, Full Time	$1	$174,242	1.00	$174,242	G Patz, DOT	
		Equipment Operator	WG 53, Seasonal	$1	$106,232	0.50	$53,116	G Patz, DOT	

		administrative overhead	15% of personnel costs		$0		$62,709	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	4	$280,960	1.7	$280,960	G. Patz	
	Avalanche-related operators	Seasonal operators for explosives makeup	Wage group 53D		$2,451		$2,451		
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		temp. flagger	Wage group 56 (hourly)	$2	$118	50.8	$5,988	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		forecasters	3	$1,500	$4,500	annually	$4,500	AAS	professional development
Total Annual Operating Budget							**$1,665,746**		

Operating Budget - East Lynn Canal Option E: Blaster Boxes Top 10 Paths, Heli. Elsewhere									
							Total annual cost	**Information source**	**Notes**
Explosive delivery	Equipment			**Cost oer round**		Number of rounds	Annual cost		Annual number of rounds
	Blaster boxes			$192		629	$120,975	ARR	2012 prices plus 15% for shipping and expected cost increases. Cost per round includes $2.00 per round for RECCO reflectors
	Heli explosives			$99		126	$12,456	Austin Powder Ketchikan Alaska	includes ANFO, boosters, cap and fuse, igniters, sandbag, tape, shipping, and RECCO reflectors
		RECCO detector rental					$700	RECCO AB, Sweden	
Helicopter time		(A-Star)	Hours per mission	Hourly rate	Number of missions	Total annual hours	Annual Cost		
	Explosive delivery	flight time		$1,760		37	$65,120	Coastal Helicopters	
		standby		$880		33	$29,040	Coastal Helicopters	
	Weather station maintenance	flight time	2	$1,760	16	32	$56,320	Coastal Helicopters	includes two trips annually for blaster box loading and unloading
		standby	4	$880	16	64	$56,320	Coastal Helicopters	
	Snow study	flight time	2.5	$1,760	8	20	$35,200	Coastal Helicopters	
		standby	2	$880	8	16	$14,080	Coastal Helicopters	
Vehicles/heavy equipment			Number of vehicles	Monthly cost per vehicle	Monthly cost	Number of months	Annual cost		
Debris removal equipment	Operating rate	Cat 988G loader	2	$1,128	$2,256	12	$27,072	G. Patz	includes repair and maintenance
Debris removal equipment	Replacement rate	Cat 988G loader	2	$3,092	$6,184	12	$74,208	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	Cat 988G loader	2	$1,008	$2,016	12	$24,192	G. Patz	4 gal/hr burn rate; 6 hrs/day; 10 days/month
Debris removal equipment	Operating rate	D9R dozer	2	$1,250	$2,500	12	$30,000	G. Patz	includes repair and maintenance
Debris removal equipment	Replacement rate	D9R dozer	2	$5,160	$10,320	12	$123,840	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	D9R dozer	2	$1,260	$2,520	12	$30,240	G. Patz	5 gal/hr burn rate; 6 hrs/day; 10 days/month
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	3	$277	$831	12	$9,972	G. Patz	1-forecasters, 2-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	3	$250	$750	12	$9,000	G. Patz	includes payments to credit bank to replace at end of service life
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	3	$280	$840	12	$10,080	G. Patz	1000 miles per mo. @ $0.25/mi
Annual replacement costs	Item		Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost		Replacement figured with 3% inflation
	Chains for loaders		2	$10,500	$21,000	3	$7,210		
	Avalanche caches		2	$18,744	$37,487	5	$7,722		
	Vehicle caches		4	$5,445	$21,780	5	$4,487		see budget detail spreadsheet
	Forecasting office equipment			$23,300	$23,300	4	$6,000		see budget detail spreadsheet
	Forecasting field equipment			$17,172	$17,172	5	$3,410		see budget detail spreadsheet
	Signage	avalanche zone signs	196	$100	$19,600	8	$2,524		
		highway entry signs	2	$500	$1,000	8	$129		
		trailhead warning signs	40	$20	$800	8	$103		

	Weather station maintenance	replacement parts					$51,000	Mark Moore, NWAC	15% of equipment cost annually
Forecasting office operations			Number	Unit cost	Monthly cost	Number of months	Annual cost		
	Telephones		4	$35	$140	12	$1,680	DOA	
	Long distance				$150	12	$1,800	AAS	
	Networking charge	monthly charge per employee		$60		30	$1,800	DOA	30 is the number of employee-months per year
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		All wages multiplied by 1.63 per N. Slagle
	Forecasting staff	Equipment Operator	WG 52, Full Time	$1	$190,702	1.00	$190,702	G Patz, DOT	
		Equipment Operator	WG 53, Full Time	$1	$174,242	1.00	$174,242	G Patz, DOT	
		Equipment Operator	WG 53, Seasonal	$1	$106,232	0.50	$53,116	G Patz, DOT	
		administrative overhead	15% of personne l costs				$62,709	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	$4	$280,960	1.7	$280,960	G. Patz	
	Avalanche-related operators	Seasonal operators for explosives makeup	Wage group 53D		$2,451		$2,451		
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		temp. flagger	Wage group 56 (hourly)	$2	$117.87	50.8	$5,988	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		forecasters	3	$1,500	$4,500	annually	$4,500	AAS	professional development
Total Annual Operating Budget							**$1,591,346**		

Operating Budget - West Lynn Canal option F: Howitzer Only

							Total annual cost	Information source	Notes
Explosive delivery		**Equipment**	**Number**	**Cost**			**Annual Cost**		
	Annual lease of 105mm Howitzer	available model	3	$100			$300	T. Onslow	The Army is in the process of setting an annualHowitzer lease rate. It could be higher than this estimate or lower, pending Congressional legislation.
Explosive s				**Cost per round**		**Annual number of shots**	**Annual cost**		
		Howitzer		$113		842	$95,399	G. Patz	
Helicopter time		**(A-Star)**	**Hours per mission**	**Hourly rate**	**Number of missions**	**Total annual hours**	**Annual Cost**		
	Weather station maintenance	flight time	2	$1,760	$16	$32	$56,320	Hourly rates from	
		standby	4	$880	$16	$64	$56,320	Coastal Helicopters	
	Snow study	flight time	2.5	$1,760	$8	$20	$35,200		
		standby	2	$880	$8	$16	$14,080		
Vehicles/ heavy equipment			**Number of vehicle s**	**Monthly cost per vehicle**	**Monthly cost**	**Number of months**	**Annual cost**		
Debris removal equipment	Operating rate	Cat 988G loader	2	$1,128	$2,256	12	$27,072	G. Patz	includes repair and maintenance
Debris removal equipment	Replacement rate	Cat 988G loader	2	$3,092	$6,184	12	$74,208	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	Cat 988G loader	2	$1,008	$2,016	12	$24,192	G. Patz	4 gal/hr burn rate; 6 hrs/ day; 10 days/month
Debris removal equipment	Operating rate	D9R dozer	2	$1,250	$2,500	12	$30,000	G. Patz	includes repair and maintenance
Debris removal equipment	Replacement rate	D9R dozer	2	$5,160	$10,320	12	$123,840	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	D9R dozer	2	$1,260	$2,520	12	$30,240	G. Patz	5 gal/hr burn rate; 6 hrs/ day; 10 days/month
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	3	$277	$831	12	$9,972	G. Patz	1-forecasters, 2-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	3	$250	$750	12	$9,000	G. Patz	includes payments to credit bank to replace at end of service life

