

## **DISTRICT OF NORTH VANCOUVER**

# **1576 AND 1582 MERLYNN CRESCENT LANDSLIDE RISK REASSESSMENT**

**FINAL**

PROJECT NO.: 0404081

DATE: October 24, 2017

October 24, 2017  
Project No.: 0404081

Fiona Dercole, Section Manager, Public Safety  
District of North Vancouver  
355 Queens Road West  
North Vancouver, BC V7N 4N5

Dear Ms. Dercole,

**Re: 1576 and 1582 Merlynn Crescent Landslide Risk Reassessment**

Please find attached our above referenced report dated October 24, 2017. 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:



Sarah Kimball, M.A.Sc., P.Geo.  
Engineering Geologist

## EXECUTIVE SUMMARY

The District of North Vancouver (DNV) retained BGC Engineering Inc. (BGC) to reassess the landslide risk at three properties along the Westlynn Escarpment, North Vancouver. DNV requested BGC complete this reassessment after remedial work was undertaken at 1576 and 1582 Merlynn Crescent, including fill removal and construction of new retaining walls.

The remedial work was mandated by the DNV following studies by Horizon Engineering Inc. (Horizon) and BGC in 2013 that indicated there was a greater than average likelihood of a landslide originating from the escarpment crest at 1576 and 1582 Merlynn Crescent (relative to other Westlynn Escarpment properties). While the estimated risk of loss of life to home occupants from a landslide originating from these two properties met DNV's risk tolerance criteria for existing development, there was an elevated likelihood of a landslide occurring that could cause damage to public and private property and pose risks to home occupants downslope along Carmaria Court. Landslide safety criteria were formally adopted by the DNV in 2009 (DNV 2009) and comprise criteria for factor of safety assessments and for quantitative risk assessments.

Data collected by BGC for this assessment included visual observations of current conditions, remedial options and slope stability analysis reports, as-built drawings, field review documentation, and Letters of Assurance for the remedial works. Visual observations at each location focused on the main factors affecting slope stability that were considered during BGC's 2013 assessment and for previous studies completed by BGC for the DNV. No evidence of slope deformation since the 2013 inspection was observed. Slope stability assessments were completed by others prior to design and construction of the walls and no further slope stability assessments were completed by BGC.

At 1576 Merlynn Crescent, remedial works consisted of fill removal and replacement of a timber crib retaining wall with a 2.4 m high concrete retaining wall. The original slope stability analyses indicate the DNV's risk tolerance criteria was met using the factor of safety method (Horizon, 2013b). The design and construction was subsequently taken over by GeoPacific Consultants Ltd. (GeoPacific); documentation demonstrating GeoPacific's design met DNV's Factor of Safety risk tolerance criteria was not available for review, however Structural and Geotechnical Letters of Assurance as required by the BC Building Code, as-built documentation by the Engineer of Record (Appendix A) and an options assessment completed by Horizon (2013b) imply this criterion has likely been met.

At 1582 Merlynn Crescent, remedial works consisted of fill removal and replacement of a timber crib retaining with a 2 m to 2.5 m high mechanically stabilized earth (MSE) retaining wall. Slope stability analyses (Horizon, 2014) indicate the DNV's risk tolerance criteria using the factor of safety method was met.

An algorithm referred to as the Berkley Escarpment Method was used to estimate the individual landslide risk for properties located at the crest and base of the West Hastings Escarpment (BGC

2006a, 2006b). This methodology was developed in 2005 and 2006, to estimate the annual probability of extremely rapid, flow-type landslides originating from the crests of escarpments in the Berkley area, and the associated potential risk of loss of life to home occupants. It includes parameters related to thickness of loose fill and colluvium, evidence of slope deformation, slope inclination, and surface and groundwater. Since 2007, the Berkley Escarpment Method has been used to estimate landslide hazard and risk along other escarpments within the DNV that share a similar geological setting and residential development history. This included the 2008 and 2013 risk assessments along the West Hastings Escarpment (BGC 2008, 2013).

In the 2013 assessment, the algorithm's water score for 1582 Merlynn Crescent was manually adjusted to include the potential of surface water runoff from 1588 Merlynn Crescent (due to topography) (BGC, 2013). Since 2013, BGC understands 1582 Merlynn Crescent has been connected to DNV's stormwater network which is accounted for with a lower water score using the Berkley Method. The drainage over the 1582 Merlynn Crescent escarpment slope has improved with the addition of the retaining wall work and internal wall drainage, however the escarpment slope is still potentially subject to surface water runoff from the neighbouring property, therefore a range of water scores is presented (Scenario A and B in Appendix D).

The remedial work undertaken at 1576 Merlynn Crescent and 1582 Merlynn Crescent has reduced the likelihood of a landslide originating from the two properties located along the escarpment crest. At 1576 Merlynn Crescent, the estimated likelihood of a landslide originating has reduced from  $1.5 \times 10^{-2}$  in the 2013 assessment to  $5.3 \times 10^{-4}$  in this assessment (about a factor of 28). At 1582 Merlynn Crescent, the likelihood of a landslide originating has reduced from  $6.0 \times 10^{-3}$  in the 2013 assessment to  $5.3 \times 10^{-4}$  to  $1.1 \times 10^{-3}$  in this assessment (about a factor of 5 to 11).

The 2017 risk reassessment, indicates that potential landslides originating from 1576 and 1582 Merlynn Crescent properties do not pose 'unacceptable' landslide risk based on the DNV's risk tolerance criteria for existing developments. Landslide risks to occupants of 1576 and 1582 Merlynn Crescent have improved from 'tolerable' in the 2013 QRA to 'broadly acceptable' in the current study because of the remedial works. Reassessment of the landslide risk for the 2180 Carmaria Court property located downslope remains 'broadly acceptable' for slides originating from 1576 Merlynn Crescent and ranges from 'broadly acceptable' to 'tolerable' for potential landslides originating from 1582 Merlynn Crescent.

The risk estimates for 2180 Carmaria Court from potential landslides originating from 1582 Merlynn Crescent decreased to between  $1.3 \times 10^{-5}$  and  $6.7 \times 10^{-6}$  following mitigation; the upper end of this range approaches  $1.0 \times 10^{-5}$  which is the boundary between 'tolerable' and 'broadly acceptable'. Furthermore, slope stability analyses by Horizon (2014) indicate the slope at 1582 Merlynn Crescent meets DNV's risk tolerance criteria using the factor of safety methodology. In combination, the QRA results and factor of safety analysis indicate improvement in the stability of the slope behind 1582 Merlynn Crescent following mitigation.

Given that the home at 1582 Merlynn Crescent is connected to the municipal storm sewer system and that fill removal and retaining wall reconstruction have already been undertaken and meets DNV's factor of safety risk tolerance criteria (Horizon, 2014), additional remediation work does not seem reasonable or practical at this time. To fulfill the ALARP requirement and as good practice, BGC recommends that periodic visual monitoring of this slope and others along with West Hastings escarpment is conducted to confirm that observed slope movements abate, and to prevent new surface erosion or landslide hazards from developing and going undetected. We suggest that the DNV encourage property owners or members of the public to dispose of their yard trimmings away from the escarpment crest, conduct periodic visual monitoring of drainage systems to ensure they remain functional and to report any observed changes in slope or drainage conditions to the DNV.

## TABLE OF CONTENTS

<b>EXECUTIVE SUMMARY .....</b>	<b>i</b>
<b>TABLE OF CONTENTS .....</b>	<b>iv</b>
<b>LIST OF TABLES .....</b>	<b>iv</b>
<b>LIST OF FIGURES .....</b>	<b>iv</b>
<b>LIST OF APPENDICES .....</b>	<b>v</b>
<b>LIST OF DRAWINGS .....</b>	<b>v</b>
<b>LIMITATIONS .....</b>	<b>vi</b>
<b>1.0 INTRODUCTION .....</b>	<b>1</b>
<b>1.1. Background .....</b>	<b>1</b>
<b>1.2. Risk Management Framework.....</b>	<b>2</b>
<b>2.0 RISK CONTROL .....</b>	<b>3</b>
<b>2.1. 1576 Merlynn Crescent .....</b>	<b>5</b>
<b>2.2. 1582 Merlynn Crescent .....</b>	<b>6</b>
<b>3.0 FIELD INSPECTIONS.....</b>	<b>7</b>
<b>3.1. 1576 Merlynn Crescent .....</b>	<b>7</b>
<b>3.2. 1582 Merlynn Crescent .....</b>	<b>7</b>
<b>4.0 RISK ASSESSMENT .....</b>	<b>9</b>
<b>4.1. General.....</b>	<b>9</b>
<b>4.2. Risk Tolerance Criteria .....</b>	<b>3</b>
<b>4.3. Results .....</b>	<b>9</b>
<b>5.0 SUMMARY AND RECOMMENDATIONS.....</b>	<b>11</b>
<b>6.0 CLOSURE .....</b>	<b>13</b>
<b>REFERENCES .....</b>	<b>14</b>

## LIST OF TABLES

Table 1-1.	DNV’s risk tolerance criteria (DNV, 2009) .....	4
Table 4-1.	2013 and 2017 individual landslide risk estimates .....	10

## LIST OF FIGURES

Figure 1-1	DNV Landslide Risk Management Cycle (after CAN/CSA-Q850-97).....	3
------------	--	---

## **LIST OF APPENDICES**

- APPENDIX A 1576 MERLYNN CRESCENT ASSURANCE OF PROFESSIONAL  
FIELD REVIEW AND COMPLIANCE
- APPENDIX B 1582 MERLYNN CRESCENT ASSURANCE OF PROFESSIONAL  
FIELD REVIEW AND COMPLIANCE
- APPENDIX C SITE INSPECTIONS
- APPENDIX D LANDSLIDE LIKELIHOOD, CONSEQUENCE, AND RISK ESTIMATES

## **LIST OF DRAWINGS**

- DRAWING 01 Location Map
- DRAWING 02 Greylynn Crescent, Merlynn Crescent and Carmaria Court

## LIMITATIONS

BGC Engineering Inc. (BGC) prepared this document for the account of 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 document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is 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 document.

