BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

#500–1045 Howe Street
Vancouver, B.C.
Canada V6Z 2A9
Tel: (604) 684-5900
Fax:(604) 684-5909

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Project No. 0405-001-02

Mr. Jozsef L. Dioszeghy, P.Eng.
District North Vancouver
355 West Queens Road
North Vancouver, BC
V7N 4N5

Dear Sir,

RE: SLOPE STABILITY ANALYSES AT 2157 AND 2191 BERKLEY AVENUE

This letter presents the results of a slope stability evaluation for the houses located at 2157 and 2191 Berkley Avenue.

GEOTECHNICAL SITE INVESTIGATION

Following the landslide, a geotechnical site investigation was carried out, which included completion of topographic surveys, test pits, cone penetration tests, shallow and deep drill holes, laboratory testing, and installation and monitoring of piezometers. The results have been used to establish the slope geometry, soil stratigraphy, shear strength and groundwater conditions necessary for slope stability modelling.

SLOPE STABILITY MODEL CALIBRATION

Two stratigraphic cross sections were analysed; one for each property under consideration (Figures 1 and 2).

Limit equilibrium slope stability analyses were carried out using the commercially available software GeoStudio 2004-Slope/W, produced by Geo-Slope International. The Morgenstern-Price method was used to determine the factor of safety against failure for trial slip surfaces.

Soil strength parameters were determined based on visual classification, cone penetration testing, laboratory testing, and engineering judgement. Slope/W's 'Auto Locate' function was used to identify the slip surface with the lowest factor of safety along each cross section.

A number of 'reality checks' were carried out, including verification that:

- groundwater levels measured in the piezometers matched observations of seepage around the headscarp of the landslide; and,
- the factor of safety under the highest groundwater conditions measured by the piezometers following the landslide exceeded 1.0 near the edge of the escarpment for the cross sections shown in Figures 1 and 2.

FACTORS OF SAFETY AGAINST SLOPE FAILURE AFFECTING THE SUBJECT HOUSES

Once the models were calibrated, additional analyses were undertaken to evaluate the factor of safety against failure along hypothetical slip surfaces that were forced to intersect the edge of the houses on the subject properties. Groundwater conditions measured on June 7, 2005 (the most recent data) and on March 21, 2005 (the highest groundwater conditions observed since piezometer installation) were used in the analyses. Additional analyses were carried out using groundwater conditions 0.5 m higher than observed on March 21. This level was selected arbitrarily so as to evaluate the sensitivity of the analyses to an elevated water table. Table 1 summarizes the results:

Table 1. Calculated Factors of Safety for Slip Surfaces Intersecting the Subject Houses

Cross Section	Property	June 7, 2005 Groundwater Level	March 21, 2005 Groundwater Level	March 21, 2005 Groundwater Level + 0.5 m
A-A'	2157 Berkley	1.5	1.5	1.3
C-C'	2191 Berkley	1.5	1.5	1.2

It is important to note that the factors of safety presented in Table 1 and the slip surface geometries shown in Figures 1 and 2 do not represent critical slip surfaces or minimum factors of safety near the edge of the natural escarpment and headscarp of the January 19, 2005 landslide. Shallower slip surfaces located closer to the edges of these scarps have lower factors of safety than those presented in Table 1. For example, the factor of safety on the critical slip surface for cross section A-A' under March 21, 2005 groundwater levels is about 1.1, compared to a factor of safety of 1.5 for a slip surface that is forced to pass deeper into the slope and intersect the house at 2157 Berkley. Similarly, the critical slip surface for cross section C-C' has a factor of safety of about 1.0 under March 21 groundwater levels, while a deeper slip surface intersecting the house has a factor of safety of 1.5. This issue of personal safety for any person standing at or near the edge of these scarps when a shallow landslide occurs is beyond the BGC scope of work reported here.