Operating Budget - West Lynn Canal option F: Howitzer Only

Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	3	$280	$840	12	$10,080	G. Patz	1000 miles per mo. @ $0.25/mi
Annual replacement costs	**Item**		**Number**	**Unit cost**	**Total cost**	**Lifespan (years)**	**Annual replacement cost**		Replacement figured with 3% inflation
	Chains for loaders		1	$10,500	$10,500	3	$3,605		
	Avalanche caches		2	$18,744	$37,487	5	$7,722		
	Forecasting office equipment		1	$23,300	$23,300	4	$6,000		
	Forecasting field equipment		1	$17,172	$17,172	5	$3,537		
	Signage	avalanche zone signs	32	$100	$3,200	8	$412		
		highway entry signs	2	$500	$1,000	8	$129		
		trailhead warning signs	20	$20	$400	8	$52		
	Weather station maintenance	replacement parts					$51,000	Mark Moore, NWAC	
Forecasting office operations			**Number**	**Unit cost**	**Monthly cost**	**Number of months**	**Annual cost**		
	Telephones		4	$35	$140	12	$1,680	DOA	
	Long distance				$150	12	$1,800	AAS	
	Networking charge	monthly charge per employee		$60		30	$1,800	DOA	
Personnel		Position	Pay level		Annual cost with multiplier	FTE	Total annual cost		
	Forecasting staff	Equipment Operator	WG 52, Full Time	$1	$190,702	1.00	$190,702	G Patz, DOT	
		Equipment Operator	WG 53, Full Time	$1	$174,242	1.00	$174,242	G Patz, DOT	
		Equipment Operator	WG 53, Seasonal	$1	$106,232	0.50	$53,116	G Patz, DOT	
		administrative overhead	15% of personnel costs				$62,709	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	$4	$280,960	1.7	$280,960	G. Patz	
				Number of flaggers	Cost per hour with multiplier	Number of hours	Total annual cost		
		temp. flagger	Wage group 56 (hourly)	$2	$117.87	50.8	$5,988	G. Patz	
Training			Number of people	Cost per person	Cost		Annual cost		
		forecasters	3	$1,500	$4,500	annually	$4,500	G Patz, DOT	avalanche mitigation training
Total Annual Operating Budget							$1,446,176		

Operating Budget - West Lynn Canal Option G: Howitzer-Blaster Box

							Total annual cost	**Information source**	**Notes**
Explosive delivery		**Equipment**	**Number**	**Cost**	**Total monthly costs**	**Number of months**	**Annual cost**		
	Annual lease of 105mm Howitzer	available model	1	$100			$100	T. Onslow	
Explosives				**Cost per round**		**Number of rounds**	**Annual cost**		**Annual number of rounds.**
	Howitzer			$113		67	$10,212	G. Patz	per round cost w/ shipping plus 10 percent for emergency shipments. Includes rounds needed for targeting.
	Blaster boxes			$192		563	$31,247	ARR	$535 per box (includes freight), 10 in box. Cost per round includes RECCO reflectors
		RECCO detector rental					$700	RECCO AB, Sweden	
Helicopter time		**(A-Star)**	**Hours per mission**	**Hourly rate**	**Number of missions**	**Total annual hours**	**Annual Cost**		
	Explosive delivery	flight time		$1,760		17	$22,308	Hourly rates from	

Operating Budget - West Lynn Canal Option G: Howitzer-Blaster Box									
		standby		$880		28	$11,240	Coastal Helicopters	
	Weather station maintenance	flight time	2	$1,760	$16	$32	$56,320		includes two trips annually for blaster box loading and unloading.
		standby	4	$880	$16	$64	$56,320		
	Snow study	flight time	2.5	$1,760	$8	$20	$35,200		
		standby	2	$880	$8	16	$14,080		
Vehicles/heavy equipment			**Number of vehicles**	**Monthly cost per vehicle**	**Monthly cost**	**Number of months**	**Annual cost**		
Debris removal equipment	Operating rate	Cat 988G loader	2	$1,128	$2,256	12	$27,072	G. Patz	includes repair and maintenance
Debris removal equipment	Replacement rate	Cat 988G loader	2	$3,092	$6,184	12	$74,208	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	Cat 988G loader	2	$1,008	$2,016	12	$24,192	G. Patz	4 gal/hr burn rate; 6 hrs/day; 10 days/month
Debris removal equipment	Operating rate	D9R dozer	2	$1,250	$2,500	12	$30,000	G. Patz	includes repair and maintenance
Debris removal equipment	Replacement rate	D9R dozer	2	$5,160	$10,320	12	$123,840	G. Patz	includes payments to credit bank to replace at end of service life
Debris removal equipment	Fuel	D9R dozer	2	$1,260	$2,520	12	$30,240	G. Patz	5 gal/hr burn rate; 6 hrs/day; 10 days/month
Pickup trucks	Monthly operating rate	3/4 ton 4WD, extended cab	3	$277	$831	12	$9,972	G. Patz	1-forecasters, 2-maintenance crew
Pickup trucks	Monthly replacement rate	3/4 ton 4WD, extended cab	3	$250	$750	12	$9,000	G. Patz	includes payments to credit bank to replace at end of service life
Pickup trucks	Fuel costs	3/4 ton 4WD, extended cab	3	$280	$840	12	$10,080	G. Patz	1000 miles per mo. @ $0.25/mi
Annual replacement costs	**Item**		**Number**	**Unit cost**	**Total cost**	**Lifespan (years)**	**Annual replacement cost**		**Replacement figured with 3%inflation**
	Chains for loaders		1	$10,500	$10,500	3	$3,605		
	Avalanche caches		2	$18,744	$37,487	5	$7,722		
	Forecasting office equipment		1	$23,300	$23,300	4	$6,000		see budget detail spreadsheet
	Forecasting field equipment		1	$17,172	$17,172	5	$3,537		see budget detail spreadsheet
	Signage	avalanche zone signs	32	$100	$3,200	8	$412		
		highway entry signs	2	$500	$1,000	8	$129		
		trailhead warning signs	20	$20	$400	8	$52		
	Weather station maintenance	Replacement parts	4 stations				$51,000	Mark Moore, NWAC	15% of equipment cost annually
Forecasting office operations			Number	Unit cost	Monthly cost	Number of months	Annual cost		
	Telephones		4	$35	$140	12	$1,680	DOA	
	Long distance				$150	12	$1,800	AAS	
	Networking charge	monthly charge per employee		$60		30	$1,800	DOA	30 is the number of employee-months per year
Personnel		**Position**	**Pay level**		**Annual cost with multiplier**	**FTE**	**Total annual cost**		**All wages multiplied by 1.63 per N. Slagle**
	Forecasting staff	Equipment Operator	WG 52, Full Time	$1	$190,702	1.00	$190,702	G Patz, DOT	
		Equipment Operator	WG 53, Full Time	$1	$174,242	1.00	$174,242	G Patz, DOT	
		Equipment Operator	WG 53, Seasonal	$1	$106,232	0.50	$53,116	G Patz, DOT	
		administrative overhead	15% of personnel costs				$62,709	standard estimate	
	Avalanche-related operators	seasonal operators for debris clearing	Wage group 53D	$4	$280,960	1.7	$280,960	G. Patz	four operators at $27,663/month for 0.5 month/ year avalanche duty
		temp. flagger	Wage group 56 (hourly)	$2	$118	50.8	$5,988	G. Patz	
Training			**Number of people**	**Cost per person**	**Cost**		**Annual cost**		
		forecasters	3	$1,500	$4,500	annually	$4,500	G Patz, DOT	avalanche mitigation training

