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GEOTECHNICAL INVESTIGATION AND STABILITY ASSESSMENT

Corona Crescent Area, Coquitlam, BC

Submitted to:
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REPORT

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by the City of Coquitlam (City) to provide geotechnical investigation and geohazard assessment services related to the ongoing slope stability assessment along the Suter Brook ravine in the Corona Crescent area of Coquitlam, BC (Figure 1). Residential properties along the ravine, identified by others as being at high to very high landslide risk or exposed to potential landslide risk from upslope properties, were included in Golder's investigation and assessment. The services were carried out in accordance with Golder's proposal dated August 2, 2013. This report provides the factual results of the geotechnical investigation carried out by Golder and presents the engineering comments and recommendations along with quantified landslide risk assessment for the identified properties, as well as mitigation measures.

This report should be read in conjunction with the "*Important Information and Limitations of This Report*" which is attached following the text of this report. The reader's attention is specifically drawn to this information as it is essential for the proper use and interpretation of this report.

2.0 SITE DESCRIPTION

2.1 Background

Metro Vancouver, the City of Coquitlam, and the City of Port Moody engaged others to complete an Integrated Stormwater Management Plan (ISMP) for the Chines Escarpment area. As part of the ISMP a Landslide Risk Management Procedure was initiated that included two phases:

- Phase 1: Development of a Landslide Risk Analysis Methodology; and
- Phase 2: Implementation of Landslide Partial Risk Analysis.

Although the ISMP includes both the Chines Escarpment and the Corona Crescent areas (Figure 1), the focus of the Golder's scope of work was the residences clustered within the Corona Crescent area. Portions of Corona Crescent and Thermal Drive form the head of the Suter Brook ravine, which is characterized by a steep, irregular upper ravine, with ravine slopes having lower relief to the north, along Park Crescent. The Suter Brook catchment includes discharge flows from several ravine seepages and stormwater drainage outlets. Residential development began in the 1970s both along the top (Corona Crescent) and bottom (Park Crescent) of the ravine with excavated soils for basements, garages and driveways understood to have been spread around the backyard and ravine crest areas and not trucked offsite.

As part of the Phase 2 Landslide Partial Risk Analysis, Associated Engineering (AE) (2013) developed partial risk ratings for residential properties along the Suter Brook ravine. The assessment included classification of properties as having very low, low, moderate, high, and very high risk to landslide hazard, along with exposed properties downslope. Golder's scope of work included a static and seismic assessment of the properties rated high to very high, along with a landslide risk assessment of all properties rated high, very high, and exposed, using the District of North Vancouver (DNV) landslide risk tolerance criteria.

2.2 Site Description

The Corona Crescent area of the Chines Escarpment investigated by Golder is located along portions of Thermal Drive, Corona Crescent, and Park Crescent in Coquitlam, BC (Figure 1). Based on the information provided to Golder, the legal land descriptions of the properties included in our geotechnical assessment are summarized in Table 1.

Table 1: Legal Land Descriptions

Civic Address	Previous Partial Risk Rating	Legal Land Description
977 Thermal Drive	High to Very High Risk	Lot 308, DL 371, New West District Plan 30218
976 Corona Crescent		Lot 367, DL 371, New West District Plan 31039
980 Corona Crescent		Lot 368, DL 371, New West District Plan 31039
984 Corona Crescent		Lot 404, DL 371, New West District Plan 36456
988 Corona Crescent		Lot 405, DL 371, New West District Plan 36456
990 Corona Crescent		Lot 593, DL 371, New West District Plan 48873
992 Corona Crescent		Lot 594, DL 371, New West District Plan 48873
998 Corona Crescent	Moderate Risk (Above Exposed Properties)	Lot 591, DL 371, New West District Plan 48873
1000 Corona Crescent		Lot 590, DL 371, New West District Plan 48873
1004 Corona Crescent		Lot 589, DL 371, New West District Plan 48873
1008 Corona Crescent		Lot 588, DL 371, New West District Plan 48873
1012 Corona Crescent		Lot 587, DL 371, New West District Plan 48873
1016 Corona Crescent		Lot 586, DL 371, New West District Plan 48873
1020 Corona Crescent		Lot 585, DL 371, New West District Plan 48873
1024 Corona Crescent		Lot 595, DL 371, New West District Plan 48874
1028 Corona Crescent		Lot 596, DL 371, New West District Plan 48874
2242 Park Crescent	Properties Exposed to Upslope Risk	Lot 3, DL 371, New West District Plan LMP4979
2244 Park Crescent		Lot 2, DL 371, New West District Plan LMP4979
2246 Park Crescent		Lot 1, DL 371, New West District Plan LMP4979
2247 Park Crescent		Lot 527, DL 371, New West District Plan 40715
2251 Park Crescent		Lot 526, DL 371, New West District Plan 40715
2255 Park Crescent		Lot 525, DL 371, New West District Plan 40715
2259 Park Crescent		Lot 524, DL 371, New West District Plan 40715
2263 Park Crescent		Lot 396, DL 371, New West District Plan 34527
2267 Park Crescent		Lot 395, DL 371, New West District Plan 34527
2271 Park Crescent		Lot 394, DL 371, New West District Plan 34527

2.2.1 977 Thermal Drive

The 977 Thermal Drive property is located along the north crest of the Suter Brook Ravine and encompasses an area of about 0.20 hectares. Approximately 45% (the north and east portion) of the property is located within the steep ravine slope. A single-family residence, second story deck, and detached garage currently exist to the south, along the crest of the ravine slope which is generally vegetated and contains some large conifer trees. The adjacent, undeveloped lot to the east is marked by a wide slope concavity, likely marking a historical ravine sidewall slump.

2.2.2 Corona Crescent

The Corona Crescent properties include the 976, 980, 984, 988, 990, and 992 residential lots all located along the northeast crest of the ravine and downslope portions. The properties range in area from 0.07 to 0.25 hectares, with as much as 70% (992 Corona Crescent) to as little as 25% (980 Corona Crescent) of the properties extending onto the current ravine slopes. Single-family residences are constructed northeast of (outside) the ravine crest on all properties. Backyard decks have been constructed to the crest of the slope at 976 and 984 Corona Crescent, as well as north of the residence at 992 Corona Crescent. The backyard slopes extending down to Suter Brook are generally vegetated, with some large conifer trees.

Based on information provided by the City of Coquitlam, the depths of basement levels of residences at 992 and 984 Corona Crescent range from 0.6 m to 1.2 m and 0.9 m to 1.2 m, respectively, below the exterior ground surface.

2.2.3 Park Crescent

The Park Crescent properties include the 2242, 2244, 2246, 2247, 2251, 2255, 2259, 2263, 2267, and 2271 residential lots, all located along the toe of the ravine slope. The properties range in area from 0.07 to 0.24 hectares, and generally slope gently to the north. Single-family residences are constructed west of the ravine slope on all properties, and are generally offset greater than 10 m from the toe of the slope. Two surficial erosion gullies, originating in the area of 998 and 1000 Corona Crescent, extend downslope to 2251 and 2271 Park Crescent, respectively. In addition, an approximately 10 m wide bench is located at about the midpoint of the overall ravine slopes, below the Corona Crescent properties and above the Park Crescent properties.

2.3 Review of Available Information

A review of surficial geology information published by the Geological Survey of Canada (Map 1484, 1980) combined with Golder's experience in the area indicates that the subsoils underlying the site comprise Vashon Drift consisting of glaciomarine and glaciolacustrine deposits, underlain by Quadra fluvial channel and floodplain deposits.

Previous historic landslide events in the Chines Escarpment and Corona Crescent areas have ranged from minor creek bank erosion and debris flow events that have not extended beyond the ravine sidewalls to landslide events that have reached residential areas and damaged several residences, structures and cars, and put lives in danger.

Preparation of this report also included review of AE's (2013) "Qualitative Partial Risk Slope Analysis, Chines Escarpment and Corona Crescent Areas", provided by the City, along with BGC's (2008) "Landslide Risk Assessment: Westlynn and Pemberton Heights Escarpments" and DNV's "Natural Hazards Risk Tolerance Criteria" as references to the DNV landslide risk assessment criteria. It is understood that the City has not adopted specific criteria for acceptable landslide risk and slope stability. As such, Golder has considered the landslide risk and slope stability results discussed in this report against DNV's adopted criteria, as well as the Association of Professional Engineers and Geoscientists of British Columbia "Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC", revised May 2010. Under the DNV criteria, for existing residential developments, a factor of safety against slope failure above 1.3 and an individual risk level below $1x10^{-4}$ per year are considered acceptable.

3.0 GEOTECHNICAL INVESTIGATION

3.1 Field Reconnaissance

Two Golder personnel conducted a geotechnical field reconnaissance of the Suter Brook ravine and properties along Thermal Drive, Corona Crescent, and Park Crescent on August 29 and 30, 2013. During the reconnaissance, the slopes, soil conditions, and site drainage were examined with respect to the potential for geohazards that could impact the properties along the Suter Brook ravine. Measurements were made using approximate clinometer, tape, and compass methods. Local soil characteristics were determined by inspection of naturally occurring exposures and shallow hand-dug test pits. Weather conditions during the field reconnaissance were generally overcast and rainy, with good visibility at ground level. Site photographs were taken and are on file in Golder's Burnaby office.

Following the completion of the field reconnaissance, pertinent information on potential geotechnical hazards was reviewed and included as part of Golder's assessment of slope stability and landslide hazard risks.

3.2 Drilling Investigation

Golder conducted a geotechnical subsurface investigation between September 10 and 13, 2013 to determine the subsurface soil and groundwater conditions along the slopes of the properties previously rated as high and very high risk. As part of the detailed investigation planning and coordination, Golder obtained underground utility information from BC One Call, private utility companies, and government agencies. Prior to commencement of all subsurface investigation work, Golder retained Western Leakage Services Ltd. to identify physical utility locations in the field.