RECOMMENDATIONS

Standard geotechnical engineering practice requires permanent slopes be designed with a minimum factor of safety of 1.5. Factors of safety of 1.3 are sometimes accepted for slopes where the consequences of failure are low, or where a loss of strength during shearing is not anticipated. Neither of these conditions applies along the Berkley-Riverside escarpment, thus BGC recommends adopting a factor of safety of 1.5 as the minimum acceptable level for house re-occupation.

Based on these guidelines and the results of the slope stability analyses reported in Table 1, BGC recommends the following:

a) provided the groundwater levels in none of the site piezometers exceed their March 21, 2005 values, the residences at 2157, and 2191 Berkley may be occupied on a temporary basis; and,
b) if any of the groundwater levels exceed those observed on March 21, 2005, a visual inspection, review of all piezometer data, and assessment of predicted short-term rainfall should be promptly conducted, possibly leading to the re-evacuation of 2157 and/or 2191 Berkley.

BGC's recommendation of temporary occupation of the residences is conditional upon:

a) continued operation of a full-time rainfall and piezometer monitoring program, including protocols for re-evacuation that are maintained 24 hours per day and seven days per week until such time as a long-term mitigation strategy is developed and implemented; and,
b) continued effective control of roof and driveway surface runoff into the storm sewer system.

Furthermore, it should be emphasised that until some form of slope remediation is carried out, the potential for small landslides originating from the headscarp of the January 19, 2005 slide will remain high. Although the failure volumes from such events are expected to be small, thus not posing a significant risk to houses at the bottom of the escarpment, they could continue to undermine the slopes and place the houses and back yards of 2157 and 2191 Berkley at greater risk. These slides could also pose a risk to residents if they happen to be standing in their back yards at the time when a failure occurs.

Lastly, the potential remains for larger landslides to originate from the back yards of 2157 (south of the January 19 landslide headscarp) and 2191 Berkley (north of the January 19 landslide headscarp). For these slides to occur, groundwater levels higher than experienced during the January 2005 storm would likely be required. The potential for these groundwater levels to recur is believed to have been reduced by improved management of surface runoff water from the house roofs and driveways. Continued operation of the rainfall and piezometer monitoring system, and control of roof and driveway surface runoff, is one means of reducing the likelihood and consequence of future slides originating from the back yards of these properties.

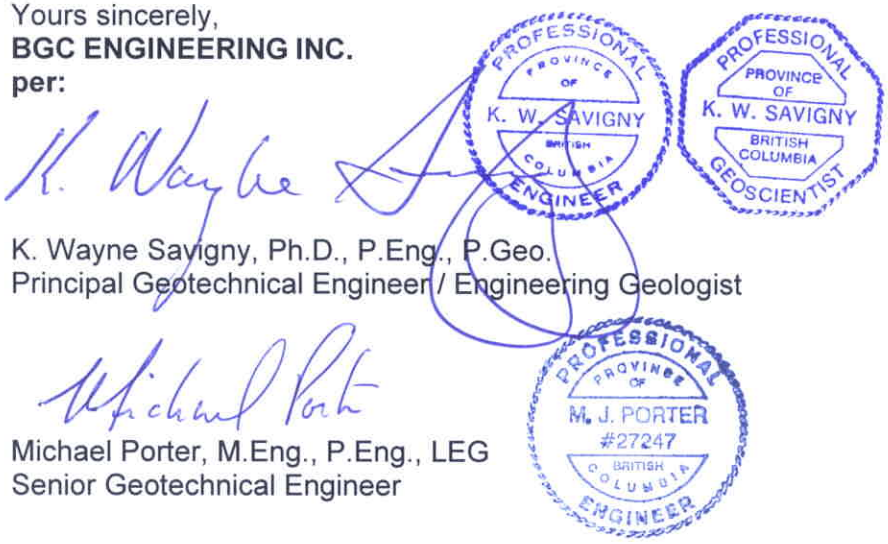
LIMITATIONS

The discussion on slope stability in this report is based on factual information gathered from site investigations, monitoring and laboratory testing, as well as on geotechnical engineering judgment. Further detailed geotechnical investigations on the subject properties or within several hundred metres around them could lead to the discovery of information that will materially influence the slope stability analyses reported here. This is a reality in geotechnical engineering practice, which stems from the need to characterize geological uncertainty at specific reporting junctures with limited information. The reader must accept that this is the standard of geotechnical engineering practice, and its inherent limitations are not unique to the study reported here.