Operating Budget - West Lynn Canal Option G: Howitzer-Blaster Box									
Total Annual Operating Budget							$1,384,025		

Operating budget detail							
Forecasting office equipment	Item	Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost	Source
	desks/chairs	4	$500	$2,000	7	$303	AAS
	desktop computer	1	$3,000	$3,000	3	$1,034	B. Reiche, DOA
	laptop computers	3	$4,000	$12,000	3	$4,134	B. Reiche
	external hard drives	4	$300	$1,200	3	$413	B. Reiche
	fax	1	$200	$200	5	$42	B. Reiche
	phones	4	$425	$1,700	5	$357	B. Reiche
	scanner	1	$200	$200	5	$42	B. Reiche
	misc. supplies	1	$3,000	$3,000	1	$3,000	AAS
ELC Options	**Total**			$23,300	4	**$9,325**	
Forecasting field equipment	Item	Number	Unit cost	Total cost	Lifespan (years)	Annual replacement cost	Source
	density kit	1	$200	$200	10	$21	Backcountry Access
	digital camera	1	$1,800	$1,800	3	$620	Canon
	binoculars	2	$200	$400	10	$43	Steiner
	snow kits	3	$85	$255	5	$54	UAF
	shovels	3	$74	$222	3	$76	G3
	snow saws	3	$50	$150	5	$31	LifeLink
	avalung packs	3	$300	$900	10	$96	Black Diamond
	helmets	3	$140	$420	10	$45	Smith
	skis or splitboards w/ poles, bindings, skins	3	$1,710	$5,130	3	$1,767	average cost by AAS
	parkas	3	$570	$1,710	3	$589	Patagonia
	bibs	3	$620	$1,860	3	$641	Patagonia
	avalanche transceivers	3	$500	$1,500	3	$517	Pieps/ Barryvox
	probes	3	$85	$255	3	$88	G3
	EX600XLS VHF radios	2	$1,000	$2,000	5	$420	Motorola
	bivvy bags	4	$55	$220	5	$46	SOL Escape Bivvy
	First Aid kits	3	$50	$150	2	$77	Helenbac, plus heat packs
	Total			$17,172	5	**$5,132**	
				Total cost	Lifespan (years)	Annual replacement cost	
Vehicle caches				$5,445	5	**$1,143**	
				Total cost	Lifespan (years)	Annual replacement cost	
Avalanche caches				$18,744	5	**$3,934**	

13.7. *APPENDIX 12: Capital Budget Spreadsheets*

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Capital Budget - East Lynn Canal Option A: Helicopter Only						
Item	**Notes**	**Equipment type**	**Number**	**Cost**	**Total**	**Information source**
Magazines	2-Comet		2	$44,000	$88,000	G. Patz/AAS
Weather stations	ridge-top		2	$120,000	$240,000	RR costs; current heli tim
Weather stations	mid-elevation		1	$100,000	$100,000	RR costs; current heli tim
Repeaters	or weather station telemetry		3	$11,000	$33,000	RR costs; current heli tim
Forecasting office		office equipment			$23,300	See capital budget detail
Forecasting office		field equipment			$23,356	See capital budget detail
Loaders	1- Comet, 1-Katzehin	Cat 988G	2	$450,000	$900,000	G. Patz specs./G. Darling
Chains for loaders		chains for Cat 988G	2	$10,500	$21,000	G. Patz
Bulldozers	1- Comet, 1-Katzehin	D9R	2	$1,000,500	$2,001,000	G. Patz specs./G. Darling
Pickup trucks or equivalent	-maintenance, 1-forecaster	/4 ton 4WD extended ca	3	$30,000	$90,000	G. Patz specs./G. Darling
Snowmobiles	2-forecasters	RMK; Summit 800	2	$13,000	$26,000	Polaris; SkiDoo
Snowmobile transportation equipment		double trailer	1	$1,800	$1,800	Mission Trailer
Road closure gates	1-Comet, 1--Katzehin	manual swing gates	2	$10,000	$20,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		15	$500	$7,500	Pieps/ Barryvox
Headsets	gear for DOTPF crew		10	$150	$1,500	G. Patz
Avalanche caches	1-Comet, 1-Katzehin		2	$18,744	$37,487	See capital budget detail
Vehicle caches			12	$5,445	$65,340	See capital budget detail
Signage		avalanche zone signs	196	$270	$52,920	G. Patz
Signage		trailhead warning signs	40	$250	$10,000	AAS
Signage		highway entry signs	2	$270	$540	G. Patz
TOTAL					**$3,742,743**	

