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TECHNICAL MEMORANDUM

Date: June 3, 2018

To: Toby Pike, Black Mountain Irrigation District

Cc: Matt Cameron PEng, CTQ Consultants Ltd.
Kevin Burtsch, Black Mountain Irrigation District

Re: Preliminary Slope Stability Assessment
Kirschner Mountain Pump Station
Loseth Road, Kelowna BC

1 Introduction

At the request of Matt Cameron PEng representing CTQ Consultants Ltd. (CTQ) on behalf of Black Mountain Irrigation District (BMID), Westrek Geotechnical Services Ltd. (Westrek) was asked to conduct a preliminary assessment of the stability of the slopes on and adjacent to the Kirschner Mountain Pump Station (the Pump Station) in Kelowna, BC.

This assessment was completed on May 30, 2018. Present were Timothy Smith PGeo, EngL representing Westrek, Matt Cameron, and Kevin Burtsch and Toby Pike representing the BMID. It was clear and sunny at the time.

2 Observations

The Pump Station is located next to the crest of steep fill slopes on the northwest side of Loseth Road, to the immediate north of the junction of Loseth and Sunrise Roads (Photo 1). We understand that the fill was placed at this site to infill a convergent-concave shaped landform (i.e. a broad gully) to create a site for the Pump Station and several lots to the southwest. No information on either the amount and type of fill, the fill placement or the level of compaction was available at the time of our assessment. The fill slope ranges from 75 to 80% and is about 25 m long next to the Pump Station. These slopes lengthen to about 30 m on the lots to the southwest, and bulging was observed in this area.

A trail is located at the toe of the fill slope, and riprap armour has been placed in the base of the unfilled gully beyond it. This generally extends downslope to Kloppenburg Road. Several houses are constructed on the low (or northwest) side of this road (Photo 1). A house is located next to the north side of the fill slope on the cul-de-sac on Kloppenburg Court.

We understand that the fill was placed in this area about 6 years ago and the Pump Station was built about 5 years ago (pers. Comm. Matt Cameron). BMID has indicated that tension cracks in the fill slopes adjacent to the pump station were first noted in October 2017; they since become progressively worse during the 2018 freshet.

Photo 1: An overview of the approximate location of known and possible tension cracks at the site.

Several, large tension cracks were observed near the crest of the fill slopes in this area (Photo1). They show both vertical and horizontal separation (Photos 2 and 3). These features are located on the Pump Station property, the adjacent lots to the southwest, and the Loseth Road shoulder where buried services are located (i.e. Fortis gas and electricity). The City of Kelowna's (the City) storm and sanitary sewer lines are buried in the adjacent road subgrade; the depth of burial is not known by Westrek at this time. A linear crack was observed in the road surface that could be related to the adjacent slope movement, although this has not been confirmed.

A crack was also observed in the concrete slab for the Pump Station that generally parallels the tension cracks in the fill, supporting this structure. It is not known if this is related to the adjacent slope movement.

BMID has indicated that the Pump Station is connected to a reservoir that is located upslope on Kirschner Mountain.