This study addresses static, near-surface slope stability at the west sides of two houses; 2157 and 2191 Berkley Avenue, specifically the factor of safety regarding retrogression of the adjacent landslide escarpment to the extent that it undermines the foundations of the houses. It does not consider possible deep-seated failure mechanisms, earthquake loadings or runout of landslides onto properties on or below the Berkley Avenue escarpment. Further, it does not assess the risk to personal safety related to more localized retrogression (i.e. shallow sloughing) of the escarpment into the back yards of these homes. The results are applicable to the period from June through approximately mid October 2005, by which time it is BGC's understanding that the results reported here will be superseded by a long-term mitigation strategy.

BGC prepared this letter for the District of North Vancouver. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of report preparation. Any use of this report, or reliance which is placed on this report by anyone other than the District of North Vancouver, is the responsibility of that person or party. BGC accepts no responsibility for damages, if any, suffered by any person or party, other than the District of North Vancouver, as a result of decisions made or actions taken based on this report. BGC also does not assume any liability for possible losses in property value that may result from this report.

Yours sincerely,
BGC ENGINEERING INC.
per:

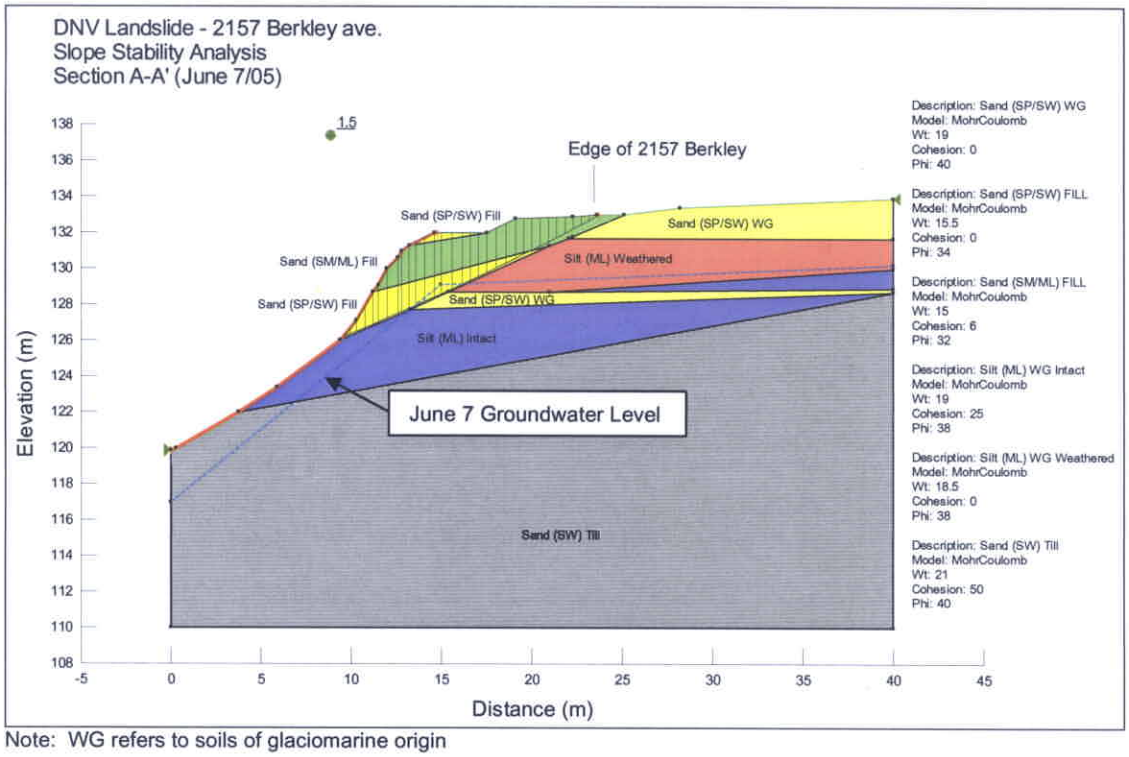


K. Wayne Savigny, Ph.D., P.Eng., P.Geo.
Principal Geotechnical Engineer / Engineering Geologist

Michael Porter, M.Eng., P.Eng., LEG
Senior Geotechnical Engineer

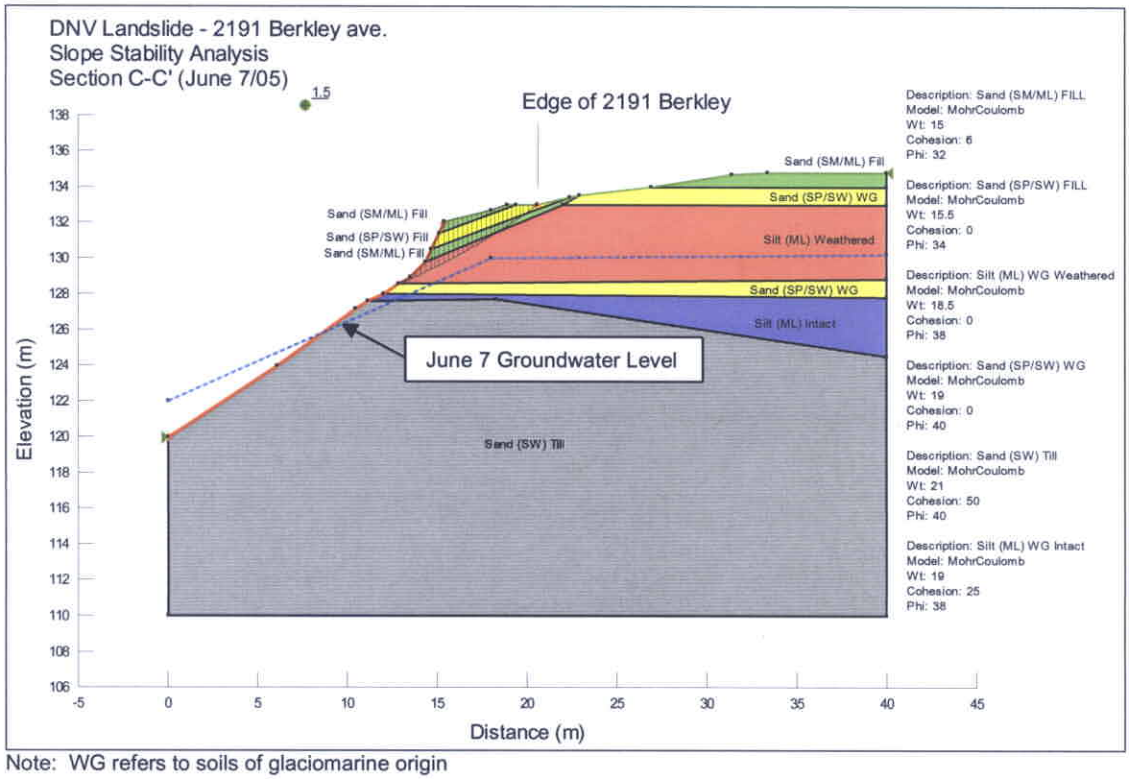
KWS/mjp

Figure 1. Slope Stability Analysis for Section A-A' (2157 Berkley Avenue)



Note: WG refers to soils of glaciomarine origin

Figure 2. Slope Stability Analysis for Section C-C' (2191 Berkley Avenue)



Note: WG refers to soils of glaciomarine origin