All utility clearance work and geotechnical investigation work was carried out under the full-time inspection of a member of Golder's geotechnical staff who identified the testhole locations in the field, coordinated all utility clearance work, logged the subsurface conditions encountered, and collected soil samples for further observation and testing in our Burnaby laboratory.

Homeowner notification of the drilling works was conducted by the City of Coquitlam, and was based on discussions with Golder staff on preferred drillhole locations and subcontractor availability.

The locations and identification of all testholes are shown on Figure 2. All testhole locations were surveyed in the field using a handheld field GPS and are considered approximate only. The survey coordinates referenced in this report are presented in Universal Transverse Mercator (UTM), NAD83 coordinate system. All elevations are referenced to geodetic datum and were determined based on site topographical information purchased from the City of Coquitlam at the time of preparing this report.

The test holes were put down between September 10 and 13, 2013 using a rubber track-mounted Bobcat MT52 auger rig, a portable Pionjar hammer drill, and custom SPT/DCPT tripod, owned and operated by Rocky Mountain Soil Sampling Inc. of Bowen Island, BC. A total of three (3) drilled augerholes, eleven (11) pionjar holes, and four (4) dynamic cone penetration test (DCPT) holes were put down as part of the geotechnical investigation work, including:

- AH/MW/DCPT13-01, PH13-08, PH13-09, PH13-10, and PH13-11, along the crest of the slope at 977 Thermal Drive;
- PH/MW13-05, along the slope below 976 Corona Crescent;
- AH13-02, PH13-01, PH13-02, and DCPT13-01, along the crest of the slope at 980 Corona Crescent;
- PH13-04, along the crest of the slope at 984 Corona Crescent;
- AH/MW/DCPT13-03, along the crest of the slope at 988 Corona Crescent; and
- PH/MW/DCPT13-03, PH13-06, and PH13-07 along the slopes at 992 Corona Crescent, both north of the house and downslope of 990 Corona Crescent.

The locations, elevations and depths of the testholes are summarized below in Table 2.

Table 2: Summary of Testholes

Testhole	UTM Coordinates (NAD 83)		Elevation (Geodetic, m)	Date	Depth (m)
	Northing	Easting			
AH/MW/DCPT13-01	5457425	512285	120.5	2013-09-10	8.4
AH13-02	5457482	512396	116.5	2013-09-11	1.2
AH/MW/DCPT13-03	5457519	512378	111.0	2013-09-12	7.6
PH13-01	5457473	512396	115.0	2013-09-11	0.8
PH13-02	5457466	512401	115.5	2013-09-11	3.7
PH/MW/DCPT13-03	5457523	512340	100.0	2013-09-11&13	6.9

Testhole	UTM Coordinates (NAD 83)		Elevation (Geodetic, m)	Date	Depth (m)
PH13-04	5457490	512389	113.5	2013-09-12	1.2
PH/MW13-05	5457460	512407	117.5	2013-09-12	1.6
PH13-06	5457537	512349	104.0	2013-09-13	2.3
PH13-07	5457563	512351	103.0	2013-09-13	1.5
PH13-08	5457448	512261	117.0	2013-09-13	1.7
PH13-09	5457448	512274	110.0	2013-09-13	1.1
PH13-10	5457448	512267	114.5	2013-09-13	0.8
PH13-11	5457433	512286	119.0	2013-09-13	1.5
DCPT13-01	5457473	512401	116.5	2013-09-11	1.7

During the drilling of the augerholes and pionjar holes, disturbed samples of the soil encountered were obtained at selected interval depths from the 102 mm diameter auger flights and 51 mm Pionjar split spoons. On completion of drilling, each augerhole was backfilled in overall conformance with the BC Ministry of Environment Groundwater Protection Regulation pertaining to geotechnical testholes and monitoring wells, as applicable. The lawn surfaces were restored by replacing divots cut prior to the drilling.

Detailed descriptions of the subsurface conditions encountered in the drilled augerholes and pionjar holes are reported in Appendix A. Classification of the soil conditions is in accordance with the Golder's Method of Soil Classification (2011). A copy of the Golder's classification legend is included in Appendix A.

3.3 Laboratory Testing Program

Upon completion of the field investigation work, Golder carried out a laboratory testing program on selected samples obtained from the augerholes and pionjar holes. The results of these tests were used to aid in the classification of the soils encountered and to assess their engineering characteristics. The specific laboratory tests included the following:

- Water content determination tests (ASTM D4959).
- Grain size distribution analysis tests (ASTM D422-63 (2007)).
- Plasticity (Atterberg limit) determination tests (ASTM D4318-10).

The results of the laboratory testing are presented in Appendix B and summarized on the testhole logs sheets in Appendix A.

4.0 SUBSURFACE CONDITIONS

The following sections describe the subsurface conditions encountered during the investigation. Further details of the subsurface conditions encountered in augerholes and pionjar holes are presented in Appendix A.

4.1 Topsoil and Fills

All testholes were advanced through a combination of topsoil and/or surficial fill, generally consisting of a mixture of gravel, sand, silt, and organics. Brown topsoil was encountered at the surface of most testholes, and generally comprised decomposed organics, roots, and silt and sand. Inferred fill material was encountered at the surface or below topsoil in AH/MW/DCPT13-01, AH13-02, AH/MW/DCPT13-03, AH/MW13-05, PH13-01, PH13-02, PH13-04, and PH13-05 to depths up to 2.6 m. Surficial fill materials varied in moisture content, but tended to be dry to moist, where encountered. Based on DCPT blow counts, the topsoil and fill materials were generally very loose to compact. Where high penetration resistance was encountered, this may represent coarser grained particles within the fill.

4.2 Glacial Till-like Soils

Underlying the topsoil and fills, a deposit of dense to very dense, grey, silty sand with varying amounts of gravel was generally encountered in all testholes put down above the crest of the Chines escarpment slopes. The upper portion of this deposit was generally moderately weathered, and extended to depths of between 0.6 m and 2.7 m. Based on our observations during the investigation, together with laboratory data and our knowledge of the area, these soils are considered to be part of the Vashon Drift glacial till deposit, and generally form a thin veneer or “cap” along the ravine crest. Testholes generally reached practical refusal during drilling within these dense deposits; however, based on auger drilling and field reconnaissance observations, the till “cap” deposit is inferred to range in thickness between approximately 7 m and less than 1 m along the crests of the 976 to 992 Corona Crescent and 977 Thermal Drive properties. DCPT blow counts in this material ranged from 19 to greater than 100 blows per 300 mm. Laboratory test results for this deposit are summarized below in Table 3.

Table 3: Summary of Laboratory Index Testing on Samples from Till-like Deposits

Borehole	Sample	Natural Moisture (%)	Atterberg Limits (%)		Particle Size Distribution (%)			
			Plastic Limit	Liquid Limit	Gravel	Sand	Silt	Clay
PH13-04	SS 2	10.5	-	-	-	-	-	-
PH13-04	SS 3	7.9	-	-	15	54	31	
PH/MW13-05	SS 2	13.6	-	-	-	-	-	-
PH/MW13-05	SS 3	7.5	-	-	26	52	22	
PH13-07	SS 1	25.3	-	-	-	-	-	-
PH13-07	SS 2	20.2	-	-	-	-	-	-
PH13-07	SS 3	26.0	-	-	0	17	61	22
PH13-11	SS 1	23.2	21	32	-	-	-	-

4.3 Glaciofluvial Deposits

Underlying surficial fills, or till-like soils in testholes that penetrated below these units, a deposit of dense to very dense, brown-grey sand to silty sand was encountered. Where encountered surficially, the upper portion of this deposit was generally weathered and contained red staining. Based on our observations during the investigation, together with laboratory data and our knowledge of the area, these soils are considered to be part of the glaciofluvial pre-Vashon Quadra Sands deposit. The deposit was encountered between depths of 0.2 m and 2.7 m, and generally terminates at an elevation of about 100 m above sea level, based on site observations and local knowledge of the area. DCPT blow counts in this material ranged from 36 to greater than 100 blows per 300 mm. Laboratory test results for this deposit are summarized below in Table 4.

Table 4: Summary of Laboratory Index Testing on Samples Glaciofluvial Deposits

Borehole	Sample	Natural Moisture (%)	Atterberg Limits (%)		Particle Size Distribution (%)			
			Plastic Limit	Liquid Limit	Gravel	Sand	Silt	Clay
AH/MW/DCPT13-01	AS 3	11.3	-	-	0	70	30	
AH/MW/DCPT13-03	AS 4	17.9	-	-	0	80	20	
AH/MW/DCPT13-03	AS 5	22.0	-	-	-	-	-	-
PH13-02	SS 4	10.8	-	-	4	89	7	
PH13-08	SS 1	24.7	-	-	-	-	-	-
PH13-08	SS 2	22.9	-	-	0	1	85	14

4.4 Glaciolacustrine Deposits

Underlying the Quadra Sands deposit, a compact to dense, grey silt to silty sand was encountered. Similar materials were also encountered at an exposed outcrop along the toe of the 2251 Park Crescent ravine slope. Based on local experience in the area, these materials are understood to be part of the pre-Vashon deposits mentioned above, but are of glaciolacustrine origin. Previous local observations, combined with the subsurface investigation suggest an upper contact at approximately 100 m above sea level. While no testholes penetrated through this unit, it is estimated to be approximately 20 m to 25 m thick. DCPT blow counts in this material generally ranged from 10 to 56 blows per 300 mm. Laboratory test results for this deposit are summarized below in Table 5.