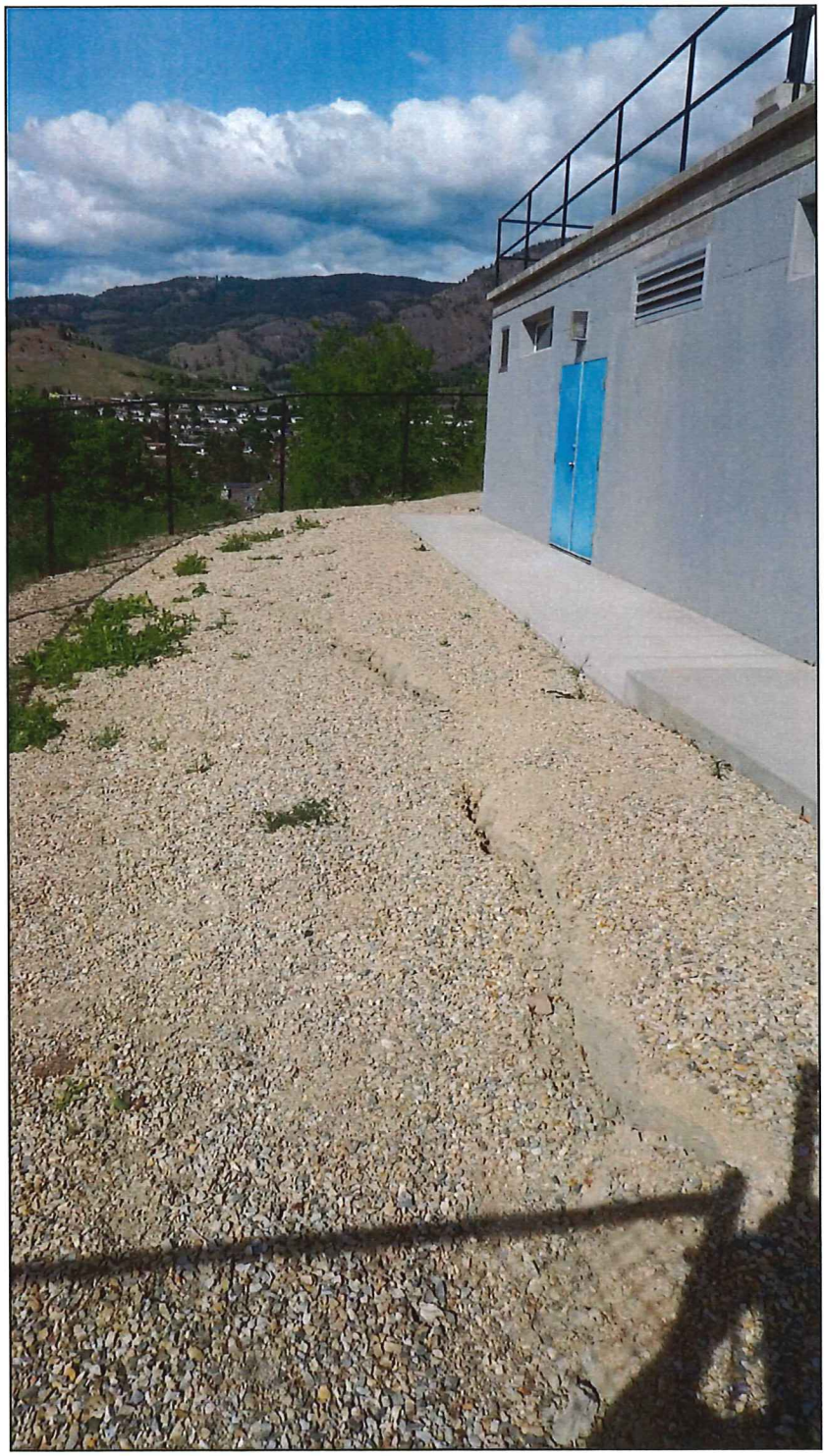


Photo 2: Looking at the tension crack on the northwest side of the Pump Station. Note the vertical and horizontal separation.

Photo 3: Looking at the tension crack in the fill slope at the rear of one of the un-developed lots to the southwest of the pump station.