Capital Budget - East Lynn Canal Option B: Daisy Bell Only						
Item	**Notes**	**Equipment type**	**Number**	**Cost**	**Total**	**Information source**
Magazines	2-Comet		2	$44,000	$88,000	G. Patz/AAS
Weather stations	ridge-top		2	$120,000	$240,000	ARR costs; current heli time
Weather stations	mid-elevation		1	$100,000	$100,000	ARR costs; current heli time
Repeaters	for weather station telemetry		3	$11,000	$33,000	ARR costs; current heli time
Forecasting office		office equipment			$23,300	See capital budget detail
Forecasting office		field equipment			$23,356	See capital budget detail
Daisy Bell	purchase cost	helicopter-slung exploder	1	$150,000	$150,000	TAS; Daisy Bell exploder; rounded from August 2012 exchange rates; 15 yr life
Loaders	1- Comet, 1-Katzehin	Cat 988G	2	$450,000	$900,000	G. Patz specs./G. Darling
Chains for loaders		chains for Cat 988G	2	$10,500	$21,000	G. Patz
Bulldozers	1- Comet, 1-Katzehin	D9R	2	$1,000,500	$2,001,000	G. Patz specs./G. Darling
Pickup trucks or equivalent	2-maintenance, 1-forecasters	3/4 ton 4WD extended cab	3	$30,000	$90,000	G. Patz specs./G. Darling
Snowmobiles	2-forecasters	RMK; Summit 800	2	$13,000	$26,000	Polaris; SkiDoo
Snowmobile transportation equipment		double trailer	1	$1,800	$1,800	Mission Trailer
Road closure gates	1-Comet, 1--Katzehin	manual swing gates	2	$10,000	$20,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		15	$500	$7,500	Pieps/ Barryvox
Headsets	gear for DOTPF crew		10	$150	$1,500	G. Patz
Avalanche caches	1-Comet, 1-Katzehin		2	$18,744	$37,487	See capital budget detail
Vehicle caches			12	$5,445	$65,340	See capital budget detail
Signage		avalanche zone signs	196	$270	$52,920	G. Patz
Signage		trailhead warning signs	40	$250	$10,000	AAS
Signage		highway entry signs	2	$270	$540	G. Patz
TOTAL					**$3,892,743**	

Capital Budget East Lynn Canal Option C: Howitzer-Blaster box-Helicopter						
Item	**Notes**	**Equipment type**	**Number**	**Cost**	**Total**	**Information source**
Blaster boxes	number of masts	Avalanche Guard	5.3	$240,000	$1,272,000	Installed ARR costs less 25% for quantity; plus 20% for increased cost since '04
105mm Howitzer refurbishment			4	$24,000	$96,000	T. Onslow
105mm Howitzer shipping	1 mobile, 3 stationary		4	$8,000	$32,000	T. Onslow
concrete Howitzer enclosures w/ magazine	Eldred Rock, Anyaka Island, Chilkat Peninsula		3	$5,750,000	$17,250,000	Liam Fitzgerald; Greens Creek Mine
Concrete pad with cutout for Howitzer	for mobile Howitzer		1	$35,000	$35,000	G. Patz
Ammunition for Howitzer targeting	First year only. Per round cost plus shipping		458	$113	$51,891	per round cost w/shipping plus 10 percent for emergency shipments
Magazines	2-Comet		2	$44,000	$88,000	G. Patz/AAS
Dud detection	includes equipment and software				$1,150	AES
Weather stations	ridge-top		2	$120,000	$240,000	ARR costs; current heli time
Weather stations	mid-elevation		1	$100,000	$100,000	ARR costs; current heli time
Repeaters	for weather station telemetry		3	$11,000	$33,000	ARR costs; current heli time
Forecasting office		office equipment			$23,300	See capital budget detail
Forecasting office		field equipment			$23,356	See capital budget detail
Loaders	1- Comet, 1-Katzehin	Cat 988G	2	$450,000	$900,000	G. Patz specs./G. Darling
Chains for loaders		chains for Cat 988G	2	$10,500	$21,000	G. Patz
Bulldozers	1- Comet, 1-Katzehin	D9R	2	$1,000,500	$2,001,000	G. Patz specs./G. Darling
Pickup trucks or equivalent	2-maintenance, 1-forecasters	4 ton 4WD extended ca	3	$30,000	$90,000	G. Patz specs./G. Darling
Snowmobiles	2-forecasters	RMK; Summit 800	2	$13,000	$26,000	Polaris; SkiDoo
Snowmobile transportation equipment		double trailer	1	$1,800	$1,800	Mission Trailer
Road closure gates	1-Comet, 1--Katzehin	manual swing gates	2	$10,000	$20,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		15	$500	$7,500	Pieps/ Barryvox
Headsets	gear for DOTPF crew		10	$150	$1,500	G. Patz
Avalanche caches	1-Comet, 1-Katzehin		2	$18,744	$37,487	See capital budget detail

Capital Budget East Lynn Canal Option C: Howitzer-Blaster box-Helicopter						
Vehicle caches			12	$5,445	$65,340	See capital budget detail
Signage		avalanche zone signs	196	$270	$52,920	G. Patz
Signage		trailhead warning signs	40	$250	$10,000	AAS
Signage		highway entry signs	2	$270	$540	G. Patz
TOTAL					**$22,480,784**	

Capital Budget - East Lynn Canal Option D: Blaster Boxes on Major Paths, Heli Backup						
Item	**Notes**	**Equipment type**	**Number**	**Cost**	**Total**	**Information source**
Blaster boxes	number of masts	Avalanche Guard	27	$240,000	$4,860,000	ARR costs less 25% for quantity; plus 20% for increased cost since '04
Magazines	2-Comet		2	$44,000	$88,000	G. Patz/AAS
Dud detection	includes equipment and software			$1,150	$1,150	AAS
Weather stations	ridge-top		2	$120,000	$240,000	ARR costs; current heli time
Weather stations	mid-elevation		1	$100,000	$100,000	ARR costs; current heli time
Repeaters	for weather station telemetry		3	$11,000	$33,000	ARR costs; current heli time
Forecasting office		office equipment			$23,300	See capital budget detail
Forecasting office		field equipment			$23,356	See capital budget detail
Loaders	1- Comet, 1-Katzehin	Cat 988G	2	$450,000	$900,000	G. Patz specs./G. Darling
Chains for loaders		chains for Cat 988G	2	$10,500	$21,000	G. Patz
Bulldozers	1- Comet, 1-Katzehin	D9R	2	$1,000,500	$2,001,000	G. Patz specs./G. Darling
Pickup trucks or equivalent	2-maintenance, 1-forecasters	3/4 ton 4WD extended cab	3	$30,000	$90,000	G. Patz specs./G. Darling
Snowmobiles	2-forecasters	RMK; Summit 800	2	$13,000	$26,000	Polaris; SkiDoo
Snowmobile transportation equipment		double trailer	1	$1,800	$1,800	Mission Trailer
Road closure gates	1-Comet, 1--Katzehin	manual swing gates	2	$10,000	$20,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		15	$500	$7,500	Pieps/ Barryvox
Headsets	gear for DOTPF crew		10	$150	$1,500	G. Patz
Avalanche caches	1-Comet, 1-Katzehin		2	$18,744	$37,487	See capital budget detail
Vehicle caches			12	$5,445	$65,340	See capital budget detail
Signage		avalanche zone signs	196	$270	$52,920	G. Patz
Signage		trailhead warning signs	40	$250	$10,000	AAS
Signage		highway entry signs	2	$270	$540	G. Patz
TOTAL					**$8,603,893**	