Table 5: Summary of Laboratory Index Testing on Samples from Glaciolacustrine Deposits

Borehole	Sample	Natural Moisture (%)	Atterberg Limits (%)		Particle Size Distribution (%)			
			Plastic Limit	Liquid Limit	Gravel	Sand	Silt	Clay
PH/MW/DCPT13-03	SS 1	21.6	-	-	-	-	-	-
PH/MW/DCPT13-03	SS 2	33.8	-	-	-	-	-	-
PH/MW/DCPT13-03	SS 3	13.8	-	-	0	80	20	
PH/MW/DCPT13-03	SS 4	25.0	-	-	-	-	-	-

4.5 Groundwater Conditions

Golder's drilling investigation included the installation of piezometers within testholes AH/MW/DCPT13-01, AH/MW/DCPT13-03, PH/MW13-03, and PH/MW13-05 to enable groundwater level measurements. No seepage or groundwater levels were observed during any of the testholes during drilling; however, wet silty sand was noted at 4.6 m depth in AH/MW/DCPT13-03. During follow up measurements conducted on September 25, 2013, following a period of heavy rainfall, groundwater was encountered at approximately 4.9 m below the ground surface in AH/MW/DCPT13-03. No groundwater was encountered within the piezometers installed at the other three testholes. The groundwater measurements were recorded after a brief period of rainfall, which had been preceded by an extended dry period.

During site traverses, seepage was encountered along the slopes below 984 Corona Crescent, 977 Thermal Drive, and 2251 Park Crescent, at elevations inferred to be immediately above the low permeability, glaciolacustrine deposits. Groundwater conditions at the site are generally controlled by the presence of this unit, with seepage zones forming at the upper contact between the glaciolacustrine deposits and the Quadra sands.

5.0 LANDSLIDE HAZARD ASSESSMENT

A landslide hazard assessment was carried out to in order to characterize the hazards associated with the area. The tasks involved in this included the following:

- Identification of the landslide hazard types associated with the site.
- Conducting stability analyses of the slopes under static and dynamic (seismic) conditions.
- Conducting a runout angle analysis for the slopes on the site, using the parameters of the of the Berkley-Riverside study (BGC 2008).

5.1 Hazard Identification

In general, landslides are movements of significant amounts of material – rock, soil, water, trees and debris – down a slope. They can vary in size, extent and mechanism of failure, depending on the site conditions and geology. There are a number of types of landslide movements which reflect the nature of a failure mass, its mobility, the type of failure mechanism, and the triggering mechanisms. The following paragraphs briefly summarize the different types of landslides.

Rock falls and toppling events involve the movement of rock masses or single large rocks on steep slopes, cuts or bluffs. They can occur where there are steep rock slopes that are exposed to weathering, and where discontinuities within the parent rock mass results in unfavourably oriented planes of weakness. Rock slides or slumps involve the movement of blocks of rock along faults or joints of weakness.

Debris and earth falls, or slides, involve movements of significant amounts of rock, soil and debris down a slope. They can occur as block movements or planar translations of soil parallel to the slope angle. Soil slumps involve the (usually rotational) movements of large soil or rock masses along a surface of weakness. They can occur along river banks, due to the undercutting and erosion of the toe of the slope. The failure can occur along seams of fine grained soils exhibiting plasticity. Exposed soil or rock slopes are susceptible to erosion and consequent slide events where vegetation is not present, or has been removed.

Flow slides, referred to as debris torrents or flow avalanches, involve rock, soil and debris combined with water. They can occur on open slopes or down pre-existing creeks or channels.

Debris flow and debris flood hazards are most commonly associated with well-developed gully systems characterized by steep, unstable sidewalls and/or headwalls and steep channel gradients. Channelized debris flows typically involve the rapid downstream movement of saturated sediment and woody debris along a deeply-incised, well-confined, moderate to steep gradient (generally greater than about 40%) stream channel/transport zone. They may start as relatively small events but can quickly increase in volume as they move downstream and entrain debris. Debris flows are most commonly initiated by landslides that run out to the stream channel or, more rarely, by large stream discharges. Debris floods, as is the case for debris flows, typically initiate during high intensity and/or prolonged precipitation events or rain-on-snow events. The general mechanism involves either the collapse of a landslide dam in the creek channel, or landslides initiated from the sidewall slopes. Debris floods can occur on their own or in association with a debris flow, where they form a more fluid component that can travel beyond the depositional area of the debris flow.

In addition to the type of landslide movement, consideration of the runout of the slide movement is important in assessing the hazard. The potential energy of the slide mass due to its elevation is transformed into kinetic energy under the influence of gravity.

The scouring action and kinetic energy of the mass can result in the collection and mobilization of additional materials along the path of these events that increases the mass and volume of the failure material. The distance of the runout path depends in part on the nature of the material, the topography of the terrain, the presence of obstructions, together with the initial potential energy.

As part of Golder's study, a visual reconnaissance was conducted along the Chines slopes, above or below the properties listed in Table 1. Observations during the reconnaissance indicate that some surficial sloughing, creep, and larger sliding has occurred in the past.

Steepening of the natural slopes with fill materials or yard waste had been carried out along several areas of the slopes. However, the volume of ravelled material present at the toe of these steep slopes is small and has accumulated on or just below the toe of slope, with only limited runout. Extensive vegetation and tree cover is generally present over the native material along the Suter Brook ravine slopes included in the assessment.

Seepage, with evidence of minor erosion, was observed near the toe of the slope along 977 Thermal Drive. However, with this exception, no other observations of heavy seepage, erosion, or sediment transport, and undercutting along the toes of the slopes was observed below any of the high or very high risk rated sites. Development along the upslope properties inspected, along Thermal Drive and Corona Crescent, with associated curbs and drainage facilities mitigates the risk for large concentrated overland flows onto the slopes. However, drainage pipes were observed discharging onto the slopes from below the southwest facing retaining wall at 990 Corona Crescent and garage and carport drains at 977 Thermal Drive.

Based on the review of site conditions and topographical information, together with the results of our subsurface investigation, we consider the most likely slide hazard applicable to this site is a combination of a soil slump and/or flow slide. Since there is no bedrock outcrop exposed in the slope, rock falls or rock slides are not considered a hazard. Natural channels, including Suter Brook and any ephemeral streams in or adjacent to the study area, run through relatively wide, shallow gradient valleys, which have a low potential to generate significant debris flow or debris flood events.

The placement of fill and the construction of retaining walls at several of the properties has altered the natural terrain and created a potential source for slide material. In addition, loose fills, yard waste, and weathered native materials were encountered along the ravine crest up to depths of 2.6 m. The surficial fills include materials with poor drainage characteristics, and are generally weaker than the underlying native soils. Such materials have a potential for instability which could generate a soil slump.

5.2 Slope Stability Analysis

Golder conducted a series of slope stability analyses on sections of the slopes below 977 Thermal Drive, 976 Corona Crescent, 984 Corona Crescent, and 992 Corona Crescent to evaluate the potential for slope instability events, which could impact properties along the crest and base of the ravine slopes. The four properties were selected based on those previously identified as very high risk, the relative steepness of the terrain, and those assessed at higher risk of property damage based on Golder's site reconnaissance. Four stability cross sections were established, identified as A-A', B-B', C-C', and D-D' (Figures 2, 4-11), which include downslope development and Suter Brook. Residences at 980, 988, and 990 Corona Crescent are set back further from the crest of the shallower ravine slope; as such, no site specific stability analysis was conducted.

The interpreted subsurface conditions, based on the results of our subsurface investigation and field reconnaissance, are also shown on these cross sections.

The analyses were carried out using the commercially available slope stability analysis software package GeoStudio (SlopeW) Version 7.20 by GeoSlope International Ltd. The Morgenstern-Price analysis method was utilized for each configuration. The slope profile analyzed, material properties and stability analysis results are shown in Figures 4 to 11, which were based on the currently available subsurface information. It should be noted that the soil stratigraphy assumed to exist between the testhole locations is based on our interpretation of the geological conditions of the area. The actual conditions may vary from that used in our model(s). Groundwater conditions were modelled as those interpreted to be current for native deposits, and assumed a "perched" water level would develop within the fills and weathered surficial soils, as anticipated during a heavy rainfall event. Regional groundwater levels within the glaciofluvial and glaciolacustrine deposits are assumed to be relatively stable year-round, and are modelled as those inferred to be current levels. Shallow slip surfaces, extending less than 1 m depth, were not assessed as part of the stability analysis, and are considered in subsequent sections.

The theoretical method used to calculate the (Factor of Safety) FoS is the General Limit Equilibrium (GLE) method which calculates a FoS based on satisfying both force and moment equilibrium. The process of assessing the FoS against failure for a slope involves finding the minimum factor of safety against failure by searching a large number of potential individual slip surfaces. Golder carried out the analysis using soil parameters summarized in Table 6 below.

Table 6: Soil Strength Parameters

Soil Unit	Condition	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle (°)
Topsoil and Surficial Fill	Weathered	17	0	30
Glacial Till	Weathered	19	0	35
	Intact	21	25	40
Quadra Sand	Intact	20	0	38
Glaciolacustrine	Intact	19	10	35

Drained soil strength properties were used to model long-term loading conditions. The DNV (2009) risk criteria uses a minimum tolerable factor of safety of 1.3 against slope instability under long term, static load conditions for existing residences with re-development involving less than 25 percent of the gross floor area.

5.2.1 Static Loading

The results of the analyses for the four sections (A-A’, B-B’, C-C’, and D-D’) indicate that the factor of safety against slope failures directly impacting residences are generally in excess of 1.3 as summarized in Table 7. However, factors of safety for decks, detached garages, and other portions of the properties closer to or downslope of the crest of the ravine slopes are generally lower than those potential slope failure planes extending to the residences. Notably, the garage and carport located at 977 Thermal Drive has FoS values of less than 1.1 (Figure 4B). Decks and patios extending at or close to the ravine crest at 976, 984, and 992 Corona Crescent are also anticipated to have FoS values significantly lower than those of the residences, particularly for those not founded on dense native materials. These factors of safety are consistent with observations on site, where leaning and “pistol-butted” trees were noted during the field reconnaissance suggesting creep-type movements within the surficial soils.

Table 7: Static Stability Analysis of Residences

Section	Factor of Safety
A-A’ (977 Thermal Drive residence)	~1.4
B-B’ (976 Corona Crescent residence)	~1.5
C-C’ (984 Corona Crescent residence)	~2.0
D-D’ (992 Corona Crescent residence)	~1.3

The analysis also indicated that there is potential for instability within existing surficial fills that have been placed along the crest of the slopes investigated. It should be noted that failure surfaces generally passing though the 992 Corona Crescent residence along section D-D’ are anticipated to impact the residence at 2244 Park Crescent, where the toe of the slip surface daylights.