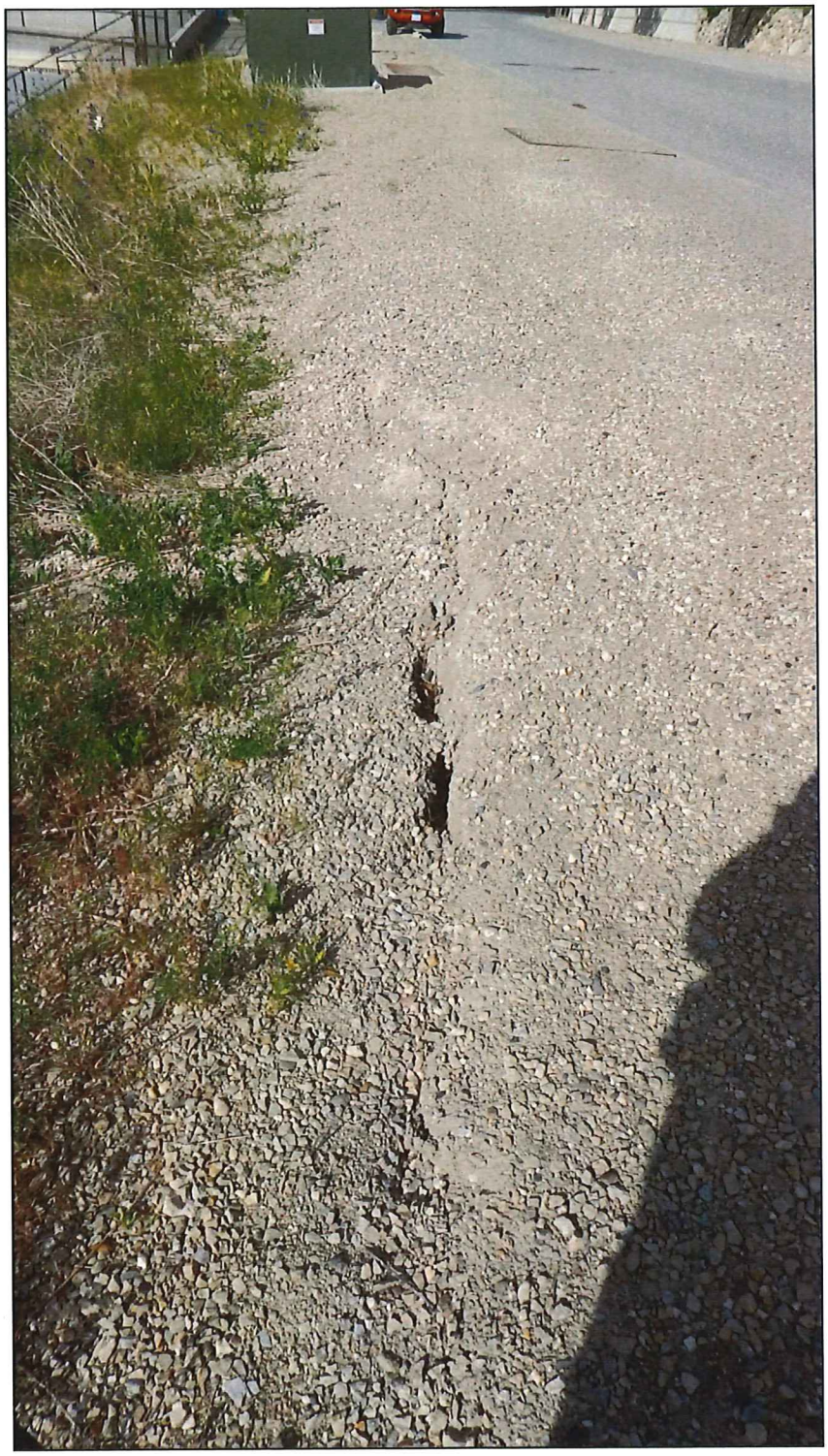


Photo 4: Looking at the tension crack in the shoulder of Loseth Road. The kiosk in the background belongs to Fortis.

3 Analysis

The slopes on and adjacent to the Pump Station site are unstable, and could fail catastrophically. The failure could be triggered by:

- Moderate to heavy rainfall.
- Prolonged rainfall.
- Snowmelt.
- Ongoing slope movement that causes either the pipes or pipe connections at the Pump Station to break or separate creating uncontrolled flow (from the reservoir).
- Ongoing slope movement that causes the City's pipes to break or separate creating uncontrolled flow.

If the slopes fail, and the failure is either triggered or perpetuated by uncontrolled flow from the reservoir (as it drains), there a very high likelihood that the debris will reach the houses downslope, i.e. those on the northwest side of Kloppenberg Road. This creates a very high partial risk to these structures.

If these structures are occupied at the time, it could create a significant risk to the occupants.

In addition, the supply of drinking water (derived from the upslope reservoir) will be affected.

4 Recommendations

We recommend the following:

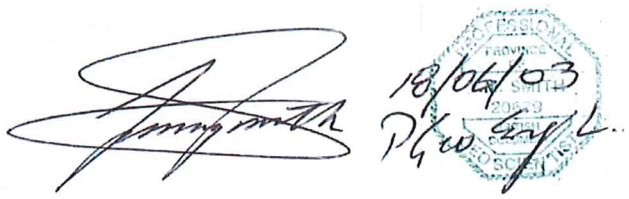
- All stakeholders affected by these unstable slopes should be made aware the hazard and risk. At a minimum this should include, but not be limited to, the City, BMID, Fortis, and the adjacent property owners to the southwest. It is suggested that a site meeting be held with the affected stakeholders and Westrek to discuss the gravity of the situation and the necessary steps moving forward.
- The City and BMID should develop a management strategy in advance of a slope failure at this site. At the minimum, this should include (i) consultation with adjacent property owners to advise them of the situation, (ii) consideration of issuing evacuation orders to the affected property owners downslope, and (iii) developing a contingency plan for the supply of drinking water to the Kirschner Mountain area.
- The City and BMID should thoroughly check all infrastructure in the area to determine if there are any leaks. All leaks should be fixed as soon as possible.
- A detailed investigation of the landslide should be undertaken to characterize it and determine possible causes. This should include surface monitoring, advancing boreholes and installing instrumentation on all affected properties.
- Once the site geology and possible causes have been determined, conceptual measures to stabilize the site should be developed.

