

DISTRICT OF NORTH VANCOUVER

MOUNT FROMME EAST

PRELIMINARY LANDSLIDE HAZARD ASSESSMENT AND RISK ANALYSIS

FINAL

PROJECT NO: 0404-018
DATE: April 30, 2009

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April 30, 2009

Project No. 0404-018

Mr. Jozsef L. Dioszeghy, P.Eng.
Director: Environment, Parks and Engineering Services
District North Vancouver
355 West Queens Road
North Vancouver, BC
V7N 4N5

Dear Jozsef,

Re: Mount Fromme East: Preliminary Landslide Hazard Assessment and Risk Analysis

Please find attached one digital and nine hardcopies of our above-referenced report dated April 30, 2009.

Should you have any questions or comments, please do not hesitate to contact me at the number listed above.

Yours sincerely,
BGC Engineering Inc.
per:

Michael Porter, M.Eng., P.Eng.
Vice President, Senior Geological Engineer

SRF/mjp

EXECUTIVE SUMMARY

In 2006, as part of the District of North Vancouver's (DNV's) ongoing Natural Hazard Management Program BGC Engineering Inc. (BGC) and DNV reviewed and compiled an inventory of records pertaining to geotechnical and geohazard issues across the District. On the basis of this review DNV identified priority areas for preliminary landslide hazard assessments, including:

- Berkley Escarpment;
- Indian Arm Debris Flow Fans;
- Pemberton Escarpment;
- Westlynn Escarpment;
- Deep Cove/Cove Cliff;
- Riverside West;
- Mosquito Creek West;
- Capilano River East; and,
- Mount Fromme East.

Hazard inventories and quantitative risk assessments have already been completed for the crest of the Berkley, Westlynn and Pemberton Heights Escarpments and known debris flow fans along Indian Arm.

This report documents a landslide hazard assessment and preliminary risk analysis for the Mount Fromme East study area, North Vancouver. Similar studies will be completed at the remaining priority areas listed above in early 2009. The results of this report are intended to support the 'Preliminary Analysis' phase of the risk management decision-making process as outlined in the Canadian Standards Association risk management guidelines for decision-makers (CAN/CSA Q850-97).

A desk-based screening study was completed to focus field inspections at sites most likely to pose elevated landslide risks to the public. Qualitative partial risk ratings ranging from 'very high' to 'very low' were estimated for approximately thirty properties located near the base of the escarpment. No areas posing 'very high' partial risk were identified. Three areas posing 'high' partial risk were identified. Risks posed to individuals at the areas of 'high' partial risk should be reduced further, if practical. Landslide risks posed at the remaining sites, ranked 'moderate', 'low', or 'very low', are considered tolerable.

Recommended response protocols for each risk scenario are provided below in Table 1, although the response and timing are ultimately linked to the level of risk tolerance which should be determined by DNV and the affected residents.

Table 1 Response Protocols Based on Preliminary Analysis of Partial Risk

Landslide Partial Risk	Number of Sites	Recommended Response Protocol
Very High	0	Further site characterization and quantitative risk assessment within 1 year
High	3	Further site characterization and quantitative risk assessment within 3 years
Moderate	11	Documentation of site observations; visual geotechnical inspection every 1 to 5 years
Very Low and Low	16	No further action

Neither the desk-based study nor the field investigation identified landslide hazards that appear to pose an imminent threat to public safety.

Records have been added to DNV's natural hazard database, which is currently under development, to help facilitate future geotechnical inspections. DNV should encourage affected property owners to have regular geotechnical inspections conducted by qualified professionals experienced in slope stability and landslide risk assessment issues.

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LIMITATIONS OF REPORT

BGC Engineering Inc. (BGC) prepared this report for the account of the District of North Vancouver (DNV). It presents the results of a preliminary landslide hazard assessment and risk analysis. A systematic procedure was used to identify and prioritize sites requiring additional investigation as part of DNV's landslide risk management program. Other natural hazards, such as flooding, soil erosion and debris flows are not included in this study. The preliminary landslide risk assessment is limited to landslides triggered by intense rainfall. Landslides triggered by earthquakes, slope excavation, or other processes are not included in this study.

The material in this report reflects the judgement of BGC staff in light of the information available to BGC at the time of report preparation. Any use which a Third Party makes of this report, or any reliance on decisions to be based on it are the responsibility of such Third Parties. BGC accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report. In particular, BGC accepts no responsibility for changes in real estate values that may occur as a consequence of this report.

As a mutual protection to our client, the public, and ourselves, all reports and drawings are submitted for the confidential information of our client for a specific project. Authorization for any use and/or publication of this report or any data, statements, conclusions or abstracts from or regarding our reports and drawings, through any form of print or electronic media, including without limitation, posting or reproduction of same on any website, is reserved pending BGC's written approval.

It is understood that the District of North Vancouver might make this report and drawings available to the community for the sole purpose of conveying current information about landslide risk management as limited in paragraph one, above.