As a mutual protection to our client, the public, and ourselves, all documents and drawings are submitted for the confidential information of our client for a specific project. Authorization for any use and/or publication of this document or any data, statements, conclusions or abstracts from or regarding our documents 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. A record copy of this document is on file at BGC. That copy takes precedence over any other copy or reproduction of this document.

## 1.0 INTRODUCTION

The District of North Vancouver (DNV) retained BGC Engineering Inc. (BGC) to reassess the landslide risk at three properties along the Westlynn Escarpment, North Vancouver. DNV requested BGC complete this reassessment following removal of fill material and the construction of new retaining walls at the 1576 and 1582 Merlynn Crescent properties located along the crest of the Westlynn Escarpment.

The scope of this assessment includes:

- Review of available design and as-built documentation for the fill removal and the construction of the new retaining walls at 1576 and 1582 Merlynn Crescent at the crest of the escarpment (Drawings 01 and 02). Design and as-built documentation by others is provided in Appendix A and B.
- Collection of post fill removal and retaining wall construction field observations at 1576 and 1582 Merlynn Crescent to update the landslide risk assessment input parameters (Appendix C).
- Reassessment of the landslide risk to 1576 Merlynn Crescent, 1582 Merlynn Crescent and 2180 Carmaria Court (at the base of the escarpment) based on the current site conditions (Appendix D).
- Comparison of the landslide risk reassessment results to DNV's landslide risk tolerance criteria.

BGC's scope of work was outlined in a proposal, dated January 8, 2017 (BGC 2017). Work was carried out under the terms and conditions outlined in DNV's purchase order number 97812-OS-125 dated, March 26, 2017.

### 1.1. Background

In 2007, a preliminary landslide hazard assessment was completed by BGC for the Westlynn Escarpment, including an area located west of Hastings Creek that is referred to herein as the West Hastings Escarpment (Drawing 01). The results of the 2007 screening study were used by BGC and the DNV to prioritize locations where a more detailed Quantitative Risk Assessment (QRA) was required (BGC 2007). BGC completed a QRA for the highest priority areas in 2008 (BGC 2008). The results, based on information available at that time, indicated that landslide risks along the West Hastings Escarpment did not exceed the DNV's risk tolerance criteria for existing development, but did exceed the DNV's criteria for new development at some locations.

In 2011, a landslide initiated from below the 2590 and 2602 Lauralynn Drive properties and travelled down the slope to Carmaria Court (BGC 2011). The landslide was triggered by a leak in a water main along Lauralynn Drive. No structural damage to homes on Carmaria Court occurred as a result of the landslide, but the event modified slope conditions along the escarpment.

In 2013, work by Horizon Engineering Inc. (Horizon), carried out for the DNV at properties along the West Hastings Escarpment, identified other site conditions that may have changed since

BGC's 2007 and 2008 studies (Horizon 2013). These site conditions included the settlement of ornamental ponds, placement of additional fill and/or yard trimmings along the crest of the escarpment, and evidence of additional settlement and tension cracks within some of the backyards.

In 2013, DNV retained BGC to update the 2008 QRA along the West Hastings Escarpment. The objectives of this update were to compare the current site conditions to conditions that were observed in 2008, determine if the landslide risk levels have changed, and determine if the updated risk levels at any properties exceed the DNV's landslide risk tolerance criteria for existing and proposed new residential development (BGC 2013).

Results from the 2013 updated landslide risk assessment for the West Hastings Escarpment indicated that no properties at the slope crest posed an 'unacceptable' landslide risk; however, there was a greater than average likelihood of a landslide occurring at 1576 and 1582 Merlynn Crescent. Landslide risks at the crest of the slope for occupants of 1576 and 1582 Merlynn Crescent were found to be 'tolerable' according to DNV's landslide risk tolerance criteria (Section 1.3). Landslide risk estimates for 2180 Carmaria Court (located downslope) were found to be 'broadly acceptable' for slides originating from 1576 Merlynn Crescent and 'tolerable' for slides originating from 1582 Merlynn Crescent.

While the estimated risk of loss of life to home occupants from a landslide originating from these two properties continued to meet DNV's risk tolerance criteria for existing development, there was an elevated likelihood of a landslide occurring that could cause damage to public and private property along Carmaria Court. DNV elected to require that the property owners undertake remedial work to reduce the likelihood of landslide occurrence from these properties based on the results of the 2013 Horizon and BGC studies. Removal of fill and/or reconstruction of retaining walls were recommended by BGC (2013) and Horizon (2013b, 2014) as the most practical options to reduce landslide hazard at 1576 and 1582 Merlynn Crescent. Risk control measures implemented at these two properties is summarized in Section 1.3.

## **1.2. Risk Management Framework**

Following the January 19, 2005 landslide along the Berkley Escarpment, the DNV initiated a proactive risk-based approach to managing landslide hazards. DNV's risk based approach follows the risk management framework outlined in Figure 1-1. The framework follows the Canadian and international guidelines for risk management (CAN/CSA Q850-97).

To be consistent with the landslide risk estimates that were completed in 2008 and 2013, this updated landslide risk assessment follows the same framework, methodology, and risk tolerance criteria. Section 1.3 summarizes DNV's risk tolerance criteria. The reader should refer to BGC (2013) for additional information on landslide risk estimation, evaluation, and background on the West Hastings Escarpment.

The results of this updated QRA are intended to support the 'Action/Monitoring' phases of the risk management decision-making process (Figure 1-1).

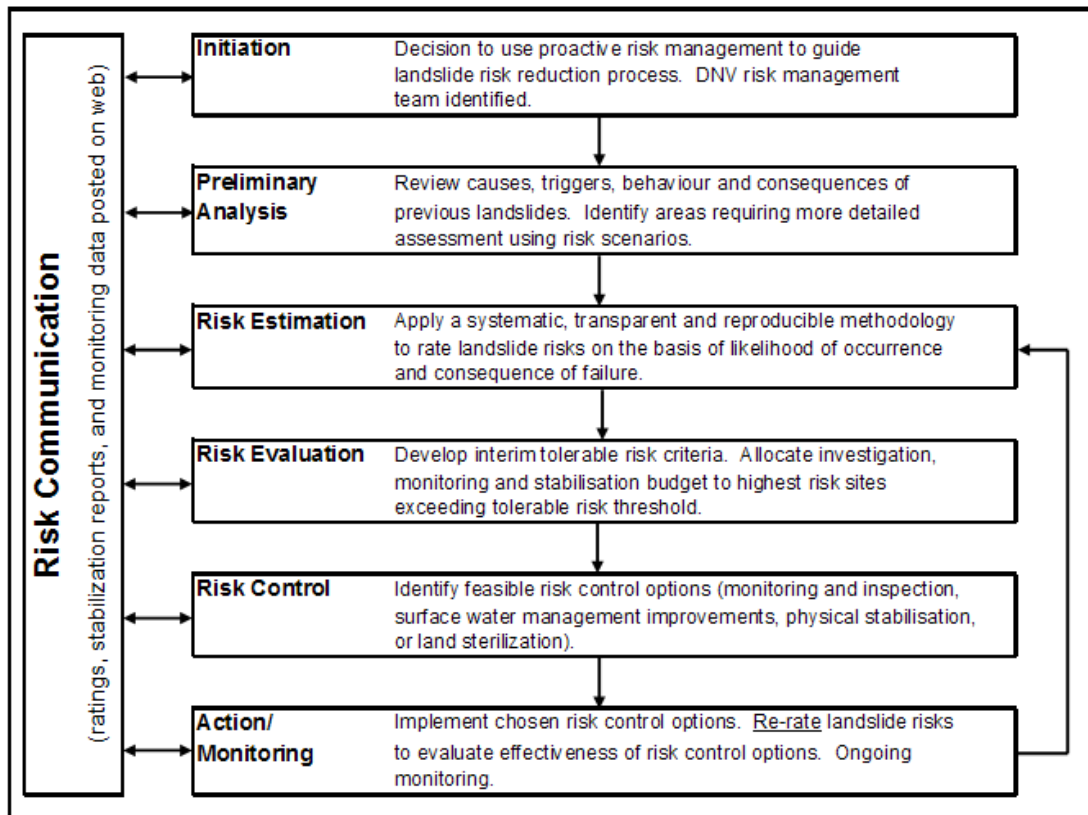


Figure 1-1. DNV Landslide Risk Management Cycle (after CAN/CSA-Q850-97).

### 1.3. Risk Tolerance Criteria

In 2009, the DNV adopted Natural Hazard Risk Tolerance Criteria for applicants for subdivisions, development approvals and building permits (DNV 2009). The purpose of the risk tolerance criteria is to reduce natural hazard risks posed to individuals to As Low As Reasonably Practicable (ALARP) and provide guidance for decision-makers approving new and existing developments. Typically, levels of landslide safety for homes located beneath steep escarpments or on debris flow fans are based on estimates of risk to loss of life, while levels of landslide safety for homes located on or above potentially unstable slopes are usually based on estimates of the factor of safety for a potential failure surface that intersects the building foundation. Factor of safety criteria are presented in Table 1-1.