5.2.1.1 *Stability Assessment of 990 Corona Crescent*

It should be noted that no detailed information was available regarding the actual design and construction of the existing retaining structure at the southeast property line of 990 Corona Crescent and 992 Corona Crescent. As such, no stability analysis was completed for this section, G-G’ (Figure 3). Based on a preliminary assessment of global stability of the section, slope failure is not considered to be an issue along section G-G’, under current conditions. However, this assessment does not take into account the contribution of loading associated with the retaining structure, its degradation over time, and the potential for a large volume of surface water discharge from the above pool in the event of a failure, possibly contributing to a debris slide.

However, it is understood, based on discussions with the City, that consideration is being given to decommissioning of the pool and replacement with light-weight fills and other mitigation measures. It is recommended that a detailed stability and risk assessment be carried out for the residence, following the confirmation of proposed remediation works.

5.2.2 Seismic Loading

In addition to the above analysis considering static loading cases, the stability of the ravine slopes was analysed considering seismic loading conditions in accordance with APEGBC “Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC”. A design peak firm ground horizontal acceleration of 0.246g (24.6 percent of the acceleration of gravity), corresponding to a 10% in 50-year seismic event (1 in 475-year) was utilized in the analyses, consistent with DNV risk criteria for existing residential development. A factor of safety of 1.0 or more determined using pseudo-static analysis methods is generally considered acceptable for unsaturated slopes subject to earthquake loading.

The four sections described above were initially analysed for stability under seismic loading considering pseudo-static conditions. The results of these analyses indicate that the 977 Thermal Drive and 976 and 992 Corona Crescent residences at the crest of the slopes in the cross sections have a FoS less than 1.0 against failure. As such, an additional detailed seismic slope analysis was conducted using a displacement-based seismic horizontal acceleration, k_{15}, corresponding to 15 cm of tolerable displacement under the 10% in 50-year seismic event. As described in the APEGBC 2010 guidelines, fifteen (15) cm of displacement is considered tolerable with respect to “life safety”, provided that all critical failure surfaces passing through the residence have a FoS in excess of 1.0. The 984 Corona Crescent residence has a FoS greater than 1.0 under pseudo-static conditions and is considered stable under the 10% in 50-year seismic event. Consequently, it was not included in the displacement-based seismic analysis.

Under a k_{15} loading of 0.145g, the FoS values for critical failure surfaces between the residences and the crest of Suter Brook ravine are greater than the FoS = 1.0 criteria of the APEGBC 2010 Guidelines and DNV 2009 criteria for displacement-based seismic stability, and are summarized in Table 8.

Table 8: Seismic Stability (15 cm Median Displacement) Analysis of Residences

Section	Factor of Safety
A-A’ (977 Thermal Drive residence)	~1.2
B-B’ (976 Corona Crescent residence)	~1.3
D-D’ (992 Corona Crescent residence)	~1.1

As discussed above, critical slip surfaces under seismic loading are anticipated to extend close to or through the downslope 2244 Park Crescent residence.

5.2.3 Runout Assessment

Runout of a slide mass refers to the distance the debris from the slide travels from the initiation point before coming to rest. This runout angle is typically measured from the horizontal, extending from the terminal point of the slide mass back to the pre-existing crest. The length of the runout path depends on a number of factors, including the nature of the slide material, the topography of the terrain, the presence of obstructions, and the initial potential energy. In general, a given slide mass would have higher kinetic energy closer to the toe of the slope than further away, since energy is dissipated as the slide debris travels further from the point of failure. Depending on the composition of the slide mass, and particularly whether there is a large component of water within it, runout lengths can vary significantly. Slide masses without a significant amount of water are not likely to have flow-like characteristics, and will generally not travel as far as more fluid masses. In addition, smaller slide masses will typically not travel as far as larger slide failures since they have less initial potential energy.

A schematic illustration of runout angle is presented below.

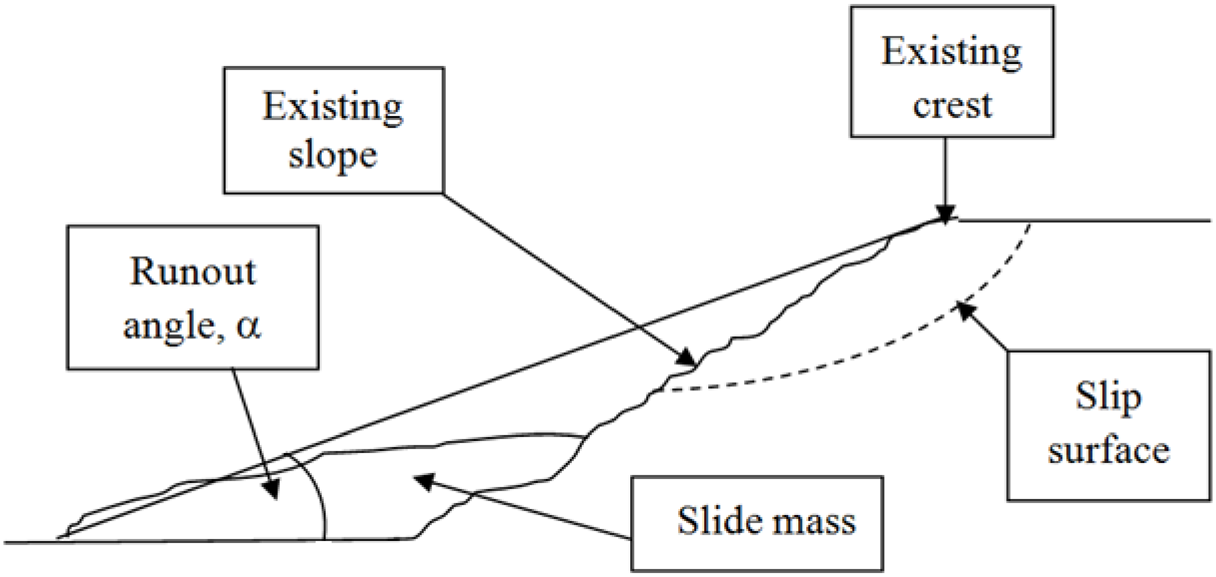

Figure 1: Schematic Illustration of Runout Angle

As described in BGC 2008, significant structural damage is considered likely or probable to occur to dwellings located within the slide path at runout angles greater than 25º. At progressively shallower angles (21º to 25º), the amount of slide material decreases dramatically, as does structural damage. At angles below 23°, the runout was limited to those events including flooding and organic soils. The above noted study assigned a range of angles from 19º to 25º to assess the possible extent of travel for potential landslide events for their analysis. Review of the historical slide events along the Chines escarpment indicates that the majority of the slides were relatively shallow, wet, flow slide events, rather than soil slumps involving generally unsaturated granular soils. Similarly, the hypothetical events modelled in the runout analysis were considered to have flow-like behaviour.

Golder's runout assessment has considered angles for potential landslides originating at or close to the crest of adjacent upslope areas, with possible impact to residences and Suter Brook below. At risk residences and properties are summarized along section lines below in Table 9 and in further detail in Appendix C.

Table 9: Runout Assessment

Section	Runout Angle Range		
A-A'	Suter Brook (19°-21°)	2242 Park Crescent (<19°)	-
B-B'	Suter Brook (21°-23°)	-	-
C-C'	Suter Brook (<19°)	-	-
D-D'	2244 Park Crescent (>25°)	2246 Park Crescent (23°-25°)	2242 and 2247 Park Crescent (19°-21°)
E-E'	2251 Park Crescent (<19°)	-	-
F-F'	2263 Park Crescent (19°-21°)	2267 Park Crescent (<19°)	2271 Park Crescent (<19°)
G-G'	Suter Brook (21°-23°)	-	-

In the event of a flow slide originating at the crest of a given section, and based on the above analysis of runout angles, limited flooding and deposition of organic soils is anticipated to reach Suter Brook along Section A-A' and B-B', and G-G', in addition to residences located at 2242, 2247, and 2263 Park Crescent. In the event of flow slides originating along Section C-C', debris is unlikely to reach Suter Brook as the crest properties are somewhat further offset from the creek.

Along section D-D', 2244 and 2246 Park Crescent are within runout angles greater than 23°. As such, in the event of a slide originating at the north and/or west crest of 992 Corona Crescent, significant structural damage to 2244 and 2246 Park Crescent may occur, while further downslope, at 2242 and 2247 Park Crescent, runout would be limited to flooding and deposition of organic soils.

All of the previously rated exposed properties between 2251 and 2271 Park Crescent are considered to be susceptible to low levels of runout risk in the event of an upslope slide. However, due to a relatively shallow, benched upslope topography, and erosional channels trending towards 2251 and 2271 Park Crescent, the limited runout is anticipated to generally be channeled to these and adjacent properties at 2247, 2255, and 2267 Corona Crescent. Runout angles reaching these residences, which are set back from the toe of the slope, along sections E-E' and F-F' (2247, 2251, 2263, 2267, and 2271 Park Crescent) are all less than 21°, such that impacts are expected to be limited to flooding and deposition of organic soils, with no significant structural damage. Backyards extending to the toe of the slope and above, between 2247 and 2271 Park Crescent, may be subject to deposition of larger sediment and debris volumes in the event of a landslide.

6.0 LANDSLIDE RISK ASSESSMENT

In addition to the analysis of slope stability and the runout assessment presented above, Golder has carried out an evaluation of landslide consequence and risk using the BGC (2008) criteria. Readers are directed to this report for additional details and explanation.

