MINISTRY OF FORESTS, LANDS AND NATURAL RESOURCE OPERATIONS
INFORMATION NOTE

Date: October 24th, 2016
File: 17275-20

ISSUE: 2016 Mount Currie Rock Fall and Local Instabilities

BACKGROUND:

Rock falls along the Mount Currie Ridge are a common occurrence during warm and dry Spring seasons with increasing frequencies of rock falls during hot Summer seasons and into the early Fall. A rock fall was investigated in June 2015, and there have been several recent rockfalls in September 2016 along the southwest end of the Mount Currie Ridge. The location of the 2015 and 2016 rock falls are show in Photo 1. An increase in rock fall occurrences have been noted by local residents and FLRNO Wildfire staff based at the Pemberton airport during this past summer.

Engineering staff from the Coast Engineering Group along with FLNRO's Research Geomorphologist have reviewed recent photos and recent research papers written for this location and have concerns with the increase rock fall frequency and potential instability along the Mount Currie Ridge above and beyond the rock slide noted this past summer. Slope movements along the ridge have been documented in research literature (Bovis and Evans, 1995[1]). The recent rockfall in another location along the Mount Currie Ridge, combined with observed weak bedrock integrity, and significant jointing and discontinuities have raised questions as to the overall stability of the Mount Currie Ridge Massive rockfall with potential impacts to Pemberton valley residents cannot be ruled out at this point.

When reviewing the proximity of public infrastructure and residential areas with that of the Ridge, location of recent rock fall sources, gullies, fans potentially connected to these public areas further detailed analysis is needed to determine the risk to the public. Current estimates indicate rock avalanches with volumes greater than 100,000m^3 will have an approximate 50% probability of reaching the Green River and adjacent private properties below the ridge. Larger events will have a higher probability of reaching these areas.

DISCUSSION:

During the summer of 2016 many reports of frequent rock falls along the Mount Currie Ridge were reported from FLNRO Wildfire base located at the Pemberton airport along with one concerned public citizen reporting directly to FLNRO. On September 8, 2016 a flight took place with FLNRO district engineering officer (Malcolm Schulz) and the Squamish Lillooet Regional District (SLRD) representative (Ryan Wainwright). A second flight with Malcolm Schulz and Gino Fournier took place September 27th to the site of the identified rock fall to investigate concerns raised by the SLRD when the photos from Sept 8th were reviewed. Rock falls noted in 2015 and 2016 are shown on photo 1 along with their proximity to the valley bottom and Pemberton/Mount Currie communities.

[1] Bovis, M.J. and Evans S.G. 1995 Rock Slope Movements along the Mount Currie "fault scarp," southern Coast Mountains, British Columbia. Can. J. Earth Sci 32: 2015-2020.

In July 2016, a member of the public emailed the Ministry with concerns of rock falls and supplied a photo of the associated dust cloud from the rock fall event recorded. This event is seen in photo 2. This person also reported rockfall from the same location in 2015, however Pierre Friele (P.Geo., Cordilleran Geoscience Ltd) in a June 2015 helicopter reconnaissance did not observe rockfall from this area, but did observe fresh rockfall from an adjacent area to the southwest (Photo 1). It is possible that the local resident's line of sight from valley bottom prevented determination of an accurate location of this rockfall.

The September 2016 rockfall (observed by air on September 8th, 2016) has an estimated volume of 10,000- 15,000 m^3. It initiated in the headwaters of a large gully. When the failure area was re-visited on September 27th, 2016 measurements were taken from the helicopter to estimate the volumes noted above. The debris field and slide track were reviewed in both instances where it was noted the rockfall travelled approximately 1400m downslope. The fan of the gully is located a further 1500m downslope and extends approximately 600m in distance where it meets low lying flats with saturated soils and a high water table prior to reaching the Green River located approximately 4440m from the rock slide source location. The rockfall occurred at an elevation of roughly 2180m and the valley bottom elevation is at 210m roughly determined from Google Earth. The fan, associated low lying saturated area, Green River and golf courses are all visible on photo 3.