Anyone in the community receiving a copy of this report and drawings is urged to recognize that these documents represent one of many steps in the risk management process as defined by Canadian Standards Association Guidelines¹.

If this report is issued in an electronic format, an original signed and sealed paper copy is on file at BGC Engineering Inc. and that copy is the primary reference with precedence over any electronic copy of the document, or any extracts from our documents published by others.

¹ As referenced on page 1.

1.0 INTRODUCTION

In 2006, as part of the District of North Vancouver's (DNV's) ongoing Natural Hazard Management Program BGC Engineering Inc. (BGC) and DNV reviewed and compiled an inventory of records pertaining to geotechnical and geohazard issues across the District. On the basis of this review DNV targeted areas for preliminary landslide hazard assessments which included the Mount Fromme East study area (Drawing 1).

BGC's scope of work was outlined in a proposal dated January 28, 2008 (BGC 2008a).

Data used for preliminary landslide hazard assessment and risk analysis of the Mount Fromme East study area are derived from a desk-based study and field inspections. The results of this study are intended to support the 'Preliminary Analysis' phase of the risk management decision-making process as outlined in Canadian Standards Association risk management guidelines for decision-makers (CAN/CSA Q850-97) (Figure 1). The purpose of 'Preliminary Analysis' is to prioritise areas requiring further investigation in the 'Risk Estimation' and 'Risk Evaluation' phases of the risk management process, and to identify locations where risks are tolerable and no further investigation is required.

This report prioritises sites for further investigation by assigning qualitative estimates of Hazard Probability, P_H , and Spatial Probability of Impact, $P_{S:H}$, for elements at risk (i.e. houses or habitable structures) and combining these estimates to derive a qualitative partial risk estimate. The partial risk estimates are assigned to qualitative categories ranging from 'very high' to 'very low' (discussed in detail in Section 6).

Section 2 of this report describes the landslide risk management process. Section 3 outlines the geology of the Mount Fromme East study area, the history of residential development and evidence of slope instability and historic landslides. Details of the site screening process are described in Section 4 and the field inspection procedures are described in Section 5. Qualitative partial risk assessment procedures are expanded upon in Section 6. Section 7 summarises recommendations for each rated site and provides recommendations for the management of landslide hazards within the Mount Fromme East study area.

1.1 Study Area Location

The Mount Fromme East study area is located in North Vancouver, west of Mountain Highway, south of Borthwick Road and north of Mill Street (Drawing 2). The study focused on residential development and did not address landslide risk to commercial structures or municipal infrastructure.

2.0 LANDSLIDE RISK MANAGEMENT

Following the January 19, 2005 landslide along the Berkley Escarpment, DNV initiated a proactive risk-based approach to the management of landslide hazards. The first phase encompassed a detailed quantitative risk assessment (QRA) and mitigation of landslide hazards along the crest of the Berkley Escarpment (BGC 2006a, 2006b, and 2007a). Quantitative risk estimates were also prepared for debris flow hazards throughout the District (BGC 2007b). Subsequent phases have included a preliminary landslide hazard assessment followed by a quantitative risk assessment of landslide hazards originating from the Westlynn and Pemberton Heights Escarpments. In all cases, the potential for loss of life to house occupants exposed to known landslide hazards was quantified.

The landslide risk management framework used in all studies is outlined in Figure 1. It follows Canadian and international guidelines for risk management (CAN/CSA Q850-97).