**Table 1-1. DNV's risk tolerance criteria (DNV 2009)**

Application	Risk of Loss of Life (per annum)		Factor of Safety (static)	
	<1:10,000 + ALARP	<1:100,000	FOS >1.3	FOS >1.5
Existing Development <sup>1</sup>	X	-	X	-
New Development (including new retaining walls >1.2 m high) <sup>2</sup>	-	X	-	X

1. Application type: Building Permit (<25% increase to gross floor area)
2. Application type: Building Permit (>25% increase to gross floor area and/or retaining walls >1.2 m high), re-zoning, sub-division, new development.

Under non-static conditions, the slope stability factor of safety must be greater than 1.0 or predicted ground displacement must be less than 0.15 m with a 1:475 annual chance of exceedance for existing developments. For new developments and for re-developments involving an increase to gross floor area on the property of greater than 25%, the slope stability factor of safety must be greater than 1.0 or predicted ground displacement must be less than 0.15 m with a 1:2,475 annual chance of exceedance.

Where risk levels exceed  $10^{-4}$ , properties are shaded red on the DNV's landslide hazard and risk maps and the risks are considered 'unacceptable'. Where risk levels are less than  $10^{-4}$  but exceed  $10^{-5}$ , properties are shaded yellow on the DNV's landslide hazard and risk maps and the risks are considered 'tolerable' and within a range where further action should be taken to reduce risks to as low as reasonably practicable (ALARP). Risks less than  $10^{-5}$  are deemed 'broadly acceptable' and do not require further risk reduction.

## **2.0 RISK CONTROL**

As described in Section 1.1, DNV required that the property owners at 1576 and 1582 Merlynn Crescent undertake remedial work to reduce the likelihood of landslide initiation from their respective properties. Risk control measures implemented at each property are described below.

### **2.1. 1576 Merlynn Crescent**

#### **2.1.1. Design**

Based on site investigation work, including geotechnical reconnaissance, and subsurface investigations comprised of two test pits and one WildCat Dynamic Cone Penetration test, Horizon (2013b) identified three options for remedial works at 1576 Merlynn Crescent:

- Option 1: reslope
- Option 2: reslope and construct deck
- Option 3: construct retaining wall

For all of the above-listed options underpinning of the existing house addition was required. Horizon completed slope stability analyses under static and seismic conditions for each of the remedial options using two slope profiles. For Section A (at the south end of the property, including the deck), the potential critical slope failure surface was determined to have a Factor of Safety of approximately 1.3 for all of the proposed remedial options. For Section B (at the north end of the property, including the house), the potential critical slope failure surface was determined to have a Factor of Safety of approximately 1.4 for all proposed remedial options.

Under seismic conditions, the Factors of Safety for all proposed remedial options were found to be less than 1.0 for Section A and predicted ground displacements were approximately 0.3 m. Horizon (2013) found this to be tolerable displacement for a slope failure surface that does not intersect a house. For Section B, the Factors of Safety for all proposed remedial options were found to be less than 1.0 and predicted ground displacements were approximately 0.15 m (Horizon, 2013).

The slope stability analyses completed by Horizon indicate that DNV's risk tolerance criteria using the Factor of Safety method is met by all of the proposed remedial options for sections intersecting the house (Section B).

The homeowner elected to construct a retaining wall and complete shotcrete underpinning of the existing house addition (Option 3). The design and construction was subsequently taken over by GeoPacific Consultants Ltd. (GeoPacific). Documentation demonstrating GeoPacific's design met DNV's Factor of Safety risk tolerance criteria was not available for review

#### **2.1.2. Construction**

Between 2015 and 2016, fill removal and reconstruction of the retaining wall was undertaken at 1576 Merlynn Crescent. The existing timber crib retaining wall was replaced with a 2.4 m high concrete retaining wall, extended by two planters, on the east side of the property at the crest of

the slope. According to a memo prepared by GeoPacific dated October 18, 2016, the concrete retaining wall is supported with 13 helical piles with additional support against overturning provided by a buttress wall constructed behind the middle section of the retaining wall. A sump and pump system was also installed on the southeast end of the retaining wall. As-built drawings and Letters of Assurance for the geotechnical, structural and plumbing components of the work are provided in Appendix A.

## **2.2. 1582 Merlynn Crescent**

### **2.2.1. Design**

Based on site investigation work, including geotechnical reconnaissance, and subsurface investigations comprised of two test pits and four WildCat Dynamic Cone Penetration test, Horizon (2014) identified three options for remedial works at 1582 Merlynn Crescent:

- Option 1: reslope
- Option 2: reslope and construct deck
- Option 3: construct retaining wall

Horizon completed slope stability analyses under static and seismic conditions for each of the remedial options using two slope profiles. For Section A (at the south end of the property, including the patio), the potential critical slope failure surface was determined to have a Factor of Safety of approximately 1.5 for all of the proposed remedial options. For Section B (at the north end of the property, including the house), the potential critical slope failure surface was determined to have a Factor of Safety of approximately 1.8 for all proposed remedial options.

Under seismic conditions, the Factors of Safety for all proposed remedial options were found to be approximately 1.0 for both Section A and Section B.

The slope stability analyses completed by Horizon indicate that DNV's risk tolerance criteria using the Factor of Safety method is met by all proposed remedial options at 1582 Merlynn Crescent.

### **2.2.2. Construction**

Between November 2014 and March 2015, fill removal and reconstruction of the retaining wall was undertaken at 1582 Merlynn Crescent. The existing timber crib retaining was replaced with a 2 m to 2.5 m high mechanically stabilized earth (MSE) retaining wall constructed by the Cavalry Construction Group. Horizon completed the design and construction supervision work for the project. Letters of Assurance, design drawings and field review reports for the wall construction completed by Horizon are provided in Appendix B.

### **3.0 FIELD INSPECTIONS**

The site visit for the risk reassessment at the 1576 and 1582 Merlynn Crescent properties was completed on March 22, 2017, by Sarah Kimball, P.Geo. and Heidi Manicke, E.I.T. of BGC. Visual observations at each location focused on the main factors affecting slope stability that were determined during BGC's prior studies along the Berkley Escarpment. These factors include:

- Slope angles
- The presence and thickness of fill near the escarpment crest
- Evidence of slope deformation at the slope crest and mid-escarpment
- The nature of tree cover on the escarpment
- The presence and condition of retaining walls, pools, and ponds
- The distance from each top-slope residence to the crest of the escarpment
- The slope angle from each mid-slope residence to the crest of the escarpment
- Sources of surface drainage directed towards the crest of the escarpment.

Field inspection forms were used to record the slope observations, ensuring a systematic and consistent approach. The field forms also allow new observations to be compared to the observations collected in the 2013 risk assessment.

Field inspection forms and representative site photographs are provided in Appendix C. Evidence of historic landslide activity and the location of key features are shown on Drawing 02.

Civic addresses were used to reference the field inspections and the quantitative risk estimates to communicate the landslide risk along the West Hastings Escarpment to the public. It should be noted that potential landslide initiation zones are not precisely known and are not related to the specific property boundaries. Landslide initiation zones can cross property boundaries.

Site observations from the field inspections are summarized in Section 3.1 and 3.2 below.

#### **3.1. 1576 Merlynn Crescent**

The single-family home of 1576 Merlynn Crescent is situated approximately 4.5 m upslope from the escarpment crest (Photograph 1, Appendix C). A concrete retaining wall with an overall height of 2.4 m was recently constructed along the crest of the slope (Photographs 2 and 3, Appendix C). Slope angles downslope of the retaining wall are approximately 40°. No deterioration of the escarpment slope conditions below the retaining wall was noted since the 2013 field inspections.

According to DNV's Geoweb, the perimeter drains for the residence have been connected to the storm outfall network since the 2013 assessment.

#### **3.2. 1582 Merlynn Crescent**

The single-family home of 1582 Merlynn Crescent is situated approximately 8 m upslope of the escarpment crest (Photographs 4 and 5, Appendix C). An MSE retaining wall that has an overall height ranging from 2.0 m to 2.5 m is located along the slope crest (Photographs 6 and 7, Appendix C). Slope angles downslope of the retaining wall are approximately 41°. No

deterioration of the escarpment slope conditions below the retaining wall was noted since the 2013 field inspections.

Settlement was observed in the backyard of 1582 Merlynn Crescent, where patio stones at the south side of the patio had settled approximately 15 to 20 cm (vertical distance) (Photograph 8). This settlement is interpreted to predate the construction of the retaining wall. Settlement was also observed on the south side of the property along a newly constructed fence. Settlement in this area was interpreted to be related to the removal of shrubs previously located in this area.

An approximately 10 cm 'bulge' was observed on the northwest end of the retaining wall in the fourth row (from the top). Based on the lack of additional wall deformation indicators and the fact that the bulge was isolated to a single MSE wall cage, the bulge was interpreted to be related to damage or over-compaction of the wall materials adjacent to the cage face.