Capital Budget - East Lynn Canal Option E: Blaster Box Top 10 Paths, Heli. Elsewhere						
Item	**Notes**	**Equipment type**	**Number**	**Cost**	**Total**	**Information source**
Blaster boxes	number of masts	Avalanche Guard	18	$240,000	$3,240,000	ARR costs less 25% for quantity; plus 20% for increased cost since '04
Magazines	2-Comet		2	$44,000	$88,000	G. Patz/AAS
Dud detection	includes equipment and software				$1,150	AES
Weather stations	ridge-top		2	$120,000	$240,000	ARR costs; current heli time
Weather stations	mid-elevation		1	$100,000	$100,000	ARR costs; current heli time
Repeaters	for weather station telemetry		3	$11,000	$33,000	ARR costs; current heli time
Forecasting office		office equipment			$23,300	See capital budget detail
Forecasting office		field equipment			$23,356	See capital budget detail
Loaders	1- Comet, 1-Katzehin	Cat 988G	2	$450,000	$900,000	G. Patz specs./G. Darling
Chains for loaders		chains for Cat 988G	2	$10,500	$21,000	G. Patz
Bulldozers	1- Comet, 1-Katzehin	D9R	2	$1,000,500	$2,001,000	G. Patz specs./G. Darling
Pickup trucks or equivalent	2-maintenance, 1-forecasters	3/4 ton 4WD extended cab	3	$30,000	$90,000	G. Patz specs./G. Darling
Snowmobiles	2-forecasters	RMK; Summit 800	2	$13,000	$26,000	Polaris; SkiDoo
Snowmobile transportation equipment		double trailer	1	$1,800	$1,800	Mission Trailer

Capital Budget - East Lynn Canal Option E: Blaster Box Top 10 Paths, Heli. Elsewhere						
Road closure gates	1-Comet, 1--Katzehin	manual swing gates	2	$10,000	$20,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		15	$500	$7,500	Pieps/ Barryvox
Headsets	gear for DOTPF crew		10	$150	$1,500	G. Patz
Avalanche caches	1-Comet, 1-Katzehin		2	$18,744	$37,487	See capital budget detail
Vehicle caches			12	$5,445	$65,340	See capital budget detail
Signage		avalanche zone signs	196	$270	$52,920	G. Patz
Signage		trailhead warning signs	40	$250	$10,000	AAS
Signage		highway entry signs	2	$270	$540	G. Patz
TOTAL					**$6,983,893**	

Capital Budget - West Lynn Canal Option F: Howitzer Only

Item	Notes	Equipment type	Number	Cost	Total	Information source
105mm Howitzer refurbishment			1	$24,000	$24,000	T. Onslow
105mm Howitzer shipping			1	$8,000	$8,000	T. Onslow
Spur roads for Howitzer shots	number of road miles needed	2-lane gravel road with turn	3.04	$250,000	$760,000	J. Beedle
Concrete pad with cutout for Howitzer			5	$35,000	$150,000	G. Patz
Magazines	2-Main Maintenance Station		2	$44,000	$88,000	G. Patz, AAS
Ammunition for Howitzer targeting	First year only. Per round cost plus shipping		210	$113.3	$21,210	T. Onslow
Dud detection	includes equipment and software			$1,150	$1,150	AAS
Weather stations	ridge-top		2	$120,000	$240,000	ARR costs; current heli time
Weather stations	mid-elevation		1	$100,000	$100,000	AAS
Repeaters (for weather station telemetry)			3	$11,000	$33,000	ARR costs; current heli time
Forecasting office		office equipment			$23,300	See budget detail spreadshe
Forecasting office		field equipment			$23,356	See budget detail spreadshe
Loader	Cat 988G		1	$450,000	$450,000	
Chains for loader		chains for Cat 988G	1	$10,500	$10,500	G. Patz
Bulldozer		D9R	1	$1,000,500	$1,000,500	G. Patz specs./G. Darling co
Pickup trucks or equivalent	1-maintenance, 1-forecasters	3/4 ton 4WD extended cab	2	$30,000	$60,000	G. Patz specs./G. Darling co
Snowmobiles	2-forecasters	RMK 800 or equivalent	2	$13,000	$26,000	AAS
Snowmobile transportation equipment		double trailer	1	$1,800	$1,800	AAS
Road closure gates		manual swing gates	2	$10,000	$20,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		10	$500.00	$5,000	Pieps/ Barryvox
Headsets	gear for DOTPF crew		6	$150	$900	G. Patz
Avalanche caches	1-Haines, 1-ferry landing		2	$18,743.5	$37,487	See budget detail spreadshe
Vehicle caches			10	$5,445	$54,450	See budget detail spreadshe
Signage		avalanche zone signs	32	$270	$8,640	G. Patz
Signage		trailhead warning signs	20	$250	$5,000	AAS
Signage		highway entry signs	2	$270	$540	G. Patz
TOTAL					**$3,152,833**	

Capital Budget - West Lynn Canal Option G: Howitzer-Blaster Box

Item	Notes	Equipment type	Numb er	Cost	Total	Information source
Blaster boxes	Number of masts	Doppelmayr	27	$240,000	$4,860,000	ARR costs less 25% for quantity; plus 20% for increased cost since '04