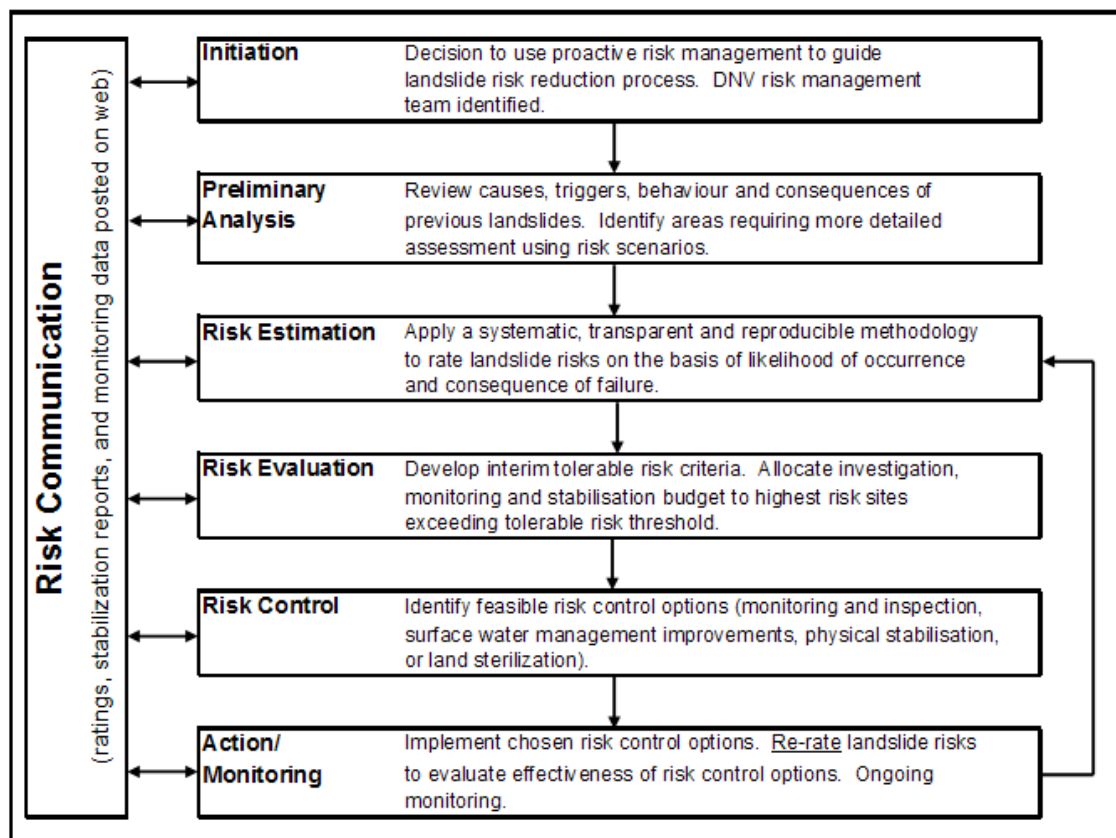


Figure 1 Proposed DNV Landslide Risk Management Cycle (after CAN/CSA-Q850-97)

In the context of this study, and as outlined in CAN/CSA Q850-97, the purpose of the 'preliminary analysis' phase is to assign a course of action for risk management based on a

review of causes, triggers, behaviour and consequences of previous landslides and an assessment of potential risks.

The preliminary analysis phase of the landslide risk management cycle determines one of the following courses of action:

- an imminent landslide risk exists and remedial action should be taken immediately;
- a landslide risk exists and a more detailed analysis should be undertaken to determine and prioritize mitigation efforts, if required; or,
- no further analysis is warranted because the risk is negligible or is clearly tolerable. In some cases, ongoing periodic inspection is recommended to confirm that hazard and risk levels do not increase over time.

3.0 MOUNT FROMME EAST

3.1 Geology of the Study Area

Glacial drift deposits including lodgement till, lenses and interbeds of glaciofluvial sand and gravel or glaciolacustrine laminated stony silt belonging to the Vashon Drift and Capilano Sediments have been mapped at a 1:50,000 scale adjacent to Mountain Highway (GSC, 1979). Locally within the mapped Vashon Drift and Capilano Sediment deposit a bouldery gravel derived from ablation till, colluvium and marine deposits mantles the lodgement till. Mesozoic granitic bedrock has been mapped for Mount Fromme beginning approximately 100 m west of Mountain Highway and includes areas where bedrock is not exposed but covered by glacial deposits and colluvium.

The rock outcrops observed by BGC were fresh, massive to blocky, coarse-grained, strong (R4), igneous intrusives (granites and granodiorites) with both regular and irregular joint patterns. Below these outcrops a thin layer of colluvium covered the slopes overlying glacial deposits or rock. An outcrop of dense grey sandy till at the western end of Mill Street was observed. Laminated glaciolacustrine or glaciomarine silts, fine sands or clays were not observed in outcrop.

3.2 Residential and Infrastructure Development

Based on interpretation of the earliest available aerial photographs limited road construction and rural development had begun within the Mount Fromme East study area by 1946. Residential development within the study area had begun west of Mountain Highway by 1957 and continued until reaching close to present-day extents by the early 1990's. Since that time residential development continued along the escarpment base in the form of residential infilling or re-development through renovations and home replacement.

3.3 Historical Landslides

The Mount Fromme East study area slopes are potentially subject to a variety of landslide hazards including creep, small scale rotational earth slides, debris slides and rockfall. Along the escarpment the type of landslides with greatest potential to cause loss of life are believed to involve rapid to extremely rapid debris slides or rockfall with sufficient magnitude and mobility to cause significant structural damage to homes. Debris slides may initiate in loose colluvial soils on an escarpment mid-slope provided rainfall and groundwater conditions can generate sufficiently high pore pressures in the colluvium to lower the effective stress and thus decrease the local factor of safety below unity. Alteration or concentration of surface runoff by road and trail construction can sometimes increase debris slide potential. Rockfall may initiate from steep rock bluffs. No evidence of large historic flow-type landslides was identified in a review of historical aerial photographs (Appendix A), the DNV hazard database, field inspections and foot traverses within the Mount Fromme study area (Appendix B and Drawing 2). Rockfall and rockslide deposits were observed within the study area (Drawing 2). Large sub-rounded glacial erratic boulders, or dropstones, were also identified adjacent to rockfall deposits.

4.0 SITE SCREENING PROCESS

Many houses situated within the Mount Fromme East study area are considered far enough away from the crest or base of the slope to have low landslide risk. In order to systematically account for this and to prioritize the field inspections, a desk-based screening process was employed. Screening criteria included slope height, slope angle and the proximity of homes to the base of the escarpment.