In BGC's (2013) report the risk algorithm's water score for 1582 Merlynn Crescent was manually adjusted to include the potential of surface water runoff from 1588 Merlynn Crescent (because of topography). Since 2013, BGC understands 1582 Merlynn Crescent has been connected to DNV's stormwater network which the Berkley Method accounts for with a lower water score. For 1582 Merlynn Crescent, the drainage over the slope has improved with the addition of the retaining wall work and internal wall drainage. The escarpment slope is still potentially subject to surface water runoff from the neighbouring property, therefore a range of water scores is presented (Scenario A and B in Appendix D).

## **4.0 RISK ASSESSMENT**

### **4.1. General**

An algorithm referred to as the Berkley Escarpment Method was used to estimate the individual landslide risk for properties located at the crest and base of the West Hastings Escarpment (BGC 2006a, 2006b). This methodology was developed in 2005 and 2006, to estimate the annual probability of extremely rapid, flow-type landslides originating from the crests of escarpments in the Berkley area, and the associated potential risk of loss of life to home occupants. Since 2007, the Berkley Escarpment Method has been used to estimate landslide hazard and risk along other DNV escarpments that share a similar geological setting and residential development history. This included the 2008 and 2013 risk assessments along the West Hastings Escarpment.

Individual risk of loss of life from a landslide is the incremental risk to the individual by the existence of a landslide hazard. The individual risk is usually expressed as an annual probability of loss of life as a result of the hazard. Individuals most at risk from a landslide hazard are the ones that spend the most time in their homes at the base of the escarpment or in their backyards at the crest of the escarpment. At the crest of the escarpment, it was assumed that individuals most at risk spend up to 15 minutes per day, on average, in their backyard on rainy days during the winter months when slides are more likely to occur. It was assumed that individuals at the base of the escarpment spend 16 hours per day in their home on rainy days during the winter months.

### **4.2. Results**

Risk estimates for two properties along the escarpment crest and one property along the base of the slope were estimated for the landslide risk reassessment. Table 4-1 compares the updated 2017 individual risk estimates following mitigation for 1576 Merlynn Crescent, 1582 Merlynn Crescent, and 2180 Carmaria Court with the estimates from the 2013 QRA described in Section 1.1. Individual risk calculations and results are presented in Appendix D.

**Table 4-1. 2013 and 2017 individual landslide risk estimates**

Property Location	2013 Estimate		2017 Estimate	
	Numeric	Description	Numeric	Description
1576 Merlynn Crescent	$5.0 \times 10^{-5}$	Tolerable	$1.8 \times 10^{-6}$	Broadly Acceptable
1582 Merlynn Crescent	$2.0 \times 10^{-5}$	Tolerable	$1.1 \times 10^{-6}$ to $2.1 \times 10^{-6}$	Broadly Acceptable
2180 Carmaria Court <sup>1</sup>	$5.8 \times 10^{-6}$	Broadly Acceptable	$2.0 \times 10^{-7}$	Broadly Acceptable
2180 Carmaria Court <sup>2</sup>	$7.7 \times 10^{-5}$	Tolerable	$6.7 \times 10^{-6}$ to $1.3 \times 10^{-5}$	Broadly Acceptable to Tolerable

Notes:

1. For potential landslide sources originating from 1576 Merlynn Crescent.
2. For potential landslide sources originating from 1582 Merlynn Crescent.

Based on the  $10^{-4}$  per annum risk acceptance criteria for existing developments, no potential landslide source areas within the study area were found to pose an 'unacceptable' landslide risk to individuals at the crest or the base of the escarpment.

Individual risk slightly exceeding  $10^{-5}$  (or a 1 chance in 100,000) per year was estimated for the 2180 Carmaria Court property for slides originating from 1582 Merlynn Crescent with the range of water scores presented and is highlighted in yellow on Drawing 02. With no manual adjustment of the water score, the individual risk estimate at 2180 Carmaria Court meets the  $10^{-5}$  tolerance criteria. The upper end of the risk estimate assuming a manually adjusted water score is  $1.3 \times 10^{-5}$  which is very close to the boundary between 'tolerable' and 'broadly acceptable'.

## 5.0 SUMMARY AND RECOMMENDATIONS

Between 2014 and 2016 fill removal and the construction of new retaining walls was completed at 1576 and 1582 Merlynn Crescent located along the crest of the Westlynn Escarpment. BGC reviewed the retaining wall design and as-built documentation and collected post construction field observations at 1576 and 1582 Merlynn Crescent. The updated site observations were used to reassess the landslide risk to occupants of 1576 Merlynn Crescent, 1582 Merlynn Crescent and 2180 Carmaria Court.

The risk control measures described in Sections 2.0 and 3.0 at 1576 Merlynn Crescent and 1582 Merlynn Crescent have reduced the likelihood of a landslide originating from either of the two properties located along the escarpment crest. At 1576 Merlynn Crescent, the likelihood of a landslide origination has reduced from  $1.5 \times 10^{-2}$  in the 2013 assessment to  $5.25 \times 10^{-4}$  in this assessment (about a factor of 28). At 1582 Merlynn Crescent, the likelihood of a landslide originating has reduced from  $6.0 \times 10^{-3}$  in the 2013 assessment to  $5.25 \times 10^{-4}$  to  $1.05 \times 10^{-3}$  in this assessment (about a factor of 5 to 11). Consequently, landslide risk levels for individuals in homes at the crest of the slope have decreased.

Slope stability analyses by the Engineer of Record confirming that DNV's factor of safety risk tolerance criteria for 1576 Merlynn Crescent were not available, however Letters of Assurance, as-built documentation by the Engineer of Record (Appendix A) and an options assessment completed by Horizon (2013b) imply this criterion has likely been met.

Slope stability analyses (Horizon 2014) and Letters of Assurance (Appendix B) for 1582 Merlynn Crescent indicate DNV's factor of safety risk tolerance criteria have been met.

Reassessment of the landslide risk for homes at the crest of the escarpment indicates landslide risks to occupants of 1576 and 1582 Merlynn Crescent have improved from 'tolerable' in the 2013 QRA to 'Broadly Acceptable' in this assessment. Landslide risk estimates for homes at the crest of the escarpment continue to meet DNV's risk tolerance criteria for quantitative risk assessments.

Reassessment of the landslide risk for the 2180 Carmaria Court property located downslope indicates landslide risk remains 'broadly acceptable' for slides originating from 1576 Merlynn Crescent and 'broadly acceptable' to 'tolerable' for potential landslide sources originating from 1582 Merlynn Crescent depending on landslide risk input parameters for surface runoff from neighboring properties. Risks from potential landslide sources originating from the 1576 and 1582 Merlynn Crescent properties continue to meet DNV's risk tolerance criteria for existing developments. However, according to the ALARP principle, 'tolerable' risks should be kept under review and reduced further if practical.

Given that the home at 1582 Merlynn Crescent is connected to the municipal storm sewer system and that fill removal and retaining wall reconstruction have already been undertaken and meet DNV's factor of safety risk tolerance criteria (Horizon, 2014), additional remediation work at this time does not seem practical. As such, we recommend that periodic visual monitoring of this slope and others along with West Hastings escarpment is conducted to ensure that drainage systems remain functional, to confirm that observed slope deformation abate, and to prevent new

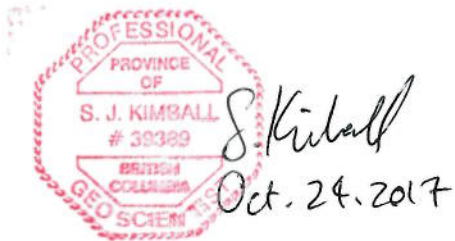
surface erosion or landslide hazards from developing and going undetected. We suggest that the DNV encourage property owners or members of the public to report any observed changes in slope or drainage conditions.

## 6.0 CLOSURE

We trust the above satisfies your requirements at this time. Should you have any questions or comments, please do not hesitate to contact us.

Yours sincerely,

**BGC ENGINEERING INC.**  
per:



Sarah Kimball, M.A.Sc., P.Geo.  
Engineering Geologist

Reviewed by:

Sam Fougère, M.Sc., P.Geo.  
Senior Engineering Geologist

SK/SF/mjp/bmn

## REFERENCES

- BGC Engineering Inc. 2006a. District of North Vancouver, Berkley Landslide Risk Management, Phase 1 Risk Assessment. January 13, 2006.
- BGC Engineering Inc. 2006b. District of North Vancouver, Berkley Landslide Risk Management, Phase 2 Assessment of Risk Control Options. May 11, 2006.
- BGC Engineering Inc. 2007. District of North Vancouver, Westlynn and Pemberton Heights Escarpments, Preliminary Landslide Hazard Assessment. Report prepared for District of North Vancouver dated November 29, 2007.
- BGC Engineering Inc. 2008. District of North Vancouver, Westlynn and Pemberton Heights Escarpments, Landslide Risk Assessment. Report prepared for District of North Vancouver dated November 27, 2008.
- BGC Engineering Inc. 2011. District of North Vancouver. 2590-2602 Lauralynn Drive Landslide. Draft project memorandum prepared for District of North Vancouver dated September 27, 2011.
- BGC Engineering Inc. 2013. District of North Vancouver, Quantitative Risk Assessment (QRA) Updated for the West Hastings Escarpment. Report prepared for District of North Vancouver dated April 4, 2013.
- BGC Engineering Inc. 2017. 1576 and 1582 Merlynn Crescent Risk Reassessment. Proposal prepared for the District of North Vancouver dated January 16, 2017.
- CAN/CSA-Q850-97. Risk Management: Guidelines for Decision Makers. Prepared by Canadian Standards Association.
- District of North Vancouver. 2009. Risk Tolerance Criteria. Presentation to the District of North Vancouver Council. November 16, 2009.
- Horizon Engineering Inc. 2013a. Slope Stability Assessment Hastings Park, North Vancouver, BC. Geotechnical Investigation Report – Draft. Report prepared for District of North Vancouver dated February 18, 2013.
- Horizon Engineering Inc. 2013b. 1576 Merlynn Crescent, North Vancouver, BC. Geotechnical Report – Proposed Remedial Earthworks. Report prepared for Mostafa Madaninejad dated November 1, 2013.
- Horizon Engineering Inc. 2014. 1582 Merlynn Crescent, North Vancouver, BC. Geotechnical Report (Revised). Report prepared for William Wallace dated October 1, 2014.
- Horizon Engineering Inc. 2016. 1576 Merlynn Crescent, North Vancouver. Geotechnical Letters of Assurance. Letter prepared for DNV Building Department, Plan Checker dated January 11, 2016.