Photos 4 and 5 shows the location of the rock fall noted during the September 8th flight. Photos 6 and 7 show different perspectives of the same rockfall area but compares photos taken on the 8th and 27th of September. During this 19 day period a significant amount of rock has fallen on the west side of the failure exposing a larger uniform failure plane in the background. Estimated volumes from this additional rock fall are in the range of 20,000-30,000m^3. It is expected more of this rock deposition from the September 8th event will continue to fall and slide from this area during the fall rains, and freeze/thaw activity. Continued failures and rock falls along this plane will expose a larger area of unsupported bedrock. Although the rock falls of the recent size do not pose a risk to valley residents, the exposure of larger volumes of unsupported bedrock potentially could result in rock fall events that do pose risk to valley residents.

Photo 8 shows the rock behind the failure head scarp being highly fractured with near vertical jointing. Determining a future failure plane will be critical as base support is being lost with continuing failures occurring as noted from September 8th to the 27th events. As failures at the base of the current slide continue to occur during the fall and into 2017 from the bench seen in photo 6, base support to the head scarp area will be lost, and the potential for larger failures increases

The potential for failures larger than 100,000m^3 are possible given the highly fractured and vertical jointing in the bedrock behind the failure surface shown in photo 8. It is currently unknown if these will fail in small volumes or in a single large rock avalanche. As the headscarp becomes larger with continuing rock falls, the potential for larger volume failures also increases as a result of base support being lost.

The potential for similar sizable events exists for other locations along the Mount Currie Ridge. From 1987 to 1991, Bovis and Evans (1995)[2] measured significant movement along a linear scarp located on the Mount Currie Ridge approximately 2 km to the northeast of the current rockfall. They interpreted the movement to be due to gravitational forces (i.e. the slope is unstable and is slowly moving due to gravity). Photos 9 and 10 show the Currie linear scarp and a tension crack with a head

[2] Bovis, M.J. and Evans S.G. 1995 Rock Slope Movements along the Mount Currie "fault scarp," southern Coast Mountains, British Columbia. Can. J. Earth Sci 32: 2015-2020.

scarp to the northwest of the Currie linear scarp. In addition, the Mystery Creek rock avalanche is located about 5.5 km to the southwest of the 2016 rockfall. This event is estimated at 40 million m^3 and 880 years before present (Evans and Savigny, 1994)[3]. Such a large failure along the Mount Currie Ridge would have a dramatic impact on the valley bottom and public infrastructure.

A recent issue identified by professionals working in rock avalanches is the loss of permafrost leading to slope instability. This is a potential factor at Mount Currie given the elevation, northerly aspect, and general loss of glaciers over recent years in southwestern BC. Similar events in both Canada and internationally have been noted where the warming of permafrost in mountainous terrain has been a contributing factor to rock failures. As the permafrost recedes, cohesion within the rock mass would be reduced resulting in rock failures. This may be a reason for the recent increase in rock fall events noted at Mount Currie.

A report completed by Hungr (1999)[4] was used to determine the probability of a rock fall with a magnitude of 10,000m^3 and 100,000m^3. Hungr's report was utilized as it was completed in this geographic area to represent the frequency and magnitude of rock fall events that would reach Highway 99. Additional data from Highway 1, CP Rail and BC Rail were plotted by Hungr which correlated well with Highway 99 events. Our estimates indicate large rock falls are probable along this ridge at a frequency between 250 and 1250 years for the respective volumes noted above. This is illustrated on photo 11.

In a similar fashion we looked at the possibility of such events reaching the valley bottom and looked for the probability of an event of reaching the Green River and Lillooet River. In each instance, we assumed a rock failure of 100,000m^3 and 300,000m^3 which are conceivable given the "strongly foliated quartz diorites of Lower Jurassic age"[5] and its competency. Photo 12 shows the probability of a 100,000m^3 (Points A and C) denoted by X and 300,000m^3 (Points B and D) rock avalanche reaching both the Green River and Lillooet River. The Green River reach is identified with points A and B. The Lillooet River reach is shown with point C and D.

The probability of a rock avalanche reaching the Green River was estimated to be in the vicinity of 50% and 60% respectively for a 100,000m^3 (Point A) and a 300,000m^3 (Point B) event. Similarly, the probability for a rock avalanche reaching the Lillooet River is in the vicinity of 35% and 42% respectively for a 100,000m^3 (Point C) and 300,000m^3 (Point D) event.