6.1 Landslide Likelihood

Based on review of information compiled by Associated Engineering (2013), there have been 22 documented landslides between 1970 and 2013, along the Chines Escarpment crest and associated slopes between Schoolhouse Creek and Suter Brook. An estimated 0.5 landslides per year was selected as a conservative estimate, including all types of documented failures, which are generally considered to comprise flow slides. These failures occurred over an escarpment crest length of approximately 8.5 km, for a scaled landslide frequency along the escarpment of 5.9 x 10^{-5} per m per year. There are no recorded landslide events originating from the properties included in Golder's investigation for this study. However, the site has a similar geologic setting, and may be considered an extension of the overall Chines Escarpment in assessing landslide likelihood. Considering an average property width of 20 m for the properties inspected, the average landslide frequency, $P_{slide(average)}$, is 1.2x10^{-3} for each of the individual properties.

The potential for landslide hazard will vary depending on the nature of individual source areas. BGC (2008) assessed the variability of landslide likelihood within individual source areas by considering factors that would tend to increase or decrease the potential for instability of one area relative to another. These factors included the angle of the slope below the source; the presence of loose fill or colluvium; the configuration of drainage or runoff from buildings and catchment areas; visible indications of slope movement, such as deformation at or below the crest; and the general composition of the slide material. These factors and their values have been adopted for this assessment and are summarized in Table 10. Readers are directed to BGC (2008) for more details and explanation of the individual parameters.

Table 10: Landslide Likelihood Parameters

Slope Score	Loose Soil Score	Water Score	Deformation Score	Gravel Score
<35º = 0.8	<1 m deep at crest and <2 m deep below crest = 0.35	Connected to storm sewer = 0.5 Runoff from backyard = 0.5 Plus half roof = 0.75 Plus full roof = 1.0 Plus driveway = 1.5 Plus street = 2.0	None observed = 0.5	Predominantly gravel = 0.8 Predominantly sand, silt, and clay = 1.0
	<2 m deep at and below crest = 0.5			
35º - 40º = 1.0	>2 m deep at or below crest = 1.0		Deformation at or below crest = 1.0	
>40º = 1.25	>2 m deep at and below crest = 2.0		Deformation at and below crest = 2.0	

Using the above parameters, the individual source area landslide potential is determined as:

$P_{slide(lot)} = P_{slide(average)}$ * [Slope Score] * [Loose Soil Score] * [Water Score] * [Deformation Score] * [Gravel Score]

Based on the existing site conditions, and considering all previously rated high to very high risk properties and properties directly above those assessed as exposed, individual source properties along the crest of the Chines escarpment site have an estimated probability of landslide occurrence ranging from approximately 3 x 10^{-4} to 2 x 10^{-3}. The higher probability values are associated with source areas at 976 Corona Crescent where increased depths of yard waste and fills were encountered. The results of the landslide likelihood assessment for each of the individual properties examined are presented in Appendix C.

6.2 Landslide Consequence

The consequences of landslides refer to the physical and economic impacts these events have on people, property, government and society. Such impacts include loss of life, injury, property damage, and economic loss. For a fatality to occur, people must be present at the time of a landslide event and be in a location where they are impacted by it. Although people may be present at the time of an event, and in a location where they are impacted, it may not result in a fatality. The degree of impact from a landslide event decreases with distance away from the point of initiation, as reflected by the runout angle and distance from crest values. The potential number of fatalities may be expressed mathematically as:

$$N = P_{S:H} \times P_{T:S} \times V_{L:T} \times E$$

where,

N	is the expected number of fatalities due to a landslide event.
E	refers to elements affected by the occurrence of a landslide and could include property, infrastructure, or people. In the current study this parameter refers to the number of people expected to reside at any individual property.
$P_{S:H}$	quantifies the potential of a landslide, should it occur, to affect the location occupied by an element (person).
$P_{T:S}$	quantifies the probability that a person is present at the location of impact at the time a landslide occurs.
$V_{L:T}$	quantifies the estimated probability of total loss or damage to an individual given a landslide occurs, and they are present at that time. This term quantifies the vulnerability of the element.

The values of these parameters adopted by the DNV (BGC 2008) are summarized in Table 11 and Table 12. The following assumptions were made in determining the parameters for assessing consequences to individuals residing at the base and crest of the ravine slopes:

- The value of $P_{T:S}$ is based on the probability of an individual being present at the affected area when a landslide is most likely to occur. This is assumed to be 12 hours per day in the residence or 10 minutes per day in their backyards, during rainy periods when landslides are most likely. Individuals most at risk are assumed to spend 16 hours per day in the residence or 15 minutes per day in their backyards.
- The probability of a backyard being occupied is equal regardless of yard size. It has been assumed that a 3 m wide strip of ground along the full width of each backyard will fail rapidly in the event of a landslide, such that the ratio of backyard area lost decreases with its size.
- The vulnerability, $V_{L:T}$, of occupants of houses struck by landslides is approximately 2 in 7, or 0.29 based on BGC (2008). The vulnerability of occupants located along the headscarp area is considered to be 50%, or 0.5.

6.2.1 Consequences Below Crest of Escarpment

An assessment of the consequence of a landslide event to residences previously assessed as exposed was conducted. The properties located in impact zones were selected based on Golder's field reconnaissance and review of topography information. Parameters for residences at the base of the escarpment are presented in Table 11.

Table 11: Consequence Analysis Parameter Values for Properties at the Base of the Escarpment

Parameter	Angle from Property to Point of Landslide Initiation	Value of Parameter
$P_{S:H}$	>25º	0.667
	23º - 25º	0.167
	21º - 23º	0.083
	19º - 21º	0.0025
	<19º	Not Evaluated
$P_{T:S}$		0.5
$V_{L:T}$		0.29
E		4

The expected number of fatalities, N, in the event of a landslide occurring at the downslope properties included in this investigation was less than 0.005 for all properties, with the exception of slides originating from the 992 Corona Crescent property, where N was 0.49. Although theoretical runout contours intersect a number of the exposed properties, the slopes in this area are covered by well-established vegetation and underlain by very dense deposits. Consequently, these slopes are not expected to be susceptible to flow slide-type failures. The results of each of the individual properties examined are presented in Appendix C.

6.2.2 Consequences at Crest of Escarpment

Based on field reconnaissance and subsurface investigation, it is anticipated that all of the properties previously rated as high to very high risk are founded on dense to very dense deposits of till-like soils or Quadra sands. As such, rainfall-triggered failures regressing beyond the crest to impact residential foundations are considered to be unlikely in comparison to backyards, pools, decks, and detached garages. Therefore, the consequence estimation of loss of life at properties along the crest of the escarpment focuses on a slope failure originating in the backyard, and leading to loss of life. Parameters for residences at the base of the escarpment are adopted from BGC (2008) and presented in Table 12.

Table 12: Consequence Analysis Parameter Values for Properties at the Crest of the Escarpment

Parameter	Distance from House to Crest of Escarpment	Value of Parameter
$P_{S:H}$	< 3 m	0.99
	3 – 6 m	0.67
	6 – 9 m	0.40
	9 – 12 m	0.29
	> 12 m	0.20
$P_{T:S}$		0.007
$V_{L:T}$		0.5
E		4

The expected number of fatalities, N, in the event of a landslide at the escarpment crest properties, previously assessed as high to very high risk rating, ranges from 0.00 to 0.01. The upper end of this range corresponds to houses within 3 m to 6 m of the slope crest, including 976 Corona Crescent and 992 Corona Crescent. The results for each of the individual properties examined are presented in Appendix C.

6.3 Risk Estimates

Risk is generally determined as the product of the probability of occurrence of an event and the consequence. The probability of landslide occurrence for each hypothetical source property is expressed as $P_{slide(lot)}$, and the consequence, in terms of expected number of fatalities per year, as N. For the current study, risk has been quantified in terms of annual probability of death for an individual from landslide hazards (individual risk), as well as the total number of expected fatalities considering the population as a whole (societal risk). The DNV risk tolerances are based on individual risk.

6.3.1 Individual Risk Estimates

For individual risk calculation, the resident being most at risk is considered: individuals spending the most time in their homes (at the base of the escarpment) or in their backyard (at the crest of the escarpment). Consistent with the BGC (2008) study, the current study has computed individual risk assuming the element parameter, E, is set to 1.0 for an individual, and the temporal probability parameter, $P_{T:S}$, is equal to 0.67 or 0.01, for residences at the base and crest of the escarpment, respectively, to model the person most at risk. Individual risk is computed for each of the runout angle zones and distances of the upslope houses from the crest.

The results, under existing conditions, for the annual probability of death for an individual are summarized for all runout angles and house distances from the crest for residences at the crest and base of the ravine slopes in Appendix C. However, these estimates only apply in locations where houses are present. Based on these results, a maximum individual risk value of 9×10^{-5} per year was computed for 2244 Park Crescent, considering a slide originating from the 992 Corona Crescent property. A maximum individual risk value of 4×10^{-8} per year was determined for the properties located along the escarpment crest, at 976 Corona Crescent.

6.3.2 Societal Risk Estimates

Societal risk was estimated using the predicted frequency of a landslide event for each crest property and the expected number of fatalities associated with that event. Risk is presented in terms of the product of the frequency of an event and the total expected number of fatalities associated with it. Societal risk estimates are presented in Appendix C.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Slope Stability

Based on the review of site conditions, as summarized above, together with the topographical and photographic information, review of previous studies and our recent subsurface investigation and field reconnaissance, the most likely slide hazard applicable to this site is a combination of a soil slump and/or flow slide.

The results of our analysis generally confirm those of previous studies carried out along the Suter Brook ravine properties. Under static conditions, the factors of safety against major, deep seated slope movements through the existing dense till-like and pre-Vashon deposits, with failure scarps impacting the residences are generally greater than 1.3, which is consistent with DNV criteria for acceptable risk of existing residential development, for all of the properties previously rated as high to very high risk, with the exception of 992 Corona Crescent where failure surfaces intersecting the residence were nominally below 1.3.

The subsurface investigation and field reconnaissance, combined with analysis of slope conditions indicates that there is higher potential for relatively shallow, soil slump instability within existing fills along the crest of the slopes, possibly impacting detached garages, decks, and other non-residential structures and portions of the properties close to or downslope of the crest of slope.