## **APPENDIX C SITE INSPECTIONS**

<b>SITE OBSERVATIONS:</b>	<b>DNV Landslide Risk Assessment</b>
<b>ESCARPMENT:</b>	<b>West Hastings</b>
<b>PROPERTY:</b>	<b>1576 Merlynn Crescent</b>
<b>INSPECTION DATE: (mm/dd/yy)</b>	<b>03/22/2017</b>
<b>WEATHER:</b>	<b>Overcast &amp; rain</b>
<b>BGC PERSONNEL:</b>	<b>SJK / HM</b>



<b>THICKNESS OF LOOSE MATERIALS</b>	<b>&lt;1 m</b>	<b>1-2 m</b>	<b>2-3 m</b>	<b>&gt;3 m</b>
<b>SLOPE CREST</b>	<b>X</b>			
<b>10 m DOWNSLOPE FROM SLOPE CREST</b>			<b>X</b>	

<b>SLOPE BELOW CREST / RETAINING STRUCTURE</b>	<b>SLOPE = 40°</b>		
	<b>CRACKS</b>	<b>SLIDES</b>	<b>EROSION</b>
		<b>X</b>	

**OBSERVATIONS:** Overgrown bowl shaped feature along slope suggests historic slide. Retaining wall setback 0.2 m to 2 m from crest.

<b>TREES BELOW CREST / RETAINING STRUCTURE</b>	<b>STRAIGHT</b>	<b>PISTOL-BUTT</b>	<b>LEANING</b>
<b>PERCENT CONIFER:</b>	<b>75%</b>		<b>X</b>

**OBSERVATIONS:** Area below retaining wall (approximately 15 m downslope from wall) has been recently cleared, including 5 large (~1 m) in diameter tree stumps near the crest at the north end of the property. Woody debris and concrete debris found on the slope below the retaining structure.

<b>RETAINING STRUCTURES</b>	<b>YES X</b>	<b>NO</b>	<b>HEIGHT: 2.4 m</b>	
<b>TYPE: Concrete with 12 helical piles</b>	<b>BLOCKS</b>	<b>CONCRETE</b>	<b>TIMBER CRIB</b>	<b>OTHER</b>
		<b>X</b>		
<b>DEFORMATION</b>	<b>UNDEFORMED</b>	<b>CRACKED</b>	<b>SETTLED</b>	<b>BULGING</b>
	<b>X</b>			

**OBSERVATIONS:** Backyard has been backfilled with 2cm pebbles (poorly graded, well rounded). 1.2 m high planter boxes have been constructed on either side of the retaining wall. A pump system was observed in the south corner of the retaining wall.

<b>BACKYARD DEFORMATION</b>	<b>YES</b>	<b>NO X</b>
-----------------------------	------------	-------------

**LOCATION & DESCRIPTION:** No settlement observed in patio stones or cracks in concrete retaining structure.

<b>SEEPAGE / SPRINGS IN OR BELOW FILL</b>	<b>YES</b>	<b>NO X</b>	<b>POOLS</b>	<b>YES</b>	<b>NO X</b>
			<b>OBSERVATIONS:</b>		
<b>OBSERVATIONS:</b> Setback from retaining wall to closest part of the house is 4.5m, retaining wall to farther wall of the house is 10 m			<b>HOUSE DISTANCE TO CREST</b>	4.5 – 10 m	

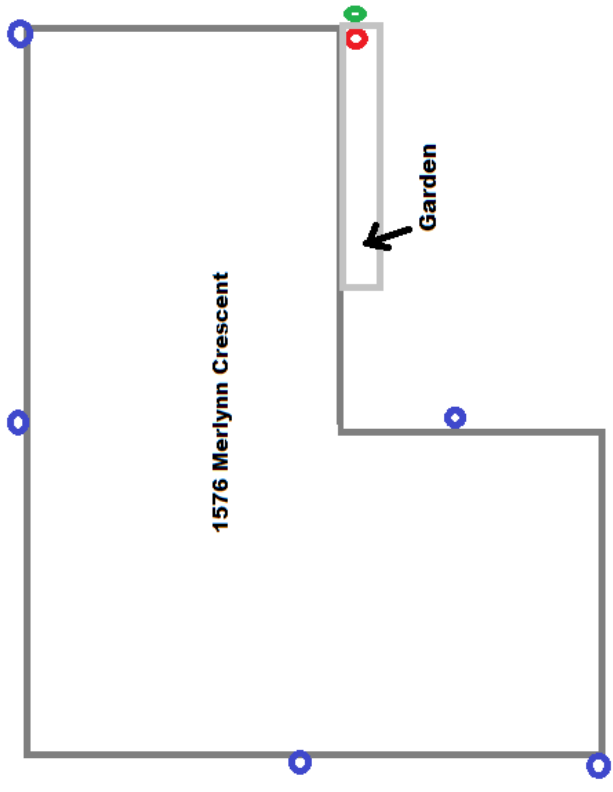
<b>SURFACE RUNOFF FROM:</b>	<b>BACKYARD</b>	<b>½ ROOF</b>	<b>FULL ROOF</b>	<b>FRONT YARD</b>	<b>STREET</b>
				<b>X</b>	

**OBSERVATIONS:** Pump system located in southeast corner of backyard.

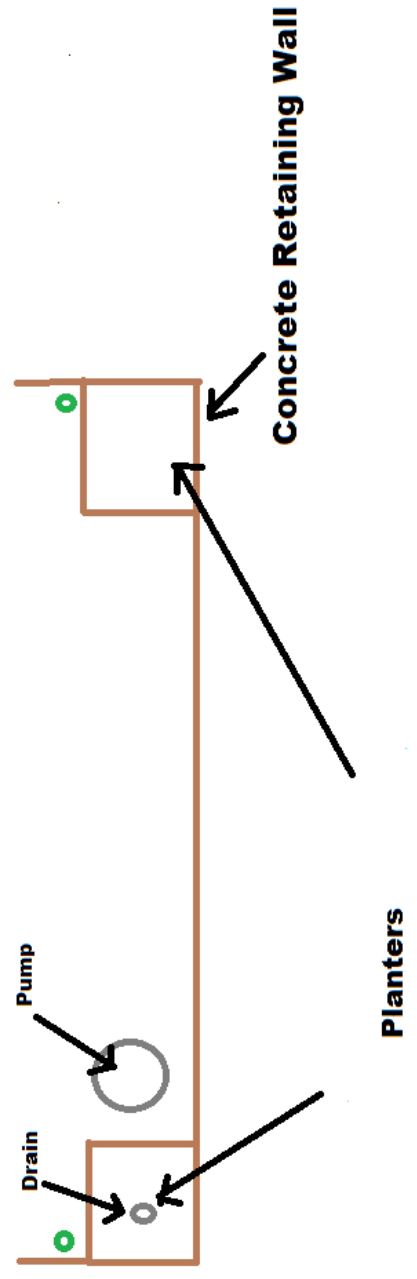
**GENERAL OBSERVATIONS:** Retaining wall is 2.3 tall from top to bottom with 1.2 m high planter boxes on either side. A drain was observed on the south side planter box, but none was found on the north side planter box.



**NTS**



- Drains into ground
- Drains into garden
- PVC pipe





**Photograph 1. 1576 Merlynn Crescent – Front view of house from street.**



**Photograph 2. 1576 Merlynn Crescent – Looking north across backyard with fence at the top of concrete retaining wall.**



**Photograph 3. 1576 Merlynn Crescent – Looking northeast at the escarpment slope below the concrete retaining wall.**

<b>SITE OBSERVATIONS:</b>	<b>DNV Landslide Risk Assessment</b>
<b>ESCARPMENT:</b>	<b>West Hastings</b>
<b>PROPERTY:</b>	<b>1582 Merlynn Crescent</b>
<b>INSPECTION DATE:</b> (mm/dd/yy)	<b>03/22/2017</b>
<b>WEATHER:</b>	<b>Cloudy and Rain</b>
<b>BGC PERSONNEL:</b>	<b>SJK / HM</b>



<b>THICKNESS OF LOOSE MATERIALS</b>	<b>&lt;1 m</b>	<b>1-2 m</b>	<b>2-3 m</b>	<b>&gt;3 m</b>
<b>SLOPE CREST</b>	<b>X</b>			
<b>10 m DOWNSLOPE FROM SLOPE CREST</b>		<b>X</b>		

<b>SLOPE BELOW CREST / RETAINING STRUCTURE</b>	<b>SLOPE = 41 °</b>		
	<b>CRACKS</b>	<b>SLIDES</b>	<b>EROSION</b>
		<b>X</b>	
<b>OBSERVATIONS:</b> No tension cracks observed in backyard above retaining wall. No erosion observed. Relict bowl-shaped structure located downslope of retaining wall.			