CONCLUSION and SUGGESTED NEXT STEPS:

With increase rock fall events noted in recent years along the Mount Currie Ridge, concerns have been raised around public safety for those occupying residences and land below the ridge. Several rock falls have been noted, with the September 2016 event the largest, estimated at 10,000 – 15,000 m^3 initially and a total failure volume of 20,000 – 45,000 m^3 to date. Fortunately, these failures have been small occurrences and are settling roughly 1400m downslope and depositing in the rock debris field within the gully system, well short of populated areas. However, large-scale rock fall events from Mount

[3] Evans, S.G. and Savigny, K.W., 1994: Landslides in the Vancouver-Fraser Valley-Whistler region; in Geology and Geological Hazards of the Vancouver Region, Southwestern British Columbia, (ed.) J. W.H. Monger; Geological Survey of Canada, Bulletin 481, p. 251-286.
[4] Hungr, O et al. 1999: Magnitude and frequency of rock falls and rock slides along the main transportation corridors of southwestern British Columbia. Can. Geotech J. 36: 224-238.
[5] Bovis, M.J. and Evans S.G. 1995 Rock Slope Movements along the Mount Currie "fault scarp," southern Coast Mountains, British Columbia. Can. J. Earth Sci 32: 2015-2020.

Currie Ridge with magnitudes of 100,000m^3 or larger have a greater than 50% probability of reaching the Green River at which point private land and residences become at risk of being impacted by the debris field as it deposits. Flooding from the Green River and/or Lillooet Rivers due to being plugged by a rock avalanche will result in damage to local infrastructure and residences located on the valley bottom.

The observed increased in rockfall, combined with the documented instability of the Mount Currie linear scarp, and the nearby, massive Mystery Creek rock avalanche suggests that large-scale rockfall or rock avalanche along much of the Mount Currie Ridge is possible. Further investigation of the stability of the Mount Currie Ridge is warranted. Given the record of rockfall and measured slope movement along a 3 km section of the Mount Currie Ridge, and the potential for larger rockfall events to reach populated areas, it would be very prudent to further analyse Mount Currie Ridge to determine the likelihood and magnitude of a rock fall/avalanche and whether it could reach the valley bottom. It would be important to quantify and qualify the risks and associated probabilities for such events as well as any suggested remedial and/or mitigation works/activities needed to inform and protect the public in the future.

We recommend a study with four components. Evaluation of landslide kinematics (type and extent of movement) on Mount Currie Ridge would indicate the potential types and size of landslides that might occur. A more detailed landslide runout analysis would provide better quantification of risk to valley residents. Evaluation of permafrost conditions on the slope may yield important information on the understanding of future events. InSAR (Interferometric Synthetic Aperture Radar) may be available, which would efficiently provide detailed information on the landslide kinematics. The area of recent rockfalls should be specifically assessed for the potential for larger rockfall occurrence as a result of loss of support due to the ongoing rockfall. Once risk has been evaluated, potential risk reduction steps could be identified.

It is recommended a consulting firm with expertise in geotechnical engineering, specializing in the field of rock fall/slides/ avalanche geohazards be engaged to complete these analyses in order to quantify the concerns raised in this review and other concerns that may be found during a more thorough review and analysis of the Mount Currie Ridge area.

Should you have any questions, please feel free to contact me.