Capital Budget - West Lynn Canal Option G: Howitzer-Blaster Box						
105mm Howitzer refurbishment			1	$24,000	$24,000	T. Onslow
105mm Howitzer shipping			1	$8,000	$8,000	T. Onslow
Spur roads for Howitzer shots	number of road miles needed	2-lane gravel road with turnout	3.04	$250,000	$760,000	J. Beedle
Concrete pad with cutout for Howitzer			5	$35,000	$175,000	G. Patz
Ammunition for Howitzer targeting	First year only. Per round cost plus shipping		76	$113.3	$8,611	AES
Magazines	2-Main Maintenance Station		2	$44,000	$88,000	G. Patz, Bill Glude
Dud detection	includes equipment and software			$1,150	$1,150	Estimate
Weather stations	ridge-top		2	$120,000	$240,000	ARR costs; current heli time
Weather stations	mid-elevation		1	$100,000	$100,000	AES
Repeaters	for weather station telemetry		3	$11,000	$33,000	ARR costs
Forecasting office		office equipment			$23,300	See budget detail spreadsheet
Forecasting office		field equipment			$23,356	See budget detail spreadsheet
Loader		Cat 988G	1	$450,000	$450,000	G. Patz specs./G. Darling costs
Chains for loader	Cat 988G	chains for Cat 988G	1	$10,500	$10,500	G. Patz
Bulldozer		D9R	1	$1,000,500	$1,000,500	G. Patz specs./G. Darling costs
Pickup trucks or equivalent	1-maintenance, 1-forecasters	3/4 ton 4WD extended cab	2	$30,000	$60,000	G. Patz specs./G. Darling costs
Snowmobiles	2-forecasters	RMK 800 or equivalent	2	$13,000	$26,000	AES
Snowmobile transportation equipment		double trailer	1	$1,800	$1,800	AES
Road closure gates		manual swing gates	2	$10,000	$20,000	G. Patz
Avalanche transceivers	gear for DOTPF crew		10	$500	$5,000	Pieps/ Barryvox
Headsets	gear for DOTPF crew		6	$150	$900	
Avalanche caches	1-Haines, 1-ferry landing		2	$18,743.5	$37,487	See budget detail spreadsheet
Vehicle caches			10	$5,445	$54,450	See budget detail spreadsheet
Signage		avalanche zone signs	32	$270	$8,640	G. Patz
Signage		trailhead warning signs	20	$250	$5,000	AES
Signage		highway entry signs	2	$270	$540	G. Patz
TOTAL					**$8,025,234**	

Capital budget detail					
Forecasting office equipment	**Item**	**Number**	**Price per item**	**Total Cost**	**Source**
	desks/chairs	4	$500	$2,000	average cost by AAS
	desktop computer	1	$3,000	$3,000	average cost by AAS
	laptop computers	3	$4,000	$12,000	average cost by AAS
	external hard drives	4	$300	$1,200	average cost by AAS
	fax	1	$200	$200	average cost by AAS
	phones	4	$425	$1,700	DOA
	scanner	1	$200	$200	average cost by AAS
	misc. supplies	1	$3,000	$3,000	average cost by AAS

Capital budget detail					
	Total			**$23,300**	
Forecasting field equipment	**Item**	**Number**	**Price per item**	**Total Cost**	**Source**
	density kit	1	$200	$200	Backcountry Access
	digital camera	1	$1,800	$1,800	Canon
	binoculars	2	$200	$400	Steiner
	snow kits	4	$85	$340	UAF
	shovels	4	$74	$296	G3
	snow saws	4	$50	$200	LifeLink
	Avalung Packs	4	$300	$1,200	Black Diamond
	helmets	4	$140	$560	Smith
	skis or splitboards w/poles, bindings, skins	4	$1,710	$6,840	average cost by AAS
	parkas	4	$570	$2,280	Patagonia
	bibs	4	$620	$2,480	Patagonia
	avalanche transceivers	4	$500	$2,000	Pieps/ Barryvox
	probes	4	$85	$340	G3
	EX600XLS VHF radios	4	$1,000	$4,000	Motorola
	bivvy bags	4	$55	$220	SOL Escape Bivvy
	First Aid kits	4	$50	$200	Helenbac, plus heat packs
	Total			**$23,356**	
Vehicle Caches	**Contents**	**Amount**	**Price per item**	**Total cost per vehicle**	**Source**
	shovels	4	$75	$300	G3
	probes	4	$80	$320	G4
	avalanche transceivers	4	$500	$2,000	Pieps/Barryvox
	headlamps	4	$60	$240	Black Diamond
	batteries	1	$25	$25	packages of 12
	wand markers	10	$1	$10	AES
	dry bag	1	$150	$150	Seal Line
	field books and pencils	4	$20	$80	Rite in the Rain
	First Aid kits	4	$50	$200	Helenbac, plus heat packs
	AED	1	$1,800	$1,800	average cost by AAS
	bivvy bags	4	$55	$220	SOL Escape Bivvy
	winter trauma kit	1	$100	$100	average cost by AAS
	Total			**$5,445**	
Avalanche caches	**Contents**	**Amount**	**Price per item**	**Total cost per cache**	**Notes**
	rucksacks or dry bag rucksacks	8	$100	$800	Seal Line
	avalanche transceivers	8	$500	$4,000	Pieps/Barryvox
	probes	8	$80	$640	G3
	shovels	8	$75	$600	G4
	headlamps	8	$60	$480	Black Diamond
	field books and pencils	8	$20	$160	Rite in the Rain
	rolls of flagging	5	$3	$15	hardware store
	glow sticks	20	$12	$240	REI
	road flares	20	$5	$100	auto supply
	duct tape (rolls)	5	$8	$40	hardware store
	electrical tape (rolls)	5	$5	$25	hardware store
	wand markers	25	$1	$13	flagged 1m(3'), bamboo or wire
	whistles	8	$5	$40	
	mountain snowshoes	8	$300	$2,400	MSR Lightning
	air horn	1	$15	$15	auto supply
	oxygen kit	3	$500	$1,500	with bag/valve/mask manual resuscitation
	probing guide cords	1	$20	$20	average cost by AAS
	batteries	3	$25	$75	packages of 12
	blankets	10	$20	$200	average cost by AAS
	sleeping bags	5	$200	$1,000	REI

Capital budget detail					
	foam pads	5	$45	$225	Therm-a-Rest
	bivvy bags	5	$55	$275	SOL Escape Bivvy
	water bottles	8	$12	$96	Nalgene
	burner, stove & pot	1	$75	$75	average cost by AAS
	backboards	3	$130	$390	average cost by AAS
	litters	3	$900	$2,700	Cascade Rescue
	winter trauma kits	5	$100	$500	average cost by AAS
	AED	1	$1,800	$1,800	average cost by AAS
	First Aid kits	8	$40	$320	Helenbac
	Total			**$18,744**	
				$70,845	