<b>TREES BELOW CREST / RETAINING STRUCTURE</b>	<b>STRAIGHT</b>	<b>PISTOL-BUTT</b>	<b>LEANING</b>
<b>PERCENT CONIFER:</b>	<b>70%</b>	<b>X</b>	
<b>OBSERVATIONS:</b> The slope is void of trees downslope of the retaining wall. Trees located on either side of the slope are pistol-butt.			

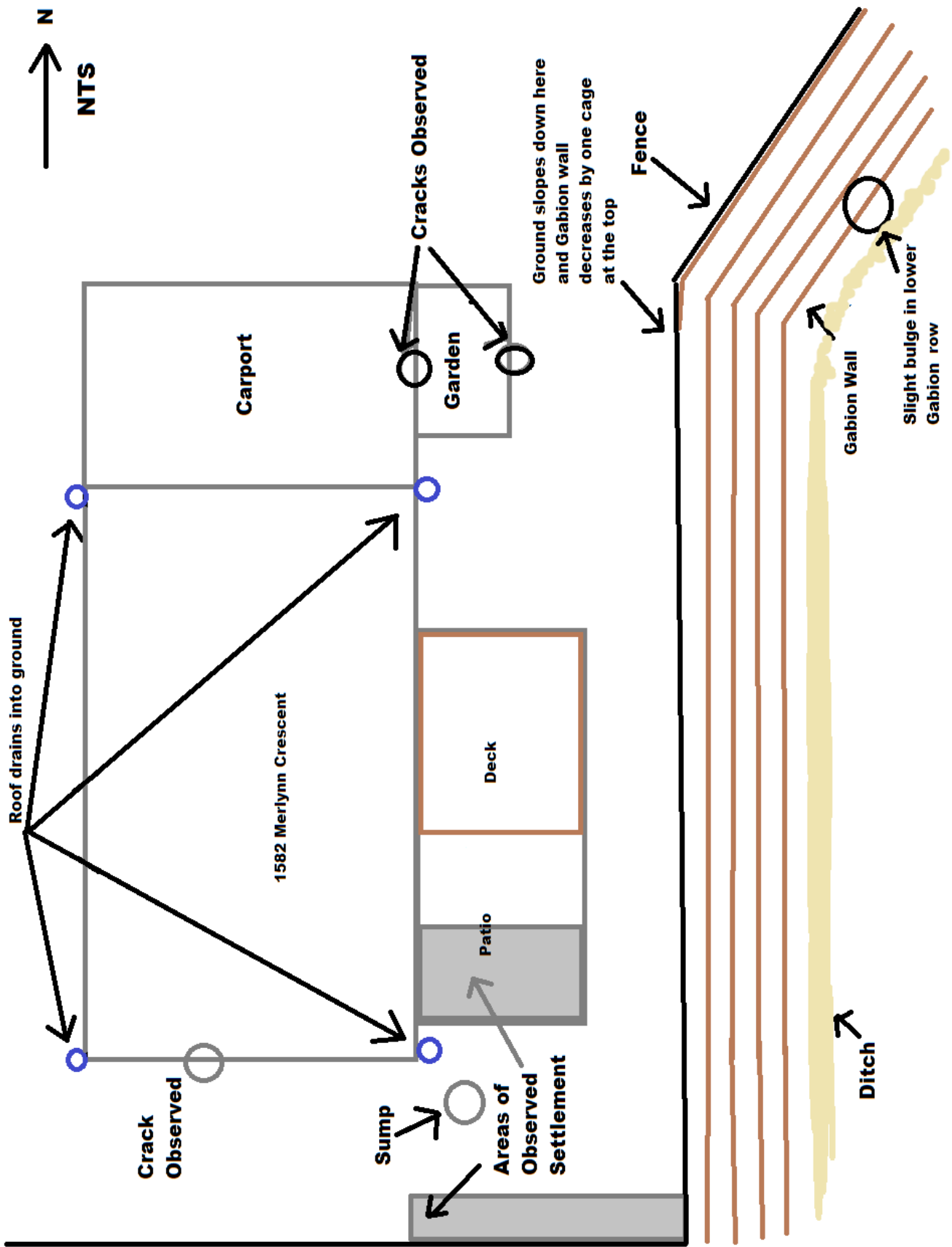
<b>RETAINING STRUCTURES</b>	<b>YES X</b>	<b>NO</b>	<b>HEIGHT: 2 to 2.5 m</b>	
<b>TYPE : MSE Wall</b>	<b>BLOCKS</b>	<b>CONCRETE</b>	<b>TIMBER CRIB</b>	<b>OTHER</b>
				<b>X</b>
<b>DEFORMATION</b>	<b>UNDEFORMED</b>	<b>CRACKED</b>	<b>SETTLED</b>	<b>BULGING</b>
				<b>X</b>
<b>OBSERVATIONS:</b> Observed 4 <sup>th</sup> cage from the top is damaged (bent outwards 5 to 10 cm), likely related to construction. MSE wall is 4 to 5 cages high (cage height 0.5 m).				

<b>BACKYARD DEFORMATION</b>	<b>YES X</b>	<b>NO</b>
<b>LOCATION &amp; DESCRIPTION:</b> Settlement of patio stones observed on south side of patio area (roughly 15 to 20 cm vertical depth) interpreted to pre-date construction of MSE wall. Approximately 1 meter wide strip of lawn on south side of lot perpendicular to retaining wall, along fence, roughly 5 cm settled and unvegetated – possibly due to construction of fence or adjacent retaining wall. No tension cracks observed.		

<b>SEEPAGE / SPRINGS IN OR BELOW FILL</b>	<b>YES</b>	<b>NO X</b>	<b>POOLS</b>	<b>YES</b>	<b>NO X</b>
	<b>OBSERVATIONS:</b>				
<b>OBSERVATIONS:</b>			<b>HOUSE DISTANCE TO CREST</b>	<b>8 m</b>	

<b>SURFACE RUNOFF FROM:</b>	<b>BACKYARD</b>	<b>½ ROOF</b>	<b>FULL ROOF</b>	<b>FRONT YARD</b>	<b>STREET</b>
				<b>X</b>	
<b>OBSERVATIONS:</b> Road curb at the crest of the driveway is 4 cm high.					

<b>GENERAL OBSERVATIONS:</b>
Some yard waste (felled trees) located on the slope. No drains were located on the slope. The deck posts located approximately 3.5 m from the house are straight. Some cracks were noted in the carport foundation and garden retaining wall. The cages of the MSE wall on the north side were filled with clean granite cobbles, while the gabion cages on the south side of the wall included more fines and organics on top of and inside the cages. A small, approximately 0.5 m wide ditch is located downslope of the retaining wall. Perimeter drains and downspouts appear to go to the front yard. Crack noted on the south side of the home.





**Photograph 4. 1582 Merlynn Crescent – Front view of house from street.**



**Photograph 5. 1582 Merlynn Crescent – Looking south at backyard. Wood fence is located on top of the retaining wall at the escarpment crest.**



**Photograph 6. 1582 Merlynn Crescent – Looking north at slope crest and GRS retaining wall. Red square showing location of close-up in Photograph 7.**



**Photograph 7. 1582 Merlynn Crescent – Slight bulge (~ 10 cm) in lower row cage (red circle). This is interpreted to be the result of construction damage.**



**Photograph 8. 1582 Merlynn Crescent – Arrows show settlement of lawn near fence (yellow) and in patio stones (red).**

## **APPENDIX D**

# **LANDSLIDE LIKELIHOOD, CONSEQUENCE, AND RISK ESTIMATES**

**Summary of Field Observations**

Address	Loose Materials at Crest	Loose Materials Down Slope	Slope Angle	Slope Deformation	% Conifers	Tree Condition	Retaining Wall	Wall Type	Wall Deformation	Backyard Deformation	Dist. To Crest	Runoff From	Pool or Hot Tub	Pool Condition	Seepage	Conn. Storm Sewer (DNV)	Mostly Gravels in Auger Holes
1582 Merlynn Crescent (2013)	2-3m	1-2m	>40 deg.	Slides	50-75%	Straight	Yes	Timbers	Bulging	Cracked	3-6m	Frontyard	No	NA	No	Yes	No
1582 Merlynn Crescent (2017)	<1m	1-2m	>40 deg.	Slides	50-75%	Pistol Butt	Yes	Other	None	None	6-9m	Frontyard	No	NA	No	Yes	No
1576 Merlynn Crescent (2013)	2-3m	2-3m	>40 deg.	Slides	50-75%	Leaning	Yes	Timbers	Bulging	Settled	3-6m	Frontyard	No	NA	No	No	No
1576 Merlynn Crescent (2017)	<1m	2-3m	>40 deg.	Slides	50-75%	Leaning	Yes	Concrete	None	None	3-6m	Frontyard	No	NA	No	Yes	No

Notes:

1. In the 2013 inspections, the general tree conditions were interpreted to be straight. In 2017, the tree condition was interpreted to be pistol butt based on the presence of multiple pistol butt trees. The difference is attributed to a difference in judgement by the inspectors.
2. Backyard deformation at 1582 Merlynn Crescent was observed in the 2017, however the deformation is interpreted to pre-date the construction of the retaining wall (i.e. the patio stones) or be construction related (i.e. along the southern property boundary). This deformation is not a reflection of the current overall slope conditions, therefore backyard deformation was classified as 'None' for the purposes of the 2017 risk estimate.