Based on experience gained from the Berkley, Westlynn and Pemberton Heights Escarpment studies, slopes susceptible to rapid landslides were typically steeper than 25° and greater than 10 m in height (BGC 2006a, 2006b, 2008b). While other types of slope instability may occur on shallower or shorter slopes along DNV escarpments, they are much less likely to cause injury or fatality to home occupants due to their lower volume and travel velocity which results in lesser impact force.

Slopes steeper than 25° and greater than 10 m in height were identified within the Mount Fromme East study area using a digital elevation model generated from a Lidar survey in 2006. Habitable structures located on or at the base of these slope segments were targeted for further field inspection and partial risk analysis. Slope segments and habitable structures captured by the screening process are shown in Drawing 2.

5.0 FIELD INSPECTIONS

Field inspections conducted as part of the preliminary landslide hazard assessment were carried out within the Mount Fromme East study area between October 2008 and March 2009. Visual observations focused on recording:

- slope angles;
- evidence of slope deformation at and immediately below the crest of the escarpment;
- the nature (species mix and signs of disturbance) of trees on the escarpment;
- an estimate of loose fill and colluvial soil thickness at the escarpment crest and approximately 10 m downslope of the crest;
- soil and rock descriptions from existing outcrops;
- sources of surface and subsurface drainage directed towards the crest of the escarpment; and,
- representative site photographs.

Evidence of landslide activity was mapped and soil and rock observations were documented by standard visual classification methods. Field observations, photographs and summary tables are provided in Appendix B and form the basis of the partial risk scenario rankings discussed in the next section. Key site features and landslide observations are shown on Drawing 2.

While field inspections and subsequent qualitative partial risk estimates are referenced to civic addresses to conveniently communicate landslide risk to the public it is important to note that the locations of potential landslide initiation zones are not known precisely and may cross property boundaries.

6.0 RISK ASSESSMENT

The Landslide Risk Management Program adopted by DNV defines the 'Preliminary Analysis' phase of the risk communication process as a risk scenario based ranking system (Figure 1). The intention of the risk scenario ranking is to prioritise areas requiring further investigation in the 'Risk Estimation' and 'Risk Evaluation' phases of the process, and to identify areas where risks are tolerable and no further investigation is required.

Rapid debris slides and rockfall originating from the slopes above residential development constitute the primary hazard considered in this study, while the consequence is determined by the spatial location of habitable structures relative to the slope. In some cases within the Mount Fromme East study area rockfall hazards are considered more significant than debris slides and where applicable criteria to determine the consequence of spatial location of habitable structures below these slopes were adjusted to reflect the lower runout potential of rockfall debris. Qualitative partial risk for each structure at or near the base of the slope was determined from qualitative estimates of Hazard Probability, P_H , and Spatial Probability of Impact, $P_{S:H}$, as defined below.

The elements at risk for this study included habitable structures located at or near the mid-slope or base of the escarpment. Garden sheds and structures such as barbeque areas or pagodas, garages, and similar non-inhabited structures were not included in this assessment.

6.1 Hazard Probability, P_H

Hazard Probability, P_H , refers to the likelihood of occurrence of a slope failure. Qualitative estimates of hazard probability were provided at each property, based on evidence of past failures or adverse slope conditions, as observed in aerial photographs, documented in other reports, or observed in the field.

Table 2 outlines the criteria used in this study to assign hazard probability.

6.2 Spatial Probability of Impact, $P_{S:H}$

Spatial Probability of Impact, $P_{S:H}$, refers to the likelihood that a landslide will impact habitable structures. In the Mount Fromme East study area, habitable structures are present only at the base of the slope. For the Mount Fromme East study area qualitative estimates of spatial probability of impact provided are based on either measurements of the inclination between the escarpment crest and the nearest habitable structure for predominantly soil slopes, or the inclination between the base of rock bluffs and the nearest habitable structure for rock slopes.

For soil slopes, hazards situated at a slope angle less than 21° from the slope crest to the downslope structure, were considered unlikely to impact those elements based on observations from previous landslides that have occurred within DNV on similar escarpments.

For rock slopes, structures situated at a slope angle less than 27° from the base of the rock bluff were considered unlikely to be impacted by rockfall (Evans and Hungr, 1993). For this preliminary risk assessment all houses within a >27° shadow angle from the base of a rock bluff were rated as a high spatial probability of impact.

Table 3 describes the criteria used to determine spatial probability of impact, $P_{S:H}$, for habitable structures at the base of the escarpment, $P_{S:H; BASE}$.