As part of Golder's analyses, the stability of the slopes was also assessed as per the APEGBC 2010 guidelines for landslide assessments for residential properties. The results of the displacement-based seismic stability analysis indicate that all properties have a factor of safety greater than 1.0 for under the 1 in 475 year (10 percent in 50 year) seismic event, based on a median displacement of less than 15 cm between the crest and residence, which is considered acceptable for residential properties.

However, minimum factors of safety less than 1.0 were found for shallower failure scarps not extending to the crest residences, but impacting landscaped portions of properties, detached garages, decks, and other non-residential structures near the crest of the slopes (Figure 8B). Consequently, the risk of damage to, or loss of these non-habitable portions of the residential properties is considered high to very high.

7.2 Runout Assessment

Runout angles were generated for sections A-A', B-B', C-C', D-D', E-E', F-F', G-G', as well as contours along less critical directions extending from the Suter Brook ravine crest properties. The results indicate that most of the backyards of properties, from 2242 to 2271 Park Crescent, are within the theoretical runout angles and may experience some level of soil and debris deposition in the event of an upslope landslide. However, with the exception of 2244 (>25°) and 2246 (23°-25°) Park Crescent, runout angles from the crest of the ravine slope to exposed residences were not in excess of 21°, and are generally less than 19°. Those residential properties exposed to runout angles of less than 21 degrees are anticipated to be at low to no risk of damage, with slide discharge onto the properties being limited to water flow and organic soil deposition.

Runout angles up to 23° from properties at 977 Thermal Drive and 976 to 990 Corona Crescent are expected to intersect or enter the channel of Suter Brook. However, as discussed above, significant debris flow and debris flood or downstream runout is not anticipated due to the wide valley bottom and moderate (about 20 degrees) gradient of the channel based on available topography.

The potential for slope failures originating at 990 Corona Crescent forming a flow slide is considered to be increased due to the pool location at the crest of the slope, but it is anticipated that runout would be limited to the south portions of 992 Corona Crescent and 2242 and 2244 Park Crescent properties, while not impacting residences.

Although the theoretical runout angles intersect portions of the backyards along the Park Crescent properties, the upslope area is generally benched, and those surficial erosional gullies where a slide debris event is likely to travel extend into wide, level backyards at 2251 and 2271 Park Crescent. As such, it is considered unlikely and improbable that limited volume of slide material resulting from shallow slumps or slides, consistent with site observations, will have runout distances impacting residences. It is considered more likely that soil slump failures, rather than failures exhibiting flow slide characteristics, will occur within the generally granular and unsaturated natural soils and that these soil slump failures would generally have runout angles steeper than 25 degrees.

The exception to the assessment presented above is the risk of failures originating from 992 Corona Crescent, and running out to downslope Park Crescent properties. For these properties, static and seismic factors of safety were computed to be approximately 1.3 and 1.1, respectively. As such, it is considered more likely that slope failures may impact 2242, 2244, and 2246 Park Crescent, and that the potential consequences and risk associated with such slope failures will be greater. Similarly, based on the runout assessment, the potential for significant structural and potential injury or fatality to persons within the steeper (23 to 25° or larger) landslide runout zones impacting the 2244 and 2246 Park Crescent residences from failures originated from the north and west slope crests at the 992 Corona Crescent property is considered to be high. However, the maximum individual risk value of 9×10^{-5} per year computed for 2244 Park Crescent is equal to or slightly below the maximum acceptable level of individual risk of 1×10^{-4} per year for existing residential developments based on the DNV criteria.

7.3 Landslide Risk Assessment

Golder's assessment of the potential landslide events along the Suter Brook ravine indicates that the expected number of fatalities for any given hypothetical landslide event ranges from 0.00 to 0.48. The upper end of this range corresponds to landslide originating along the north and west slopes at 992 Corona Crescent, as described above.

Based on the results of the analysis of landslide risk and potential consequences presented previously, individual risk levels for all exposed properties are below the 1×10^{-4} per year maximum acceptable level of individual risk criteria (DNV 2009) for existing residential developments. It is recommended that additional review of properties with risk levels near the tolerable criteria be carried out together with appropriate periodic monitoring and mitigative measures being conducted by the property owners.

7.4 Risk Mitigation Measures

The following section includes a description of general risk control options for all properties in the Suter Brook ravine area. As described in Section 6.3, risk is a product of likelihood and consequence. As such, mitigation or observation measures to reduce risk to properties along the crest and base of the slopes can target some or all of the following parameters:

$$\text{Risk} = \text{Slide Likelihood} * P_{S:H} * P_{T:S} * V * E$$

Reducing the value of any of these elements will reduce the risk associated with specific landslide hazard accordingly. The following general mitigation recommendations are consistent with that in BGC (2008).

7.4.1 Reducing Slide Likelihood

Flow slides, which can potentially have large runouts, occur in saturated, loose soils along steep slopes. As such, mitigation measures which reduce the depth of loose, poor-draining material along the slope crest, densify or otherwise strengthen the soil, or limit water inputs can reduce the likelihood of a slope failure. The following measures may be practical for reducing slide likelihood:

- Surface Drainage – It is understood that all properties included in this study are connected to the storm sewer system. However, several of the properties were observed to have large decks with no drainage system, where substantial water discharges off the deck onto the slope crest. The 977 Thermal Drive property was also observed to have two pipes, presumably from the carport area, extending down the ravine slope. Collecting and directing all precipitation and runoff flows into the storm sewer system is an effective way of reducing surficial erosion, saturation of or elevated porewater pressures in the loose near surface soils, and the landslide risk.
- Fill Removal – Removal of loose, poor-draining fills, including yard waste, is recommended along the crest of the ravine slopes, in particular at 976 and 980 Corona Crescent. Surficial fills present a source of landslide debris, but can also restrict drainage of materials further upslope, leading to buildup of excessive porewater pressures as well as saturation of the near surface soils within the slope. Thick yard waste cover can also kill underlying vegetation, reducing the root strength along the slope.
- Fill Compaction – Re-compaction of loose fills or other treatment measures, where removal is not desirable or practical, may be considered to improve shear strength and reduce surface water infiltration.
- Slope Revegetation – Erosion control and bioengineering measures should be employed in areas where large vegetation is limited, or slopes have been regraded. In addition, existing large vegetation and tree cover should not be trimmed or removed unless approved by a qualified arborist and geotechnical engineer, as the root mat provides shear strength resistance against shallow slope failures while the vegetation canopy and ground cover reduces the risk and amount of surficial erosion and infiltration.

- Retaining Wall Replacement – Non-essential retaining walls in poor condition, particularly where used to raise the levels of backyards, should be removed or replaced with suitable, stable structures. Raised backyard fills create additional loads along the crest of the slopes, and generally have poor drainage characteristics. Where practical, backyards underlain by fill material should be lowered and properly graded to reduce the imposed loadings and prevent surface runoff discharge onto the slopes.
- Slopes Inspections – Regular, detailed inspection of slopes is recommended to identify worsening slope conditions leading to failures.

7.4.2 Reducing Spatial Probability of Impact

Spatial probability of impact, the potential for a landslide, should it occur, to impact an upslope or downslope element, can be reduced by limiting the extent of the slope failure. The following measures may be practical for reduction:

- Landslide Barriers – Construction of deflection berms, ditches, or other barriers to protect against landslides or flows may be appropriate in reducing the theoretical runout at exposed properties.
- Relocation – Removal and reconstruction of the residence, if practical, to a less exposed area of the property may be considered.

7.4.3 Reducing Temporal Probability of Impact

Temporal probability of impact relates to the probability that an element is present in the impact zone at the time of the slope failure. Reductions in the time spent in areas of higher risk to persons during periods of high likelihood of landslides can be controlled by detailed monitoring of precipitation, slope movement, and groundwater conditions, combined with effective evacuation and alert systems for residents.

7.4.4 Reducing Vulnerability

Vulnerability of residents may be reduced in the event that the residence is struck by a landslide:

- Relocation – relocation of living areas, particularly bedrooms, where residents may be most vulnerable, to locations furthest from the toe of the slope may minimise the potential for fatalities; and
- Impact-Resistant House Construction – Reinforced concrete or effective methods of dissipating landslide energy.

8.0 SUMMARY OF RECOMMENDATIONS AND CLOSURE

It is understood that an individual risk level of less than 1 x 10^{-4} per year is considered tolerable for existing residences based on the DNV 2009 criteria. All properties included in Golder's investigation were found to have individual risks less than this criterion.

Based on the results of static and seismic stability for the 992 Corona Crescent property, which marginally meet the DNV risk and stability criteria, and the relatively shallow depth of the below ground foundation of the existing residence into dense native soils along the crest (approximately 1.2 m), failure surfaces impacting the residence may result in serious damage to both 992 Corona Crescent and downslope Park Crescent properties. It is recommended that consideration be given to additional monitoring on the part of the property owners, above and below the slopes along Corona Crescent and, in particular, properties near 992 Corona Crescent, along with the implementation of recommended mitigation measures discussed above. Evidence of surficial erosion and/or slope movement should be reported to the City by homeowners, and a geotechnical engineer consulted.

9.0 CLOSURE

This study has been carried out to identify and characterize potential landslide hazards originating along the crest of the Suter Brook ravine, and to provide an assessment of landslide related risks associated with those hazards. The results of the hazard and risk assessments are based on the site conditions at the time of our investigation and reconnaissance, together with the information made available to us. This report provides geotechnical engineering comments and recommendations to the City of Coquitlam as input to further detailed planning and design of potential mitigation or remedial measures for the existing residences.

Golder accepts no responsibility for actions taken, decisions made, or damages suffered by any third party who makes use of this report, or is affected by it in any way, including perceived or actual changes in real estate values.