5 Closure

This memorandum contains information relating to our preliminary stability assessment of the slopes on and adjacent to the Pump Station, and must be read in conjunction with the attached Appendices A and B.

Yours truly,

Westrek Geotechnical Services Ltd.



Timothy Smith, PGeo, EngL
Senior Engineering Geologist

Attached: Appendix A *Interpretation and Use of Study and Report and Limitations*
Appendix B *Terminology and Methodology*

APPENDIX A
INTERPRETATION AND USE OF STUDY AND REPORT AND LIMITATIONS

1. STANDARD OF CARE.

This study and Report have been prepared in accordance with generally accepted engineering and geoscience practices. No other warranty, express or implied, is made. Geological and geotechnical studies and reports do not include environmental consulting unless specifically stated in the report.

2. COMPLETE REPORT.

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

IN ORDER TO UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF THE REPORT.

The Report has been prepared for the specific site, development, design objectives and purpose that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document are only valid to the extent that there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT.

The information and opinions expressed in the Report, or any document forming the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT. WE WILL CONSENT TO ANY REASONABLE REQUEST BY THE CLIENT TO APPROVE THE USE OF THIS REPORT BY OTHER PARTIES AS "APPROVED USERS". The contents of the Report remain our copyright property and we authorise only the Client and Approved Users to make copies of the Report only in such quantities as are reasonably necessary for the use of the Report by those parties. The Client and Approved Users may not give, lend, sell or otherwise make the Report or any portion thereof, available to any party without our written permission. Any uses, which a third party makes of the Report, or any portion of the Report, are the sole responsibility of such third parties. Westrek accepts no responsibility for damages suffered by any third party resulting from unauthorised use of the Report.

5. INTERPRETATION OF THE REPORT.

(i) Nature and Exactness of Soil and Description: Classification and identification of soils, rocks, geological units, and engineering estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations utilising the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarising such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

(ii) Reliance on Provided information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations or fraudulent acts of any persons providing representations, information and instructions.

(iii) To avoid misunderstandings, Westrek should be retained to work with the other design professionals to explain relevant geotechnical findings and to review the adequacy of their plans and specifications relative to engineering issues. Further, Westrek should be retained to provide field reviews during the construction, consistent with generally accepted practices.

6. LIMITATIONS OF LIABILITY.

Westrek's liability will be limited as follows:

(a) In recognition of the relative risks and benefits of the Services to be provided to the Client by Westrek, the risks have been allocated such that the Client agrees, to the fullest extent permitted by law, to limit the liability of Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals for any and all claims, losses, costs, damages of any nature whatsoever or claims expenses from any cause or causes, whether arising in contract or tort including negligence, including legal fees and costs and disbursements (the "Claim"), so that the total aggregate liability of Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals:

i. if the Claim is satisfied by the re-performance of the Services proven to be in error, shall not exceed and shall be limited to the cost to Westrek in re-performing such Services; or

ii. if the Claim cannot be satisfied by the re-performance of the Services and:

1. if Westrek's professional liability insurance does not apply to the Claim, shall not exceed and shall be limited to Westrek's total fee for services rendered for this matter, whichever is the lesser amount. The Client will indemnify and hold harmless Westrek from third party Claims that exceed such amount; or

2. if Westrek's professional liability insurance applies to the Claim, shall be limited to the coverage amount available under Westrek's professional liability insurance at the time of the Claim. The Client will indemnify and hold harmless Westrek from third party Claims that exceed such coverage amount. Westrek shall maintain professional liability insurance in the amount of $2,000,000 per occurrence, $2,000,000 in the aggregate, for a period of two (2) years from the date of substantial performance of the Services or earlier termination of this Agreement. If the Client wishes to increase the amount of such insurance coverage or duration of such policy or obtain other special or increased insurance coverage, Westrek will cooperate with the Client to obtain such coverage at the Client's expense.