Table 2 Qualitative Landslide Hazard Probability Ratings

Factor	Rating	Criteria
Hazard Probability (P_H)	High	Evidence of active or historical landslides or slope deformation; such as - landslide scarps containing exposed soil or re-vegetated with deciduous trees or young conifers; - visible settlement in fills, retaining walls; or - abundant 'pistol-butt' or downslope leaning trees.
	Moderate	Adverse slope conditions, but no evidence of historical landslides or slope deformation; such as - slopes steeper than 35°; - the presence of random fills or yard waste; - the presence of non-engineered retaining walls; - abundant seepage or surface erosion; or, - bedrock slopes containing adverse structure (i.e. joints, faults).
	Low	Favourable slope conditions and no evidence of historical landslides or slope deformation; such as - slopes angles less than 25° and less than 10 m high; - engineered fills or retaining walls; or - bedrock slopes lacking adverse structure.

Table 3 Qualitative Spatial Probability of Impact Ratings for Downslope Elements

Factor	Rating	Criteria	
Spatial Probability of Impact to Homes at or near the Base of Escarpment Slopes ($P_{S:H; BASE}$)	High	Soil	Angle between home/habitable structure and crest of slope or source area $>23^{\circ}$; high likelihood of landslide debris impacting the element(s) at risk
		Rock	Angle between home/habitable structure and the base of the rock slope $>27^{\circ}$; high likelihood of rock fall impacting the element(s) at risk
	Moderate	Soil	Angle between home/habitable structure and crest of slope or source area between $21^{\circ} - 23^{\circ}$; moderate likelihood of landslide debris impacting the element(s) at risk
		Rock	Angle between home/habitable structure and the base of the rock slope between $23^{\circ} - 27^{\circ}$; moderate likelihood rockfall would impact the element(s) at risk
	Low	Soil	Angle between home/habitable structure and crest of slope or source area $<21^{\circ}$; unlikely that landslide debris would impact the element(s) at risk
		Rock	Angle between home/habitable structure and the base of the rock slope $<21^{\circ}$; unlikely rockfall would impact the element(s) at risk

6.3 Qualitative Partial Risk, $P_{H:A}$

A qualitative estimate of partial risk for each habitable structure was determined by combining the hazard probability and the spatial probability of impact at the base of the escarpment, as defined above. Qualitative partial risk criteria are shown in Table 4.

Qualitative partial risk estimates, do not systematically account for variations in landslide consequence, such as individuals' temporal probability of impact, vulnerability, or risk of loss of life. For this reason, more detailed investigations are needed where it is determined that quantitative landslide risk estimates are required.

Table 4 Qualitative Partial Risk Matrix

$P_{HA} = P_H \times P_{S:H}$ Probability of a specific landslide impacting the identified elements at risk		P_H (Landslide Likelihood)		
		Low	Moderate	High
$P_{S:H}$ (Spatial Probability of Impact – highest risk of either $P_{S:H}$; CREST or BASE)	Low	Very Low	Low	Moderate
	Moderate	Low	Moderate	High
	High	Moderate	High	Very High

The qualitative partial risk ratings are typically expected to correspond to the quantitative risk levels outlined in Table 5 below.

Table 5 Comparison between Qualitative Partial Risk and Typical Quantitative Landslide Risk Estimates

Qualitative Partial Risk, $P_{H:A}$	Comparable Quantitative Risk Level (Individual risk of fatality, per annum)
Very High	Risk may exceed 1:10,000
High	Risk likely less than 1:10,000
Moderate	Risk likely about 1:100,000
Low and Very Low	Risk likely less than 1:100,000

According to DNV's interim risk tolerance criteria for landslides, tolerable risks are as follows:

- < 1:10,000 for existing development; and,
- < 1:100,000 for new development.

For reference, a Canadian's annual risk of death from motor vehicle accidents is about 1:10,000.

7.0 PARTIAL RISK ASSESSMENT RESULTS

The previous section described how the combination of Hazard Probability, P_H , and Spatial Probability of Impact, $P_{S:H}$, was used to prioritize sites for further assessment within the study area. This section describes each property assigned to the 'very high' and 'high' risk categories and provides properties in the 'moderate' category. All risk ratings, including the remaining properties ranked 'low' and 'very low', are provided in Appendix C.

7.1 Very High Risk Sites

No properties were assigned to the 'very high' risk category in the Mount Fromme East study area.

7.2 High Risk Sites

Three properties were assigned to the 'high' risk category (Table 6). Consistent with our understanding of DNV's level of risk tolerance, BGC recommends more detailed landslide investigations be carried out at these locations within 3 years of the release of this report.

Table 6 High Risk Sites

Civic Address	Landslide Probability (P_H)	Spatial Probability ($P_{S:H}$)	Qualitative Partial Risk
1250 Coleman Close	Moderate	High	HIGH
1252 Coleman Close	Moderate	High	HIGH
1254 Coleman Close	Moderate	High	HIGH

7.2.1 1250 – 1254 Coleman Close

Approximately 50 m upslope of 1254 Coleman Close an old rockslide deposit is covered by moss and lichen. The angle between the base of the rock bluff and the downslope limit of the slide deposit is 30°. The rock bluff south of the slide area is convex and jointed with potentially adverse rock structure.