**Landslide Likelihood Estimates for Extremely Rapid Flow Type Failures**

Average Slide Likelihood = 0.0024 2.40E-03

Address	Slope Score	Soil Crest	Soil Slope	Soil Sum	Soil Score	Water Score *	Def Crest	Def Slope	Def Sum	Deformation Score	Gravel Content	Adjustment Factor	P <sub>slide</sub>
1582 Merlynn Crescent (2013)	1.25	1	0	1	1	1	1	1	2	2	1	2.500	0.0060
1582 Merlynn Crescent (2017)_Scenario A	1.25	0	0	0	0.35	1	0	1	1	1	1	0.438	0.0011
1582 Merlynn Crescent (2017)_Scenario B	1.25	0	0	0	0.35	0.5	0	1	1	1	1	0.219	0.0005
1576 Merlynn Crescent (2013)	1.25	1	1	2	2	1.25	1	1	2	2	1	6.250	0.0150
1576 Merlynn Crescent (2017)	1.25	0	1	1	0.35	0.5	0	1	1	1	1	0.219	0.0005

BGC (2013), manually adjusted the water score at 1582 Merlynn Crescent to reflect potential surface runoff directed on to this site from neighbouring properties.  
 Scenario A refers to water score manually adjusted, Scenario B refers to water score as per Berkleyalgorithm (no manual adjustment)

**BGC Summary Stats**

2	<0.001
1	0.001 to 0.005
2	>0.005
Total	

2013		2017	
0.021	48	0.002	635
(slides/year)	(years/slide)	(slides/year)	(years/slide)

**Risk Estimates at Base of Escarpment**

Address	# Houses >25°	# Houses >23°	# Houses >21°	# Houses 19-21°	House Spatial (P <sub>S,H</sub> )	Occupant Temporal (P <sub>T,S</sub> )	Occupant Vulnerability (V)	Element Value (E)	N (Fatalities)	F (P <sub>slide</sub> )	Societal Risk (per year)
1582 Merlynn Crescent (2013)	0	0	1	0	0.07	0.50	0.29	4	3.8E-02	6.0E-03	2.3E-04
<b>1582 Merlynn Crescent (2017)_Scenario A</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>0.07</b>	<b>0.50</b>	<b>0.29</b>	<b>4</b>	<b>3.8E-02</b>	<b>1.1E-03</b>	<b>4.0E-05</b>
<b>1582 Merlynn Crescent (2017)_Scenario B</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>0.07</b>	<b>0.50</b>	<b>0.29</b>	<b>4</b>	<b>3.8E-02</b>	<b>5.3E-04</b>	<b>2.0E-05</b>
1576 Merlynn Crescent (2013)	0	0	0	1	0.002	0.50	0.29	4	1.2E-03	1.5E-02	1.7E-05
<b>1576 Merlynn Crescent (2017)</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0.002</b>	<b>0.50</b>	<b>0.29</b>	<b>4</b>	<b>1.2E-03</b>	<b>5.3E-04</b>	<b>6.1E-07</b>

**Individuals Most At Risk (16 hrs/day)**

If Houses >25°	If Houses >23°	If Houses >21°	If Houses <21°
6.2E-04	1.6E-04	7.7E-05	2.3E-06
1.1E-04	2.7E-05	1.3E-05	4.1E-07
5.4E-05	1.4E-05	6.7E-06	2.0E-07
1.5E-03	3.9E-04	1.9E-04	5.8E-06
5.4E-05	1.4E-05	6.7E-06	2.0E-07

Estimates only apply in locations where houses are present

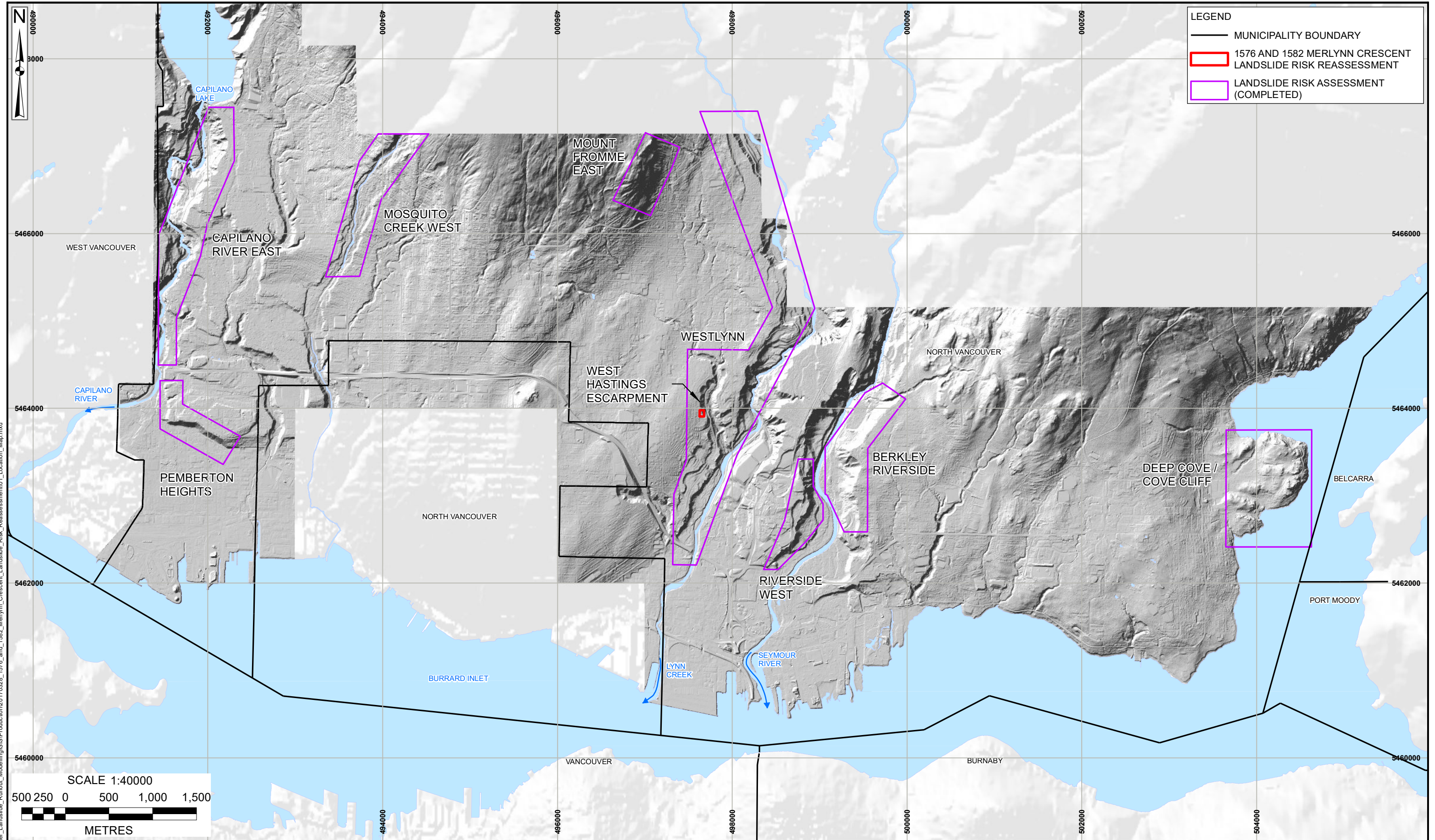
2013		2017_Scenario A		2017_Scenario B	
0.00025	4047	0.00004	24508	0.00002	48295
(fatalities/year)	(years/fatality)	(fatalities/year)	(years/fatality)	(fatalities/year)	(years/fatality)

Change	
2180 Carmaria (from 1582_A)	6.3E-05
2180 Caramaria (from 1582_B)	7.0E-05
2180 Carmaria (from 1576)	5.6E-06




**Risk Estimates at Crest of Escarpment**

Address	Yard Spatial ( $P_{S:H}$ )	Occupant Temporal ( $P_{T:S}$ )	Occupant Vulnerability (V)	Element Value (E)	N (Fatalities)	F ( $P_{slide}$ )	Societal Risk (per year)	Individuals Most At Risk (0.25 hrs/day)		
								Individual Risk (per year)		
1582 Merlynn Crescent (2013)	0.67	0.007	0.5	4	9.4E-03	6.0E-03	5.6E-05	2.0E-05		
1582 Merlynn Crescent (2017)_Scenario A	0.4	0.007	0.5	4	5.6E-03	1.1E-03	5.9E-06	2.1E-06		
1582 Merlynn Crescent (2017)_Scenario B	0.4	0.007	0.5	4	5.6E-03	5.3E-04	2.9E-06	1.1E-06		
1576 Merlynn Crescent (2013)	0.67	0.007	0.5	4	9.4E-03	1.5E-02	1.4E-04	5.0E-05		
1576 Merlynn Crescent (2017)	0.67	0.007	0.5	4	9.4E-03	5.3E-04	4.9E-06	1.8E-06		
					<b>2013</b>		<b>2017</b>			
					0.0002	5077	0.0000	92554		
					(fatalities/year)	(years/fatality)	(fatalities/year)	(years/fatality)		
<b>Change</b>										
								1576 Merlynn	4.8E-05	
								1582 Merlynn_Scenario A	1.8E-05	
								1582 Merlynn_Scenario B	1.9E-05	