It is intended that this limitation will apply to any and all liability or cause of action however alleged or arising, including negligence, unless otherwise prohibited by law. Notwithstanding the foregoing, it is expressly agreed that there shall be no claim whatsoever against Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals for loss of income, profit or other consequential damages howsoever arising, including negligence, liability being limited to direct damages.

(b) Westrek is not responsible for any errors, omissions, mistakes or inaccuracies contained in information provided by the Client, including but not limited to the location of underground or buried services, and with respect to such information, Westrek may rely on it without having to verify or test that information. Further, Westrek is not responsible for any errors or omissions committed by persons, consultants or specialists retained directly by the Client and with respect to any information, documents or opinions provided by such persons, consultants or specialists, Westrek may rely on such information, documents or opinions without having to verify or test the same.

(c) Notwithstanding the provisions of the Limitation Act, R.S.B.C. 2012 c. 13, amendments thereto, or new legislation enacted in its place, Westrek's liability for any and all claims, including a Claim as defined herein, of the Client or any third party shall absolutely cease to exist after a period of two (2) years following the date of:

i. Substantial performance of the Services,

ii. Suspension or abandonment of the Services provided under this agreement, or

iii. Termination of Westrek's Services under the agreement,

whichever shall occur first, and following such period, the Client shall have no claim, including a Claim as defined herein, whatsoever against Westrek.

APPENDIX B
TERMINOLOGY AND METHODOLOGY

SCOPE

The TSA was done in general accordance with the *Guidelines for Terrain Stability Assessments in the Forest Sector* (APEGBC / ABCFP, 2010). No other warranty is expressed or implied.

Information on the shallow subsurface conditions are gathered from exposures, trail or road cuts, shallow hand-dug pits, and root wads of fallen trees. No test pits are typically advanced using machinery to investigate the subsurface conditions.

Surficial deposits can be highly variable, even over short distances, and consequently there is a degree of uncertainty with TSAs. Westrek does not represent or warrant that the conditions described in the report are consistent throughout the site and the user should recognise that variations will exist. Where subsequent field review indicates the terrain is different than described, the person taking responsibility for the project should contact Westrek to review the conclusions and recommendations, and this may require additional investigation or engineering to meet the project objectives.

In most cases, a "comparative-observational" approach has been used to provide the rationale for the findings. This approach relies on the examination of historical air photographs, field review of past forestry practices, and professional judgement to assess the potential response of the terrain to the proposed development.

TERMINOLOGY

Terminology used to describe the terrain, are based on the BC Terrain Classification System (Howes and Kenk, 1997).

SLOPES		
Slope Type	**Description**	
Plain	0 - 3°	(0 - 5%)
Gentle	4 - 15°	(6 - 26%)
Moderate	16 - 26°	(27 - 49%)
Moderately steep	27 - 35°	(50 - 70%)
Steep	36- 42°	(71 - 90%)
Very steep	> 42°	(> 90%)

Surface expression (slope shape, profile and surface expression) are described using the terms in the following table, as adapted from the BC Ministry of Forests Land Management Handbook 18.

SURFACE EXPRESSION	
Thickness	**Description**
Blanket	Deposits mask bedrock, >1 m thick
Veneer	Deposits reflect bedrock, <1 m thick
Thin Veneer	Deposits are 10 to 25 cm thick
Variable	Deposits vary, 0 to >1 m thick
Shape	**Description**
Concave	Slope aspect converges along contour
Convex	Slopes aspect diverges along contour
Uniform	Slope aspect is consistent along contour
Irregular	Slope aspect has no pattern
Undulating	Slope aspect varies regularly
Terraced	Distinct flat surface and steep frontal slope formed by a fluvial process.
Profile	**Description**
Concave	Slope angle decreases downhill
Convex	Slopes angle increases downhill
Uniform	Slope angle is consistent
Irregular	Slope angle varies with no pattern
Benched	Slope is interrupted by narrow distinctly flatter slope gradients.

Draws	Description
Gully	Linear erosion feature >3m deep; sidewalls near angle-of-repose (usually >50%); channel gradients typically >20% (may be less for some reaches); may or may not contain an active stream channel.
Swale	Broad V or U-shaped linear feature aligned down the slope fall-line, usually <1 m deep, usually does not contain an active stream channel.
Draw	A feature not meeting the above or otherwise undifferentiated.