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Chase Reid, EIT
Geological Engineer

Richard Butler, P.Eng., FEC
Principal

CAR/RCB/sn

o:\final\2013\1447\13-1447-0330\1314470330-001-r-rev1\1314470330-001-r-rev1 chines stability assessment 06dec_13.docx

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder cannot be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

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The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder cannot be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, *etc.*) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

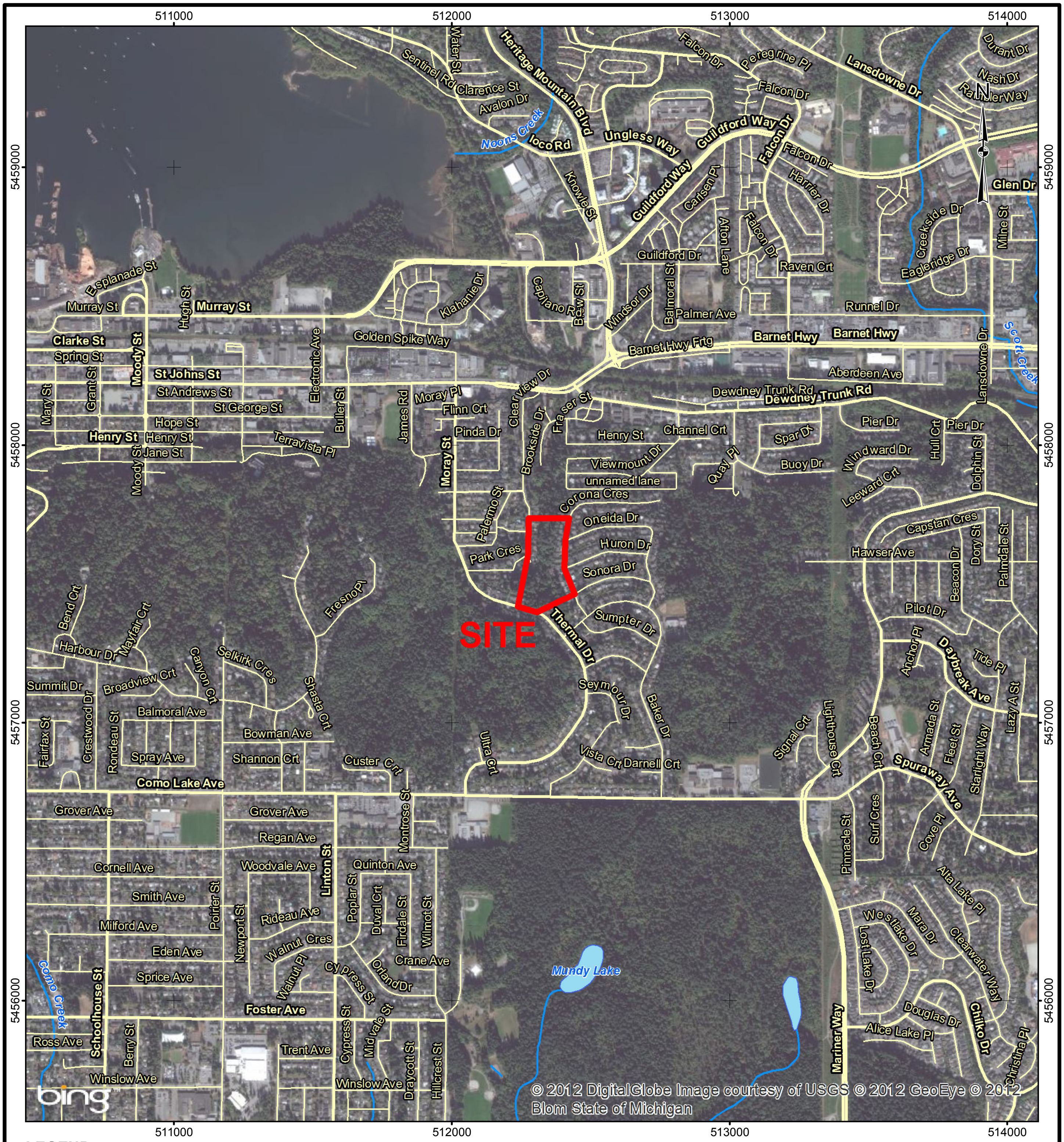
10.0 REFERENCES

AE 2013 City of Coquitlam, Qualitative Partial Risk Slope Analysis, Chines Escarpment and Corona Crescent Areas. File No. 2013-2355.000

APEGBC 2010 Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC. Association of Professional Engineers and Geoscientists of British Columbia.

BGC 2008 District of North Vancouver, Westlynn and Pemberton Heights Escarpments, Landslide Risk Assessment. File No. 0404-017

DNV 2009The District of North Vancouver, Report to Council, Natural Hazards Risk Tolerance Criteria. File No. 11.5225.00/000.000.



N:\Bur-Graphics\Projects\2013\1447\13-1447-0330\GIS\Mapping\MXD\General\Figure_1_Key_Plan.mxd

LEGEND

🟥	SITE LOCATION
—	MAJOR ROAD
—	LOCAL ROAD
—+—	RAILROAD
—	WATERCOURSE
🟦	WATERBODY
▨	WETLAND

500 0 500

SCALE 1:20,000 METRES

REFERENCE

BASE DATA OBTAINED FROM THE PROVINCE OF BRITISH COLUMBIA.
IMAGERY OBTAINED FROM BING MAPS FOR ARCGIS
PUBLISHED BY MICROSOFT CORPORATION, REDMOND, WA, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 10

PROJECT

CITY OF COQUITLAM
CHINES SLOPE STABILITY ASSESSMENT
COQUITLAM, B.C.

TITLE

KEY PLAN

Golder Associates

PROJECT No.	13-1447-0330		PHASE No. 3000/3002
DESIGN	CAR	02 Oct. 2013	SCALE AS SHOWN REV. 0
GIS	SGR	02 Oct. 2013	
CHECK	CAR	29 Nov. 2013	FIGURE: 1
REVIEW	RCB	29 Nov. 2013	

0 30 60 90
SCALE METRES

LEGEND

——	PROPERTY BOUNDARY
——	BUILDING OUTLINE
- - -	CITY OF COQUITLAM RIGHT OF WAY
⊕	BOREHOLE LOCATION
▩	EXPOSED PROPERTY
▨	ASSESSED PROPERTY

NOTES

1. TOPOGRAPHY SHOWN WITH 2 m CONTOUR INTERVAL.

REFERENCE

1. BASE DATA PROVIDED BY THE CITY OF COQUITLAM,
FILE NAME: chines_lidar_points_clip.dwg
DATED: 09/23/2013

REV	DATE	DESCRIPTION	DRW	DES	CHK	RVW
0	2013-12-06	ISSUED WITH REPORT	RH	CAR	CAR	RCB
A	2013-09-27	DRAFT REPORT	RH	CAR		

CLIENT

CITY OF COQUITLAM

CONSULTANT

Golder Associates

PROJECT 1314470330-3000-3002

CHINES SLOPE STABILITY ASSESSMENT
COQUITLAM, B.C.

TITLE

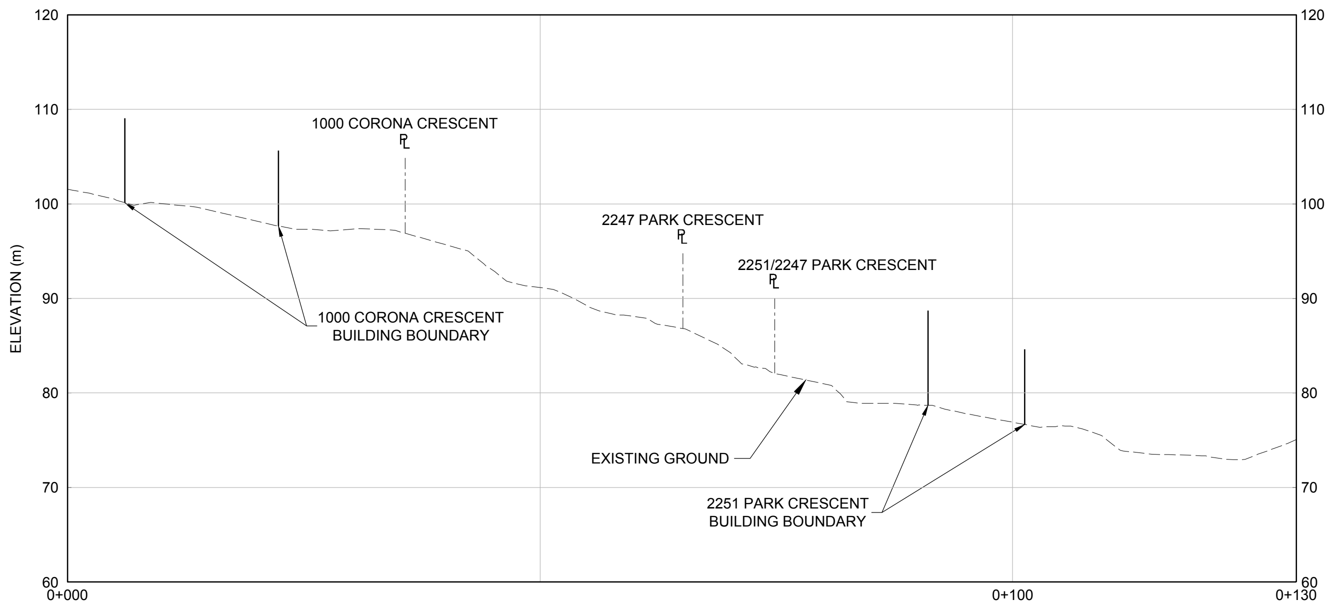
SITE PLAN

DRAWING No. FIGURE 2

SHEET No. 2 OF 2

SHEET SIZE ANSI D 25 mm 0

Drawing File: N:\Bur-Graphics\Projects\2013\1447\13-1447-0330\CAD_Phase 3000\Task 3002\PRODUCTION\1314470330-3000-3002-04.dwg Layout:SITE PLAN Friday, December 06, 2013 10:10:24 AM By: rhorlyck