Based on current observations the landslide probability, P_H , is rated moderate, and the spatial probability of impact, $P_{S:H}$, is rated high resulting in a 'high' risk scenario rating.

Further geotechnical work at this location should focus on collecting rock structure information to help refine estimates of potential rockfall frequency and size, and to determine if stabilization measures are warranted.

7.3 Moderate Risk Sites

Eleven properties were assigned to the 'moderate' risk category (Table 7). BGC recommends natural hazard records be created for these sites and that property owners

retain qualified professionals to conduct visual geotechnical inspection every few years to identify any deterioration of slope stability conditions.

Table 7 Moderate Risk Sites

Civic Address	Landslide Probability (P_H)	Spatial Probability ($P_{S:H}$)	Partial Risk
1229 Coleman Street	Low	High	MODERATE
1231 Coleman Street	Low	High	MODERATE
1233 Coleman Street	Low	High	MODERATE
1239 Coleman Street	Low	High	MODERATE
1221 Mill Street	Low	High	MODERATE
1223 Mill Street	Low	High	MODERATE
1225 Mill Street	Low	High	MODERATE
1227 Mill Street	Low	High	MODERATE
1229 Mill Street	Low	High	MODERATE
1231 Mill Street	Low	High	MODERATE
1233 Mill Street	Low	High	MODERATE

7.4 Low and Very Low Risk Sites

Sixteen properties were assigned to the 'very low and low' risk categories. No further investigation is recommended at these sites. More detailed information on the risk ratings for properties ranked 'very low and low' are provided in Appendix C. If properties are not listed in Appendix B or III they were excluded from the study based on the initial screening exercise described in Section 4.

8.0 RECOMMENDATIONS

This report documents the results of a preliminary risk analysis for the Mount Fromme East study area, intended to support the 'Preliminary Analysis' phase of the risk management decision-making process (CAN/CSA Q850-97). The basic premise of 'Preliminary Analysis' is to identify areas that require more detailed assessment in the 'Risk Estimation' and 'Risk Evaluation' phases. As outlined earlier, this report ranks sites on the basis of landslide qualitative partial risk ranging between 'very high' and 'very low' for this purpose. Recommended response protocols based on the partial risk ratings are summarized in Table 8.

Table 8 Response Protocols Based on Preliminary Analysis of Partial Risk

Landslide Partial Risk	Recommended Response Protocol
Very High	Further site characterization and quantitative risk assessment within 1 year
High	Further site characterization and quantitative risk assessment within 3 years
Moderate	Documentation of site observations; visual geotechnical inspection every 1 to 5 years
Very Low and Low	No further action

In addition to the site specific recommendations we provide the following general recommendations to help manage landslide risk within the Mount Fromme East study area:

- DNV should continue to provide information, education and updating of the public on how to reduce landslide risk when living near steep slopes.

9.0 CLOSURE

This report presents the results of a landslide hazard assessment and preliminary risk analysis for the Mount Fromme East study area slopes, North Vancouver.

We trust the information provided meets your current requirements but please do not hesitate to contact us if you have any questions or comments, or if we may be of further assistance.

Sincerely,

BGC Engineering Inc.

Per:

Reviewed by:

Sam Fougere, M.Sc., P.Geo.
Engineering Geologist

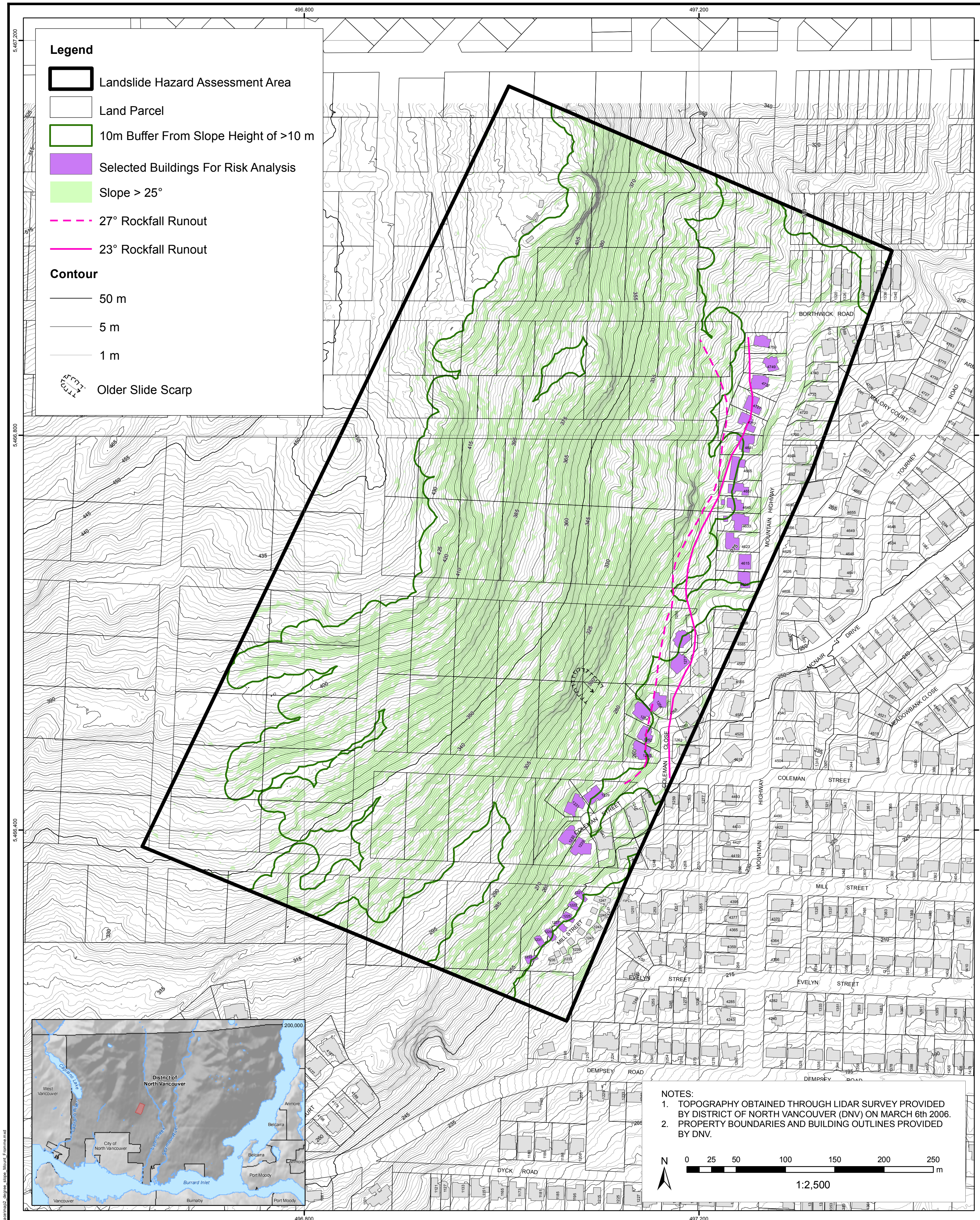
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DRAWINGS



APPENDIX A

Aerial Photography Review

MT FROMME EAST - AERIAL PHOTOGRAPH INTERPRETATION

YEAR	FLIGHT LINE	PHOTO #	SCALE	SLOPE STABILITY AND DEVELOPMENT COMMENTS	DEVELOPMENT AT CREST	DEVELOPMENT AT BASE
1946	A10497	16-17	1:25,000	Limited urban development completed on either side of Mountain Highway. A prominent gully extends the non-paved section of Mountain Highway eastward towards the northern end of Tourney Road. A second less prominent gully extends eastward from mid-slope to the backyard of present day 4665 Mountain Highway. Small scarp located at the end of Dempsey Road likely related to a borrow pit operation. Second growth cover approximately 20% of the slope, cover density increases downslope. No evidence of landslide activity originating from the Mount Fromme East study area.	N	Y
1957	BC2351	75-76	1:17,000	The prominent gully at the end of Mountain Highway referred to in the 1946 photographs is now over grown by trees and second growth conifers cover approximately 75% of the remaining study area slopes. Scarp located at end of Dempsey Road is most likely a debris avalanche/slide, no evidence of recent borrow operations observed. Urban development continues along Coleman Close and Mountain Highway.	N	Y
1963	BC5060	140-143	1:12,000	Urban development continues west of Mountain Highway. The prominent gully, referred to in the 1946 photographs, is delineated by deciduous trees. No evidence of recent landslide activity. The aerial photographs are over-exposed. Around the Dempsey Road scarp the photographs are washed out, but tree growth adjacent to the slide margins has occurred.	N	Y
1974	BC5592	43-44	1:10,000	Urban development continues along Mountain Highway, Tourney Road, McNair Drive, and Dempsey Road. Tree clearing and trail construction extends west from the end of Coleman Street. Conifer growth in the prominent gully, referred to in the 1946 photographs, as well as the smaller gully is increasing. No evidence of recent landslide activity.	N	Y
1979	30BC79044	38-39, 44-45	1:10,000	Urban development continues west of Mountain Highway. Two small depressions appear on the eastern part of slope, one leading to the backyard of 4623 and the second leading to 4665 Mountain Highway.	N	Y
1984	A26511	46-47	1:25,000	Urban development continues. Poor quality photographs.	N	Y
1992	30BCB92018	101-102	1:16,000	Urban development continues, which includes a Dempsey Road extension to East Braemar Road along with the construction of Quarry Court and Citadel Court. Small valley leading to the backyard of 4645 Mountain Highway. Gully leading to the backyard of 1239 Coleman St.	N	Y
1996	30BCC96080	133-134	1:15,000	No significant changes since 1992 photographs. Development is completed to near present day extent. Gully leading to backyard of 4633 Mountain Highway.	N	Y
2004	SRS 6929	420-421	1:20,000	No significant changes since 1992 photographs.	N	Y