Texture is described using the BC Terrain Classification System. Where mixed materials are described, descriptors are based on the Canadian Foundation Engineering Manual (CGS, 2006).

SURFICIAL MATERIAL TEXTURE	
Angular / Sub-angular Particles	
Blocks (a)	> 256 mm
Rubble (r)	2 to 256 mm
Angular fragments (x)	> 2 mm
Rounded / Sub-rounded Particles	
Boulders (b)	> 256 mm
Cobbles (k)	64 to 256 mm
Pebbles (p)	2 to 64 mm
Gravel (g)	> 2 mm
Sand (s)	0.62 to 2 mm
Silt (z)	0.002 to 0.062 mm
Clay (c)	< 0.002 mm
Other	
Mixed angular to rounded fragments (d)	> 2 mm
Mixtures	
Main component	> 50% by weight
"and"	35 to 50% by weight
Suffix "y" i.e. silty	20 to 35% by weight
"some"	10 to 20% by weight
"trace"	0 to 10% by weight

Soil drainage is described using the Canadian Soil Classification terminology (AAFC, 1998).

SOIL DRAINAGE	
Slopes	**Description**
Rapidly drained	Water is removed from the soil rapidly in relation to supply.
Well drained	Water is removed from the soil readily but not rapidly.
Moderately Well drained	Water is removed from the soil somewhat slowly in relation to supply.
Imperfectly drained	Water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season. Some mottling is common.
Poorly drained	Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soil is not frozen. Soils are generally mottled and/or gleyed.
Very Poorly drained	Water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time the soil is not frozen (i.e. wetlands).

APPENDIX B
TERMINOLOGY AND METHODOLOGY

Landslides

Landslide classification uses terminology developed by Cruden and Varnes (1996) and Hungr *et al.* (2001).

Landslide magnitude of a landslide is expressed in qualitative terms using the ranges shown below.

LANDSLIDE MAGNITUDE		
Size Rating	**Typical Area (ha)**	**Typical Volume (m³)**
Very Large	>5	>50,000
Large	0.5 - 5	5,000 – 50,000
Medium	0.05 – 0.5	500 – 5,000
Small	0.005 – 0.05	50 – 500
Very Small	<0.005	<50

RISK ANALYSIS

Risk analysis is a process that examines the chance of an injury or loss as a result of a harmful event occurring and its effect on the identified elements at risk. Hazard and risk ratings are based on the definitions and terminology in Land Management Handbook (LMH) 56 (Wise *et al*, 2006). **Unless otherwise stated a "partial risk analysis" approach, as described in LMH 56, has been used.**

In "partial risk analysis", no interpretation of the vulnerability or the degree of loss to the element at risk is considered. Risk is rated for an estimated landslide that may initiate and affect the element at risk, and it considers that an impact is negative (undesirable), even though it may not be destructive or dangerous. Therefore "partial risk" is actually an "encounter probability". Furthermore, since many risk analyses are done on a specific unmoving object or linear feature, the probability of a temporal impact is often ignored. This is a conservative approach but it is generally appropriate for TSAs for forest development. For the analysis of risk to a specific element or an analysis of total risk, an examination of other risk components and a more detailed analysis may be required.

In summary, "partial risk" is defined as: mathematically as P(HA) = P(H) × P(S:H), where:

(P:H) = the likelihood of a landslide occurring that may affect an identified element at risk;

(S:H) = the likelihood of a spatial impact given a landslide occurrence.

Qualitative relationships are used in the determination of these components, as defined below.

Likelihood of Landslide Initiation - P(H)

The likelihood of landslide initiation (or landslide hazard) is the probability that a described landslide will occur, given the proposed development or the proposed road construction method. The following table gives the probability range for each rating.

RELATIVE HAZARD PROBABILITIES P(H)		
Rating	**Alternate**	**Annual Probability**
Very Low	Remote	P_A = less than 1/10,000 (i.e. < 1% in 20 years)
Low	Unlikely	P_A = 1/10,000 to 1/500 (i.e. 1% to 4% in 20 years)
Moderate	Possible	P_A = 1/500 to 1/100 (i.e. 4% to 18% in 20 years)
High	Likely	P_A = 1/100 to 1/20 (i.e. 18% to 64% in 20 years)
Very High	Certain	P_A = > 1/20 (i.e. >64% in 20 years)

Likelihood of a Spatial Impact - P(S:H)

This defines the likelihood that a certain landslide will impact the element at risk. Travel distance estimation is difficult without topographic modelling and simulation using 3-dimensional computer modelling. Studies such as Fannin and Rollerson (1993), Fannin and Wise (2001), Millard (1999) and VanDine (1985, 1996) are useful for predicting where debris flows may begin to deposit but these models are based on data obtained in coastal settings.