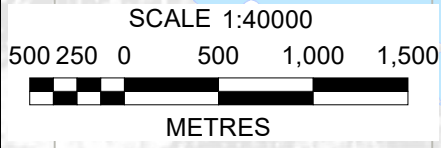
## **DRAWINGS**



**LEGEND**

-  MUNICIPALITY BOUNDARY
-  1576 AND 1582 MERLYNN CRESCENT LANDSLIDE RISK REASSESSMENT
-  LANDSLIDE RISK ASSESSMENT (COMPLETED)

X:\Projects\0404 DNV\081\_Barrier\_Landslide\_Runout\_Modelling\GIS\Production\2017\0328\_1576\_and\_1582\_Merlynn\_Crescent\_Landslide\_Risk\_Reassessment\01\_Location\_Map.mxd



**NOTES:**

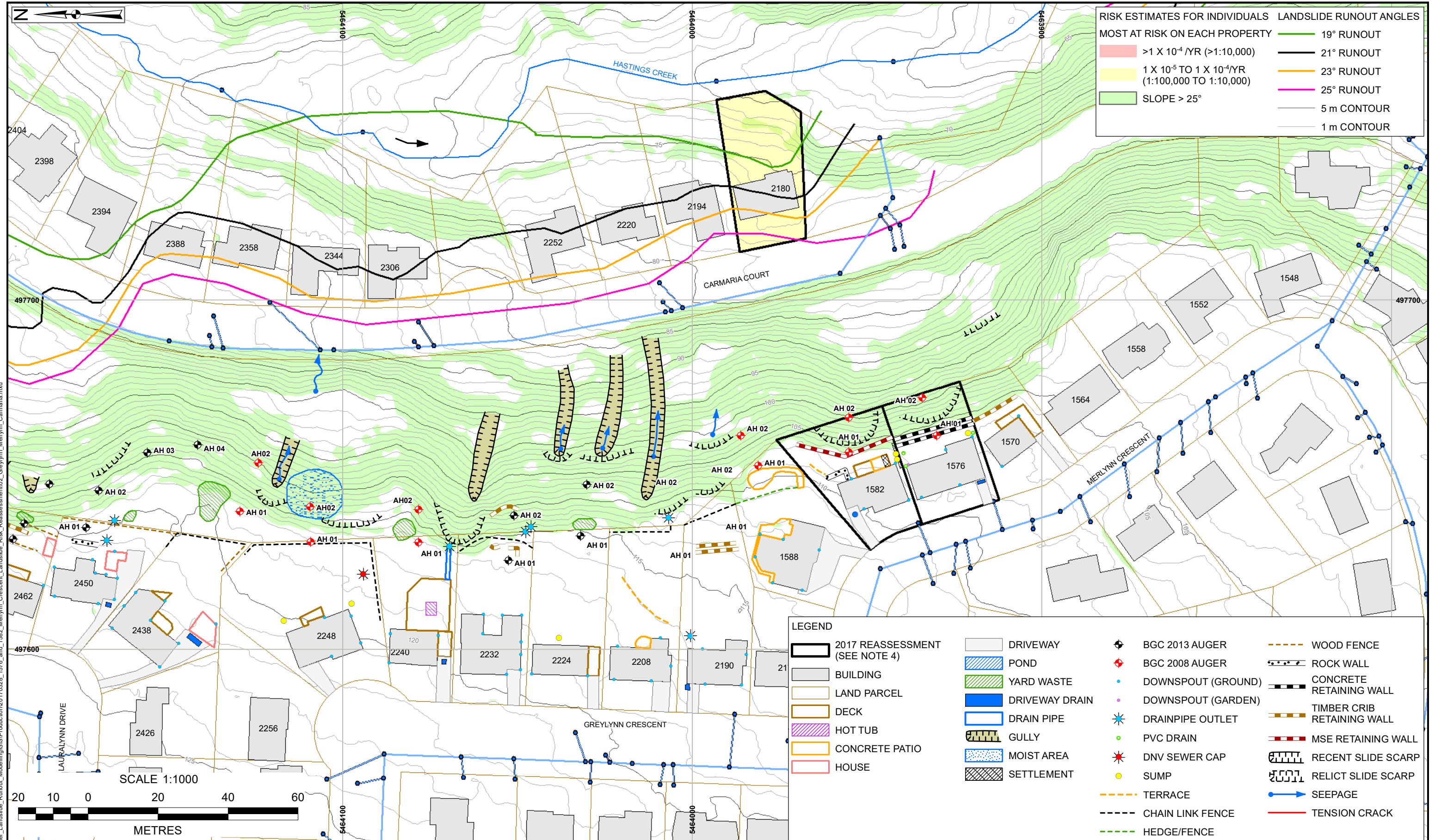
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "1576 AND 1582 MERLYNN CRESCENT LANDSLIDE RISK REASSESSMENT", AND DATED OCTOBER 2017.
3. BASE TOPOGRAPHIC DATA BASED ON LIDAR PROVIDED BY THE DISTRICT OF NORTH VANCOUVER (DNV), DATED OCTOBER 2010.
4. PROJECTION IS NAD 1983 UTM ZONE 10N.
5. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING SHALL NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES OR LOSS ARISING IN ANY WAY FROM ANY USE OR MODIFICATION OF THIS DOCUMENT NOT AUTHORIZED BY BGC. ANY USE OF OR RELIANCE UPON THIS DOCUMENT OR ITS CONTENT BY THIRD PARTIES SHALL BE AT SUCH THIRD PARTIES' SOLE RISK.

SCALE:	1:40,000
DATE:	OCT 2017
DRAWN:	JVC
CHECKED:	SJK
APPROVED:	SRF

**BGC ENGINEERING INC.**  
AN APPLIED EARTH SCIENCES COMPANY

CLIENT:  
DISTRICT OF NORTH VANCOUVER

PROJECT: 1576 AND 1582 MERLYNN CRESCENT LANDSLIDE RISK REASSESSMENT	
TITLE: LOCATION MAP	
PROJECT No.: 0404-081	DWG No: 01



**RISK ESTIMATES FOR INDIVIDUALS MOST AT RISK ON EACH PROPERTY**

- >1 X 10<sup>-4</sup> /YR (>1:10,000)
- 1 X 10<sup>-5</sup> TO 1 X 10<sup>-4</sup>/YR (1:100,000 TO 1:10,000)
- SLOPE > 25°

**LANDSLIDE RUNOUT ANGLES**

- 19° RUNOUT
- 21° RUNOUT
- 23° RUNOUT
- 25° RUNOUT
- 5 m CONTOUR
- 1 m CONTOUR

**LEGEND**

2017 REASSESSMENT (SEE NOTE 4)	DRIVEWAY	BGC 2013 AUGER	WOOD FENCE
BUILDING	POND	BGC 2008 AUGER	ROCK WALL
LAND PARCEL	YARD WASTE	DOWNSPOUT (GROUND)	CONCRETE RETAINING WALL
DECK	DRIVEWAY DRAIN	DOWNSPOUT (GARDEN)	TIMBER CRIB RETAINING WALL
HOT TUB	DRAIN PIPE	DRAINPIPE OUTLET	MSE RETAINING WALL
CONCRETE PATIO	GULLY	PVC DRAIN	RECENT SLIDE SCARP
HOUSE	MOIST AREA	DNV SEWER CAP	RELICT SLIDE SCARP
	SETTLEMENT	SUMP	SEEPAGE
		TERRACE	TENSION CRACK
		CHAIN LINK FENCE	
		HEDGE/FENCE	

**NOTES:**

- ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
- THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "1576 AND 1582 MERLYNN CRESCENT LANDSLIDE RISK REASSESSMENT", DATED OCTOBER 2017.
- BASE TOPOGRAPHIC DATA BASED ON LIDAR PROVIDED BY THE DISTRICT OF NORTH VANCOUVER (DNV), DATED OCTOBER, 2010. CONTOUR INTERVAL IS 1 m.
- FIELD OBSERVATIONS OUTSIDE THE 1576 AND 1582 MERLYNN CRESCENT PROPERTIES ARE FROM PREVIOUS ASSESSMENTS AND HAVE NOT BEEN UPDATED FOR THIS REPORT.
- PROJECTION IS NAD 1983 UTM ZONE 10N.
- UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING SHALL NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES OR LOSS ARISING IN ANY WAY FROM ANY USE OR MODIFICATION OF THIS DOCUMENT NOT AUTHORIZED BY BGC. ANY USE OF OR RELIANCE UPON THIS DOCUMENT OR ITS CONTENT BY THIRD PARTIES SHALL BE AT SUCH THIRD PARTIES' SOLE RISK.

SCALE: 1:1,000  
 DATE: OCT 2017  
 DRAWN: JVC  
 CHECKED: SJK  
 APPROVED: SRF

**BGC ENGINEERING INC.**  
 AN APPLIED EARTH SCIENCES COMPANY

CLIENT: DISTRICT OF NORTH VANCOUVER

PROJECT: 1576 AND 1582 MERLYNN CRESCENT LANDSLIDE RISK REASSESSMENT  
 TITLE: GREYLYNN CRESCENT, MERLYNN CRESCENT, AND CARMARIA COURT  
 PROJECT No.: 0404-081  
 DWG No.: 02

X:\Projects\0404 DNV\081\_Barrier\_Modeling\GIS\Production\2017\0328\_1576\_and\_1582\_Merlynn\_Crescent\_Landslide\_Risk\_Reassessment02\_Greylynn\_Merlynn\_Carmaria.mxd