APPENDIX B

Site Inspections

MOUNT FROMME EAST - SUMMARY OF FIELD OBSERVATIONS

LOCATION	LOOSE MATERIAL THICKNESS (Fill / Colluvium)	SLOPE ANGLE	SLOPE DEFORMATION	SEEPAGE	TREE CONDITION	% CONIFERS	COMMENTS
4665 - 4759 Mountain Highway	< 1 m	25-30°	None	None	Straight	>75%	Moderately steep slopes with glacial drainage channels perpendicular to the slope. No evidence of recent slide activity. A large 3 m x 2 m x 1.5 m sub-rounded boulder observed is interpreted to be a downwasted glacial derived boulder. Well forested with straight second growth conifers about 80 - 100 yrs old. No seepage zones observed. No oversteepened fill observed. Estimated loose colluvium thickness 0 - 1 m. (P _H - Hazard Probability = LOW)
4623 - 4657 Mountain Highway	< 1 m	35-40°	Rockfall	None	Straight	>75%	Evidence of rockfall below a 10 m high rock bluff. No evidence of recent significant rockfall events in a partially developed talus slope as most of the rocks are covered with moss or buried by colluvium and forest litter. Well forested with straight second growth conifers. No seepage zones observed in April 2009, water flowing over bluff in October 2008. No oversteepened fill observed. Estimated loose colluvium thickness 0 - 1 m. (P _H - Hazard Probability = MODERATE)
4599 - 4615 Mountain Highway; 1255 - 1277 McNair Drive; 1256 Coleman Close	< 1 m	30-35°	None	Yes	Straight	>75%	No evidence of recent slide activity. Well forested with straight second growth conifers. Seepage zones above 1255 McNair Drive in October 2008 during heavy rainfall. No oversteepened fill observed. Estimated loose colluvium thickness 0 - 1 m. (P _H - Hazard Probability = LOW)
1250 - 1254 Coleman Close	< 1 m	30-35°	Rock Avalanche	None	Straight	>75%	A rockslide deposit 50 m above 1254 Coleman close is covered by moss and lichen (see Drawing 2 for location). The angle between the base of the rock bluff and the downslope limit of the slide deposit is 30°. To the south of the slide debris boulders observed on the slope indicate infrequent rockfall events occur because no talus slope has formed. The rock bluff south of the slide area is convex and jointed with potentially adverse rock structure. Walking trails and old skid trails concentrating surface water flow during heaving rainfall. Well forested with straight second growth conifers. No seepage zones observed. No oversteepened fill observed. Estimated loose colluvium thickness 0 - 1 m. (P _H - Hazard Probability = MODERATE)
1229 - 1239 Coleman Close; 1221 - 1247 Mill Street	< 1 m	30-35°	None	None	Straight	>75%	Walking trails and old skid trails concentrating surface water flow during heaving rainfall. Well forested with straight second growth conifers. No seepage zones observed. No oversteepened fill observed. Estimated loose colluvium thickness 0 - 1 m. (P _H - Hazard Probability = LOW)

APPENDIX C

Partial Risk Estimates

DNV - Mt Fromme East

Qualitative Partial Risk Estimates - P_{HA}

Address	P_H - Hazard Probability	P_{SH} - Spatial Probability of Impact	P_{HA} - Qualitative Partial Risk
4759 Mountain Highway	Low	Low	VERY LOW
4749 Mountain Highway	Low	Low	VERY LOW
4737 Mountain Highway	Low	Low	VERY LOW
4727 Mountain Highway	Low	Moderate	LOW
4717 Mountain Highway	Low	Moderate	LOW
4691 Mountain Highway	Low	Moderate	LOW
4665 Mountain Highway	Low	Low	VERY LOW
4657 Mountain Highway	Moderate	Low	LOW
4645 Mountain Highway	Moderate	Low	LOW
4633 Mountain Highway	Moderate	Low	LOW
4623 Mountain Highway	Moderate	Low	LOW
4615 Mountain Highway	Low	Low	VERY LOW
4601 Mountain Highway	Low	Low	VERY LOW
1255 McNair Drive	Low	Moderate	LOW
1277 McNair Drive	Low	Moderate	LOW
1256 Coleman Close	Low	Moderate	LOW
1254 Coleman Close	Moderate	High	HIGH
1252 Coleman Close	Moderate	High	HIGH
1250 Coleman Close	Moderate	High	HIGH
1229 Coleman Street	Low	High	MODERATE
1231 Coleman Street	Low	High	MODERATE
1233 Coleman Street	Low	High	MODERATE
1239 Coleman Street	Low	High	MODERATE
1221 Mill Street	Low	High	MODERATE
1223 Mill Street	Low	High	MODERATE
1225 Mill Street	Low	High	MODERATE
1227 Mill Street	Low	High	MODERATE
1229 Mill Street	Low	High	MODERATE
1231 Mill Street	Low	High	MODERATE
1233 Mill Street	Low	High	MODERATE