Unless noted otherwise, spatial probability is determined from estimates of landslide travel distance using simple geometric models by Corominas (1996) and/or Hunter and Fell (2003). These models estimate angle-of-reach, which is the angle measured below the horizontal from the landslide initiation point to the distal edge of its debris. Input slope profiles for the analysis were generated using GeoBC data. For the Corominas model, landslide volume is estimated from site observations or local data. Areas that lie between the average and upper angle-of-reach are assigned a high likelihood of spatial impact. Areas that lie between the average and lower bound angle-of-reach are assigned a moderate likelihood of spatial impact. Areas beyond the lowest angle-of-reach are assigned a low likelihood of spatial impact. For simplicity, no account is made for the lateral spatial probability of a landslide impact, which is defined largely by topographic constraints; consequently, this approach is expected to be conservative.

Estimates of hazard and spatial probability are combined in a matrix to yield the "partial risk" estimate. Note that this approach does not estimate the degree of damage to an element, but it simply means it may reach the element. Expressed qualitatively, estimated spatial probability relationships are shown in the following table.

SPATIAL PROBABLITY RATINGS		
Rating	**Alternative Rating**	**Chance**
High	Likely	>30%
Moderate	Possible	10 – 30%
Low	Unlikely	4 – 10%
Very Low	Remote	<4%

Partial Risk Analysis P(HA)

Using the estimates for likelihood of landslides (the hazard) and the spatial probability of impact, the following matrix is used to determine the partial risk to an element at risk from a described landslide.

PARTIAL RISK ANALYSIS MATRIX				
Hazard	**Spatial Probability**			
	H	**M**	**L**	**VL**
H	VH	H	M	L
M	H	M	L	L
L	M	L	VL	VL
VL	L	L	VL	VL

where VH = very high, H = high, M = moderate, L = low, and VL = very low

Partial risk analysis does not estimate if a landslide impact would constitute a "material adverse effect", which is a societal judgement parameter. Management implications for the partial risk ratings are provided in Appendix B.

APPENDIX B
TERMINOLOGY AND METHODOLOGY

Risk Assessment and Management Implications

Risk management is a decision-making process that considers the mitigation strategy or strategies necessary to guide the owner or person responsible for the development to accept or mitigate the potential for loss or damage to an element at risk. The acceptance of these definitions by the client / owner indicates a willingness to take responsibility for the risks to the identified elements at risk. The following table is intended to provide guidance to the decision maker, but it would have to be tailored to the risk acceptability of the owner or decision maker.

RISK ASSESSMENT AND RISK MANAGEMENT CONSIDERATIONS		
Rating	**Description**	**Example of management implication**
VH	Very high risk	The risk is usually unacceptable and would require extensive detailed investigation, research, planning engineering and implementation of treatment options essential to reduce risk to acceptable levels: may be too expensive and not practical to implement.
H	High risk	The risk is probably not tolerable as is, and treatment options are likely required to reduce risk to acceptable levels. Detailed investigation, planning, engineering, and construction supervision during the implementation of risk reduction measures will be necessary. On-going risk control is likely needed.
M	Moderate risk	The risk may or may not be tolerable, depending on the risk acceptability criteria of the resource manager or approval agency. • The risk may be tolerable as is, with or without further consideration, or with the understanding that the results will be monitored. • It may be tolerable provided a treatment plan is implemented to minimize the influence of certain factors that contribute to the hazard. • It may also require additional investigation prior to making a decision, to define the risk and / or assumptions used to define the risk, in more certainty. • It may involve consideration of additional or alternate treatment options, which may require more assessment and engineering. It will likely require consideration of risk from other activities (i.e. other than landslide risk) to be weighed in terms of overall risk from the proposed activity.
L	Low risk	Usually acceptable. Treatment requirements and responsibility may be defined to maintain or reduce risk.
VL	Very low risk	Acceptable. Manage by normal operational and maintenance procedures in the development area.

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