13.8. *APPENDIX 13: Information Sources*

Information Sources	
Alaska Avalanche Specialists	**Bill Glude, lead avalanche specialist**
Alaska Dept. of Administration	Becky Reiche, Southeast Region Contract Office, Division of General Services
	Tanci Mintz, State Facilities Manager, Division of General Services
	Shelly Saviers, Divison of Personnel
Alaska Dept. of Transportation and Public Facilities	**Greg Patz, SE Region Maintenance and Operations Director**
	Jack Beedle, Engineer/Architect IV, project manager
	Gene Darling, Statewide Equipment Manager
	Nancy Slagle, Anne Zenger, Mary Siroky; Administrative Services
	Terrence Onslow, Safety and Emergency Support Specialist, retired
	Kerby Wright, Equipment Operator
	Doug Lewis, Equipment Operator
	Reid Bahnson, Equipment Operator
	Brad Bylsma, Equipment Operations Analyst
	Frank Richards, Engineer/Architect IV
Alaska Electric Light & Power (AEL&P)	**Mike Janes, Avalanche Forecaster**
Alaska Railroad Corporation	**Dave Hamre**
Austin Powder Alaska	**Tony Barajas and Melody McAllister**
BC Ministry of Transportation and Highways (MOTH)	Mike Boissonneault, avalanche specialist
Coastal Helicopters	**John JAG Garrard**, Jim Wilson, Mike WIlson
Colorado Avalanche Information Center (CAIC)	Knox Williams, director
	Nick Logan, associate director
	Andy Gleason and Jerry Roberts, Silverton forecasters
	Mark Mueller, Wolf Creek Pass forecaster
	Lee Metzger and Stu Schafer, Loveland/Berthoud forecasters
Colorado Dept. of Transportation	Greg Roth
Northern Communications Company	**radio pricing; updates by online research**
Northwest Avalanche Center (NWAC)	Mark Moore, forecaster
Parks Canada (British Columbia)	Dave Skjonsberg and Bruce McMahon, avalanche specialists
Snowbird Ski Area, Utah	Dean Cardinel, avalanche control
Southeast Alaska Avalanche Center	Bill Glude, former director and lead avalanche specialist
U.S. Army	Sue Back
Utah Dept. of Transportation	Liam Fitzgerald

Sources in bold were used for the 2013 updates.

13.9. *APPENDIX 14: Avalanche Dynamics and Impact Loads on Exposed Bridges*

Purpose of the Dynamics Analysis

The East Lynn Canal Highway alignment includes at least three bridges that cross avalanche paths (at Paths LC028, LC029, and LC041), and at least two bridges on the West Lynn Canal alignment (at Paths WLC007 and WLC008) that are exposed to avalanches. Because bridges are expensive structures that are necessary for the operation of either highway, the "design-magnitude[1]" avalanche at bridge locations was calculated to determine their exposure to flowing and powder avalanches and the magnitude of the impact and/or stagnation pressures.

The following avalanche-dynamics parameters are necessary to determine pressures (and ultimately the forces) on bridges. Bridges can be designed or structurally protected.

The avalanche starting zone[2] size and location and the design-magnitude avalanche stopping position along the path profile;

The avalanche speed at the bridge site, which is computed by an avalanche-dynamics modeling procedure after the stopping position is determined;

The avalanche flow depth at the bridge site (which determines if the proposed bridge is reached by the flowing or powder design avalanche);

The avalanche flowing bulk density;

The avalanche impact pressure and/or stagnation pressure[3] at the bridge site.

Procedures Used to Compute these Dynamics Parameters

Determining the Starting and Stopping Positions: The stopping positions for the design-magnitude events were determined by creating an avalanche path profile from the starting zone to sea level. These profiles were constructed from the detailed topography (25-foot contour intervals) provided by DOT&PF. Because all East Lynn Canal paths of concern stop in the water, the actual runout position could not be computed. Therefore, "synthetic" profiles that extended from the edge of the water on slopes of 10% (5.7°) were constructed to calibrate the parameters used in the dynamics model. This slope corresponded to typical runout-zone slopes of a large number of major avalanche events documented in coastal regions of Alaska. The stopping positions along these synthetic profiles (the α-angle or average path slope) was then computed based on the steepness of the avalanches above the 10° point (the β-angle) using a statistical regression equation, derived from the databases of Alaska coastal and Southeast region avalanches.

1

2 *Steep terrain at the top of the avalanche path where avalanche begin, accelerate and increase in mass; these areas are usually in excess of 30° inclination and discharge snow into the avalanche tracks and runout zones lower in the path.*

3 *Impact and stagnation pressures are reference pressures rather than design pressures; final design pressures require details about bridge shape and the derived coefficients of drag and lift which are ultimately used to compute drag, lift, and thrust forces.*

Avalanche Speeds at the Bridge Sites: Avalanche speeds were computed through use of a 3-component, stochastic, avalanche-dynamics model (Perla, et. al. 1984 [with 2001 revisions, unpublished]). This model simulated avalanches along the centerline profile, starting at the top of the path (the starting zone) and stopping at the point determined in the previous step.

Avalanche Flow Depth at the Bridge Site: The cross sectional area (for the denser flowing snow portion of the avalanche) was computed by dividing the computed discharge (in m^3/sec) by the speed (in m/sec). The shape of the cross sectional areas below the bridges, determined from the detailed topographic maps, was then converted to flow depth. This flow depth does not include the impact of the powder-avalanche portion of the flow, which was considered separately.***Avalanche Bulk Density:*** A density of 200 kg/m^3 was used for the density of the flowing lower core of the avalanche, assuming the design avalanche would consist of dry snow, even at sea level in the coastal climate of Southeast Alaska. Wet-snow avalanches could have densities two to three times greater than those assumed, but speed (which is the most important parameter in computing pressures) would be substantially less than those of the dry-snow avalanches. The powder-avalanche portion, which may extend as much as 100-130 feet (30-40m) above the flowing snow, was assumed to have a density of 10 kg/m^3.

Impact and Stagnation Pressures: Impact pressure from flowing snow and stagnation pressures from the powder avalanche were both computed as follows: $P = \frac{1}{2} \rho V^2$, where ρ = density (200 kg/m^3 flowing, 10 kg/m^3 powder) and V is the computed speed (in meters/sec) at the bridge site. It should be noted that the impact and stagnation pressures are not design pressures. Final design pressures would depend on structure shape, which is currently not known. The impact and stagnation pressures can be used to assess the feasibility of construction.

Additional Factors: Multiple events during a single avalanche season can raise the effective avalanche-running surface and create possible impact with structures at a higher level than snow-free topographic mapping will indicate. The possibility of deep snow deposits from previous avalanches was considered in the analysis.

Results of the Analysis

Figure 12-1 illustrates the various dimensions and parameters at each bridge site. These are:

H: Clearance range of the bottom of the bridge above the gully

Hp: Flow height of the powder avalanche (ft & m)

Hf: Flow height of the flowing avalanche (ft & m)

Ps: Powder-avalanche stagnation pressure (lbs/ft2 & kPa)

Pf: Flowing avalanche impact pressure (lbs/ft2 & kPa)

The vertical clearance, C, of the bridge <u>*above the avalanche*</u>, if any, is the difference between the height range, H and the flowing or powder-avalanche height (i.e., C = H – Hf or C = H – Hp respectively), for clearances of the flowing and powder avalanche portions.