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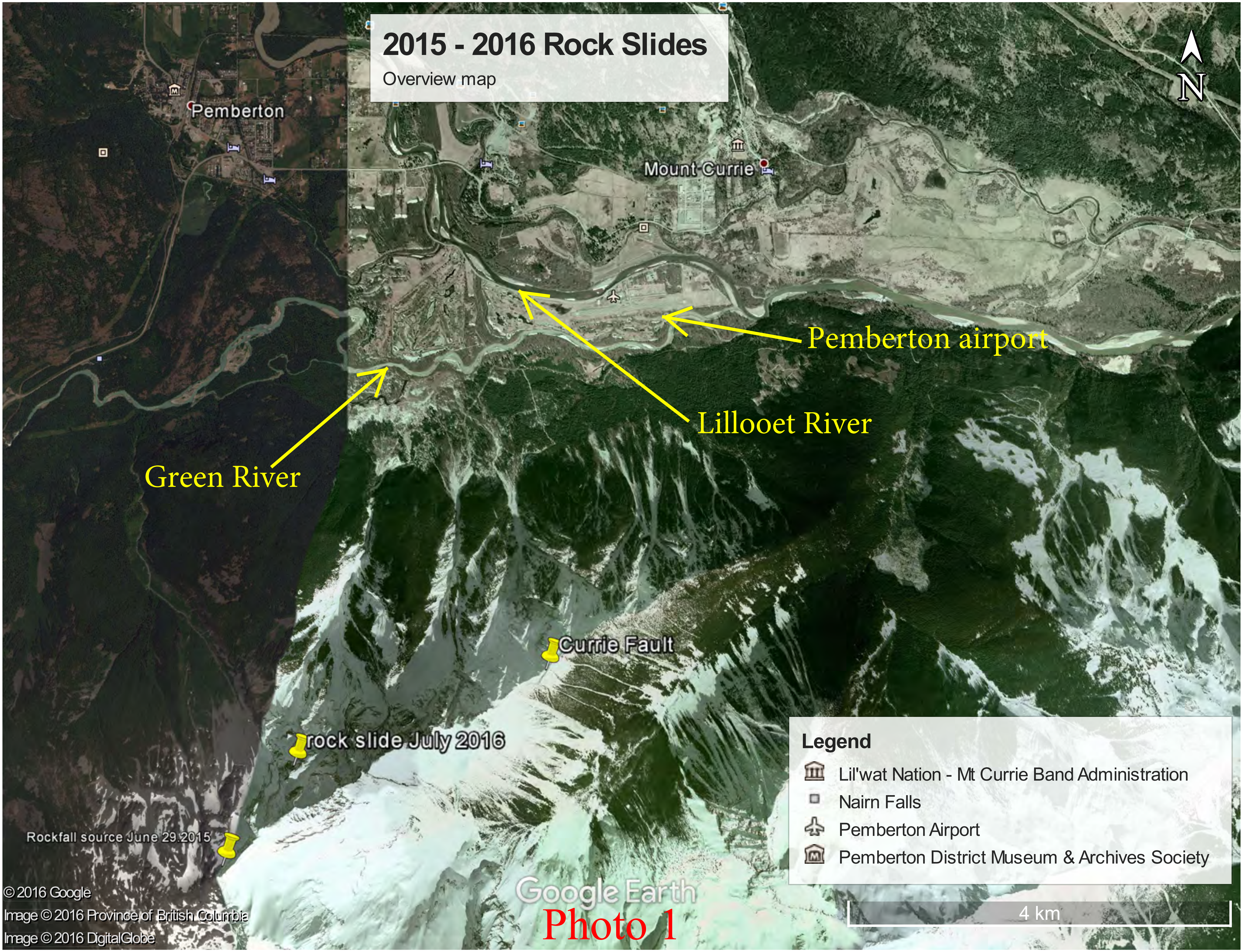
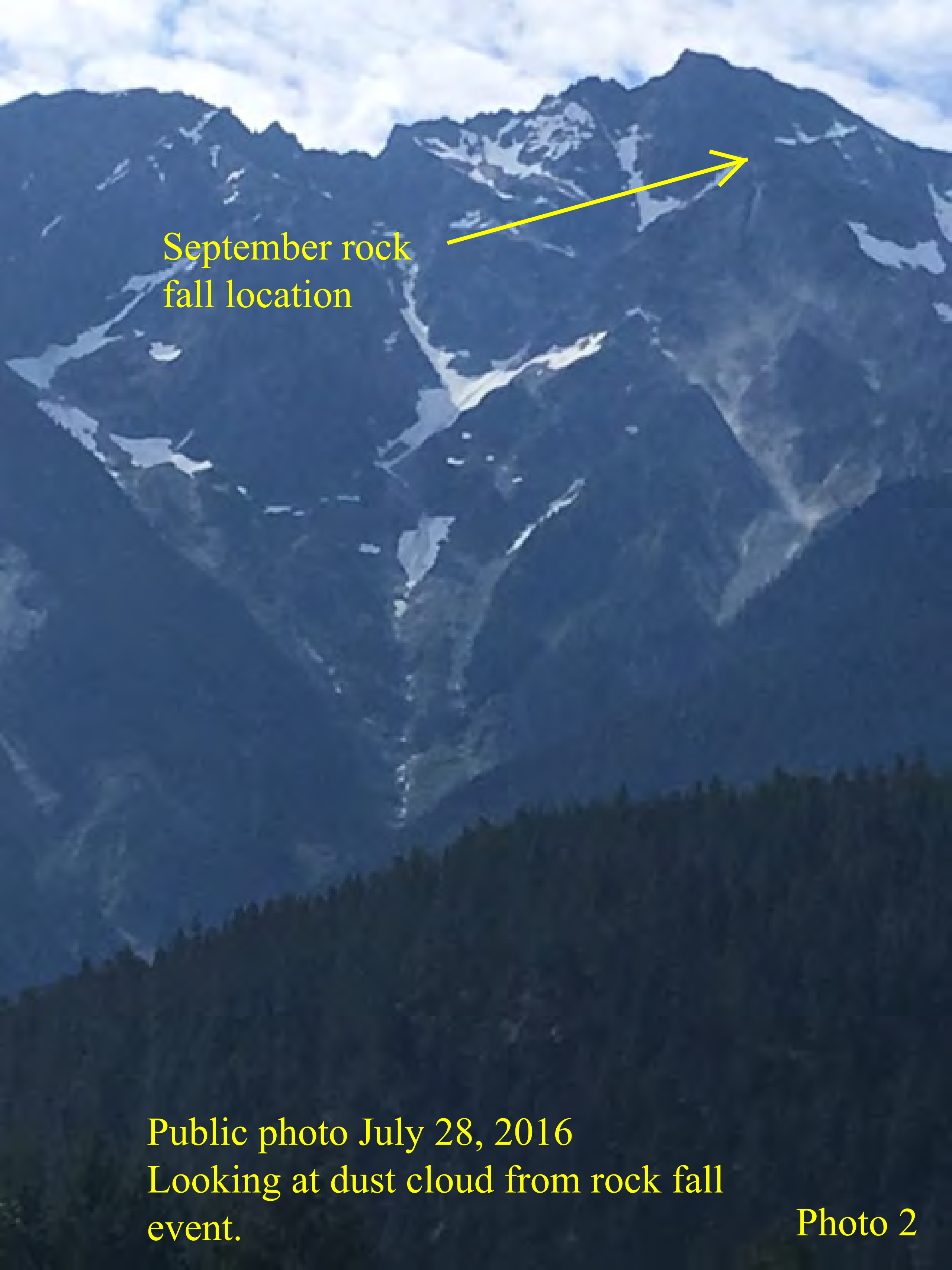
Attachments:

Supporting Photo Plates 1 through 12.



2015 - 2016 Rock Slides
Overview map
N
Pemberton
Mount Currie
Pemberton airport
Lillooet River
Green River
Currie Fault
rock slide July 2016
Rockfall source June 29.2015
Legend
Lil'wat Nation - Mt Currie Band Administration
Nairn Falls
Pemberton Airport
Pemberton District Museum & Archives Society
© 2016 Google
Image © 2016 Province of British Columbia
Image © 2016 DigitalGlobe
Google Earth
4 km

Photo 1



Public photo July 28, 2016
Looking at dust cloud from rock fall event.

Photo 2


View of community, debris fan
and valley bottom
September 8, 2016
Green River
Extent of visible fan
Start of Fan
Photo 3


Rock failure
Looking up from mid slope
towards failure. Sept 8, 2016
September 8, 2016
Photo 4


Failure zone
Rock Deposition
Extents
Slide track
September 8, 2016
Photo 5

Photo comparison of debris field from rock slide event.
Rock slope failure Post Sept 8, 2016 exposing additional failure plane. Estimated volume of rock fall 20 000-30 000 m3
Original rock slide failure estimated at 10 000-15 000 m3
September 27, 2016
September 8, 2016

Photo 6


Rock slope failure Post
Sept 8, 2016 exposing additional
failure plane. Estimated volume of
rock fall 20 000-30 000 m3
Photo comparison of debris field from rock
slide event.
September 27, 2016
Photo 7
September 8, 2016

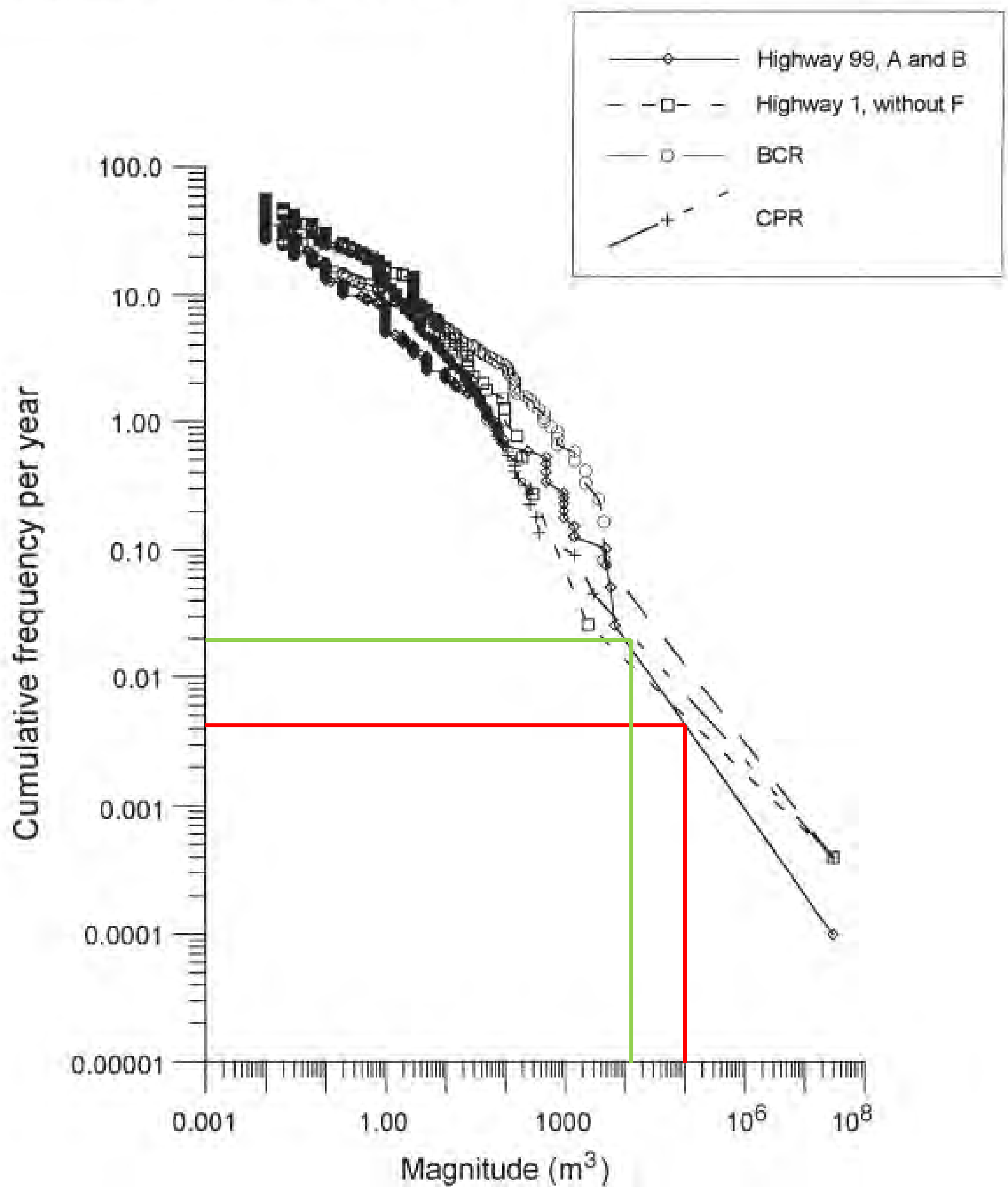

September rock slide head scarp face
Highly fractured and heavily jointed in a near vertical direction
September 27 photo 8


Tension crack and
failure. Close up
shown in photo 9
Currie fault
Photo of the Currie Fault Sept 8 2016.
Reported in a number of research
articles. A few noted below
Evans, S.G. 1987
Bovis, M.J and Evans, S.G. 1995
September 8, 2016
Photo 9


Tension crack and
headscarp noted
approximately
2.0km NE of
September rock
fall event
September 8, 2016
Photo 10

Dr Hungr's magnitude frequency relationship for transportation corridors in SW BC (Can Geotech J 36: 224-238 (1999))

Fig. 12. All magnitude – cumulative frequency curves (see Figs. 10 and 11), superimposed and extended by the addition of major rock avalanche records.



Hwy 99- a 10k cubic metre event should reach the highway every 0.02 years (50 years).

Therefore, study area being 20% of Highway 99 length a 10K m3 event would be expected every 250 years (50/0.2) in this area, based on probabilities.

Hwy 99- a 100k cubic metre event should reach the highway every 0.004 years (250 years).