The following additional comments refer to the analysis and data presented in Table 12-1:

The pressures given here should not be used for deriving final-design forces. Bridge locations have been and continued to be adjusted as design work proceeds. The locations of the crossings analyzed here have already changed. Until the final location, bridge shape, and clearance above the terrain is determined; calculated loads will change.

Design pressures (Ps or Pf) may also require adjustment by an impact factor, Fi; the final unit loads would therefore be Fi*Ps when exposed to powder avalanches and Fi*Pf when exposed to flowing avalanches; the magnitude of Fi usually is between 1.0 and 2.0 but depends critically on the free period of the bridge and the rise time of the avalanche impact, factors that must be considered in final design.

Bridges exposed to powder avalanches will also have vehicles exposed to powder avalanches; when Ps is > or = 80 psf (hurricane-force winds are usually less than 50 psf) they may be capable of pushing (or lifting and pushing) a vehicle off the bridge even if the vehicle is not exposed to the larger flowing- avalanche pressures.

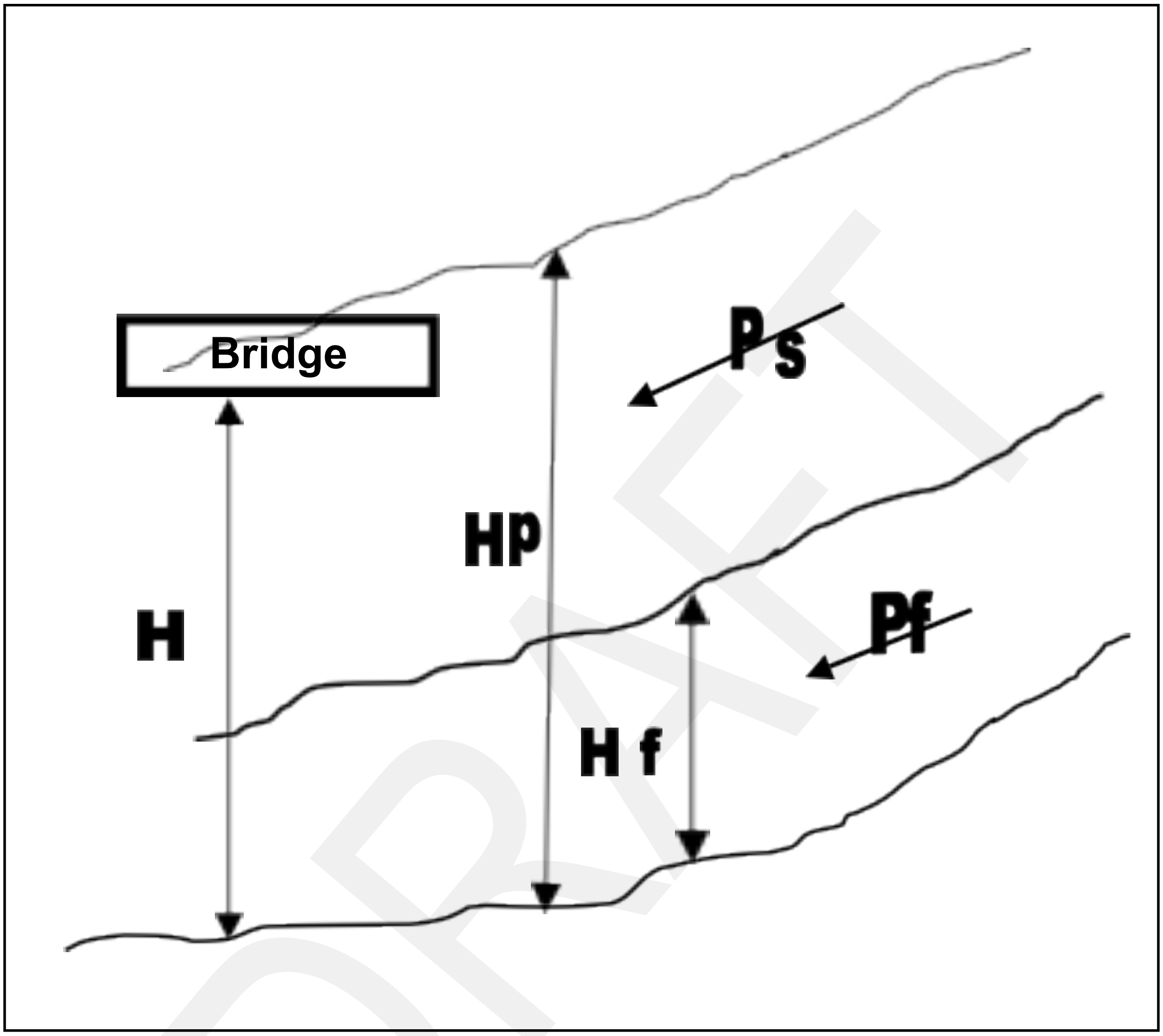
Avalanche Heights and Pressures at Bridge Locations

Path	H	Hp	Hf	Ps	Pf	Comments
ELC 028	55 ft, 17m	98 ft, 30m	44ft, 13m	119 psf, 581 kg/m	2,382 psf, 11,629 kg/m	A
ELC 029	20 ft, 6 m	131 ft, 40m	57 ft, 17m	101 psf, 493 kg/m	2,015 psf, 9,837 kg/m^2	B
WLC 007	75 ft, 23 m	98 ft, 30m	4 ft, 1.2 m	22 psf 107 kg/m^2	440 psf, 2,148 kg/m^2	A
WLC 008	75 ft, 23 m	131 ft, 40 m	31 ft, 9 m	97 psf, 474 kg/m^2	1,943 psf, 9,486 kg/m^2	B

A: Stagnation pressure (Ps) only at driving surface; flowing avalanche pressure (Pf) at exposed piers.

B: Both stagnation pressure and flowing-avalanche pressures (Ps & Pf) affect driving surface and exposed piers.

Schematic Drawing of Bridge Impact Analysis



Schematic drawing showing dimensions and avalanche pressures on bridges that span gullies. H = deck above gully; Hp = powder-avalanche height; Hf = flowing-avalanche height. Refer to table for magnitudes of lengths and pressures at various avalanche paths.

13.10. *APPENDIX 15: References*

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13.11. *APPENDIX 16: Peer Review*

The 2004 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 original study.

The 2013 updated AHI and mitigation calculations were reviewed by Arthur I Mears, PE, and Chris Wilbur, PE, of Mears and Wilbur; and they did all the structural mitigation calculations, design, and cost estimates.