Therefore, study area being 20% of Highway 99 length a 100K m3 event would be expected every 1250 years (250/0.2) in this area, based on probabilities.

Photo 11

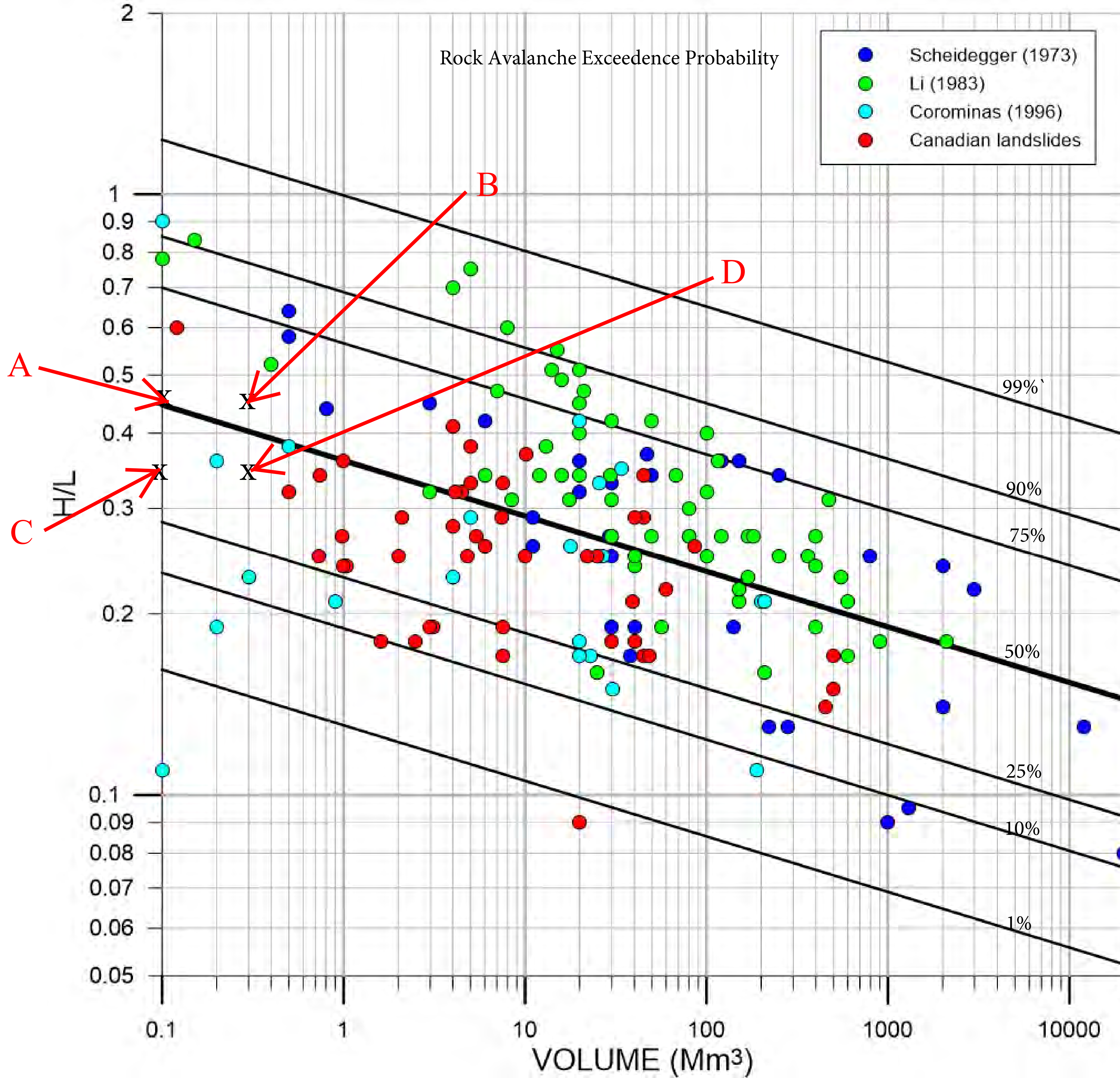

Rock Avalanche Exceedence Probability
Scheidegger (1973)
Li (1983)
Corominas (1996)
Canadian landslides
99%`
90%
75%
50%
25%
10%
1%
A
B
C
D
H/L
VOLUME (Mm3)
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
0.1
1
10
100
1000
10000

Photo 12