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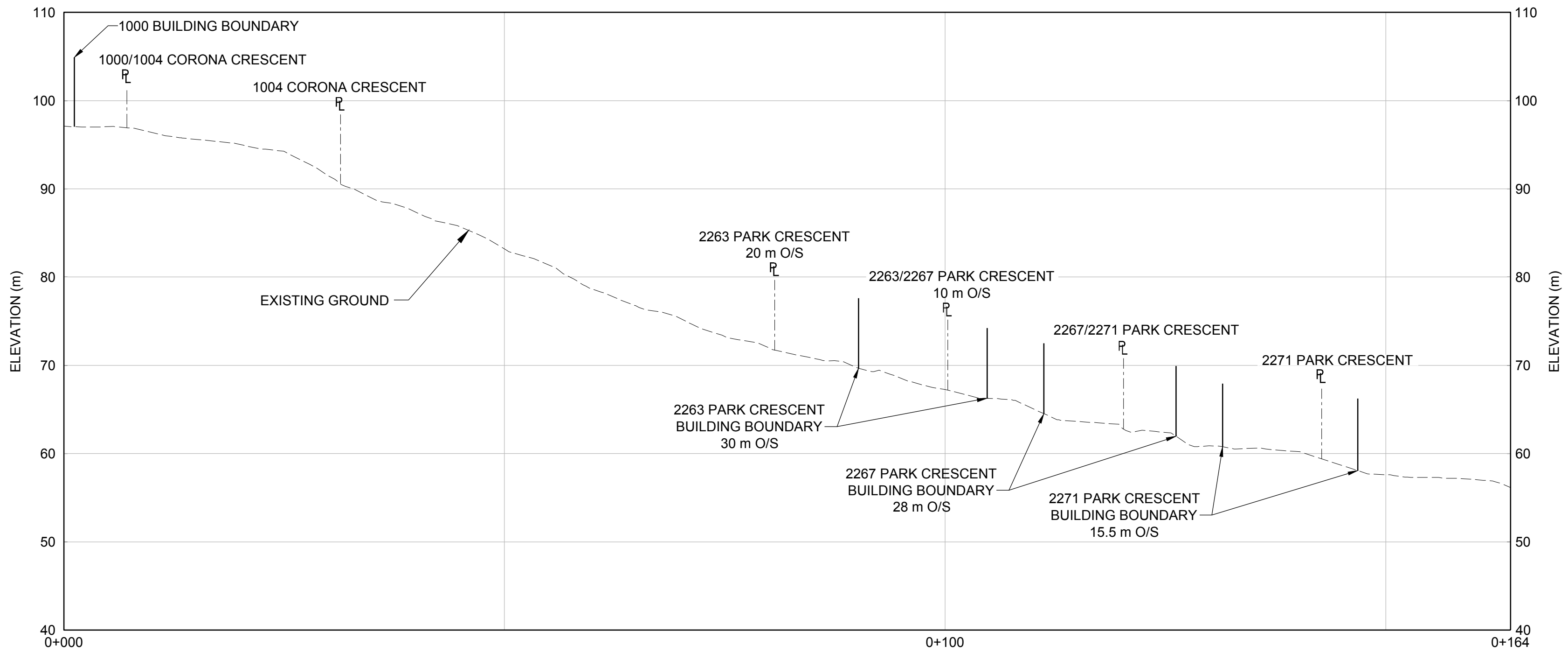

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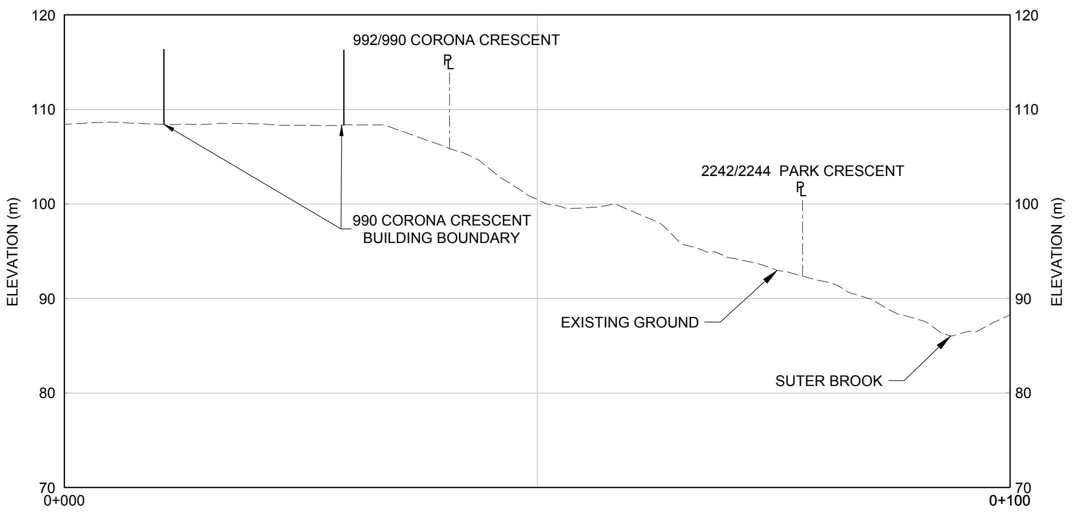

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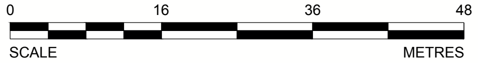
   DATED: 09/23/2013



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A	2013-09-27	DRAFT REPORT	RH	CAR		
REV	DATE	DESCRIPTION	DRW	DES	CHK	RVW

CLIENT

CITY OF COQUITLAM

CONSULTANT

Golder Associates

PROJECT 1314470330-3000-3002

CHINES SLOPE STABILITY ASSESSMENT
COQUITLAM, B.C.

TITLE

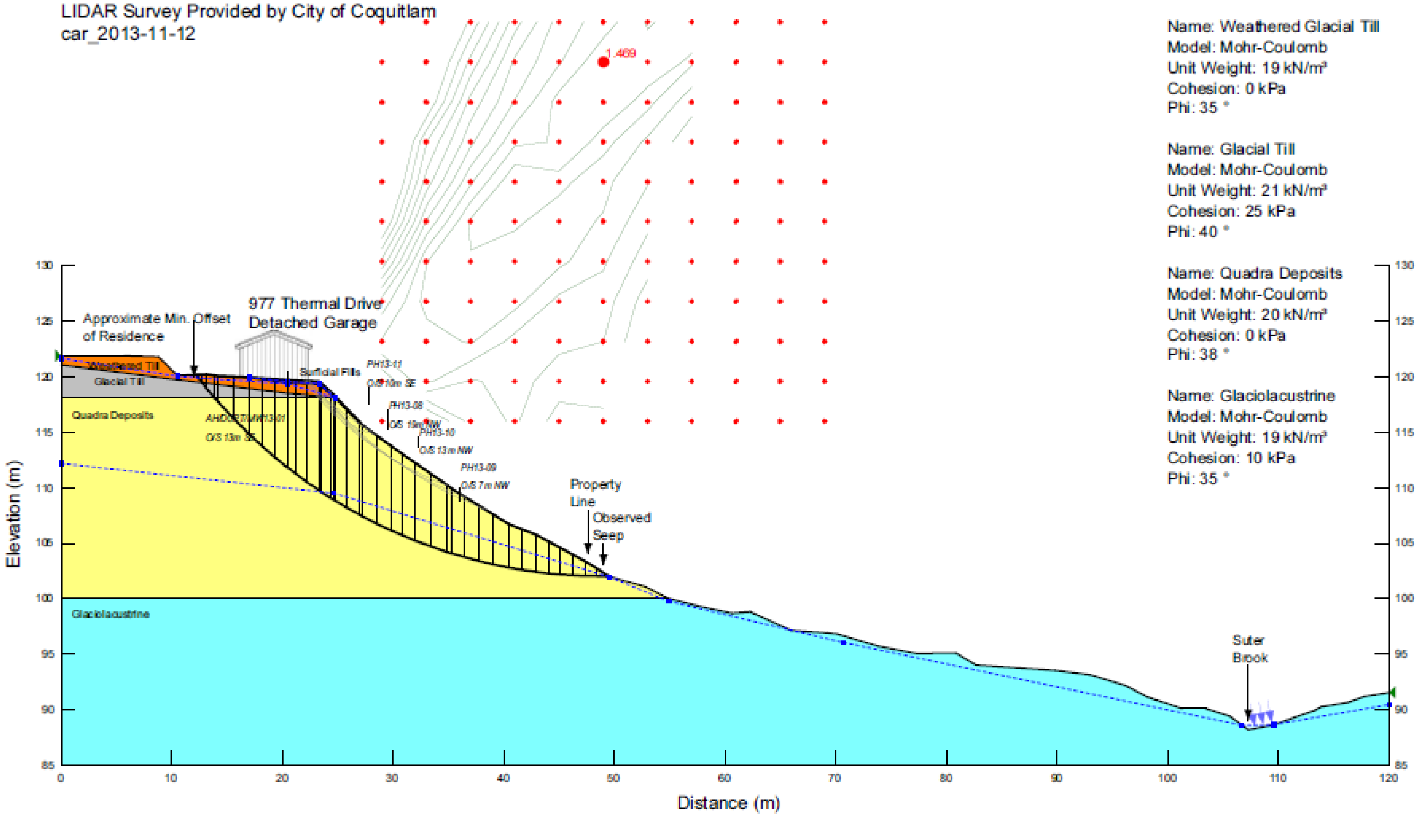
EXPOSED PROPERTY SECTIONS

DRAWING No. FIGURE 3

SHEET No. 3 OF 3

SHEET SIZE ANSI D 25 mm 0

Chines Slope Stability Assessment
City of Coquitlam
13-1447-0330
Golder Associates Ltd.
LIDAR Survey Provided by City of Coquitlam
car_2013-11-12



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Phi: 30 °

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Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 35 °

Name: Glacial Till
Model: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 25 kPa
Phi: 40 °

Name: Quadra Deposits
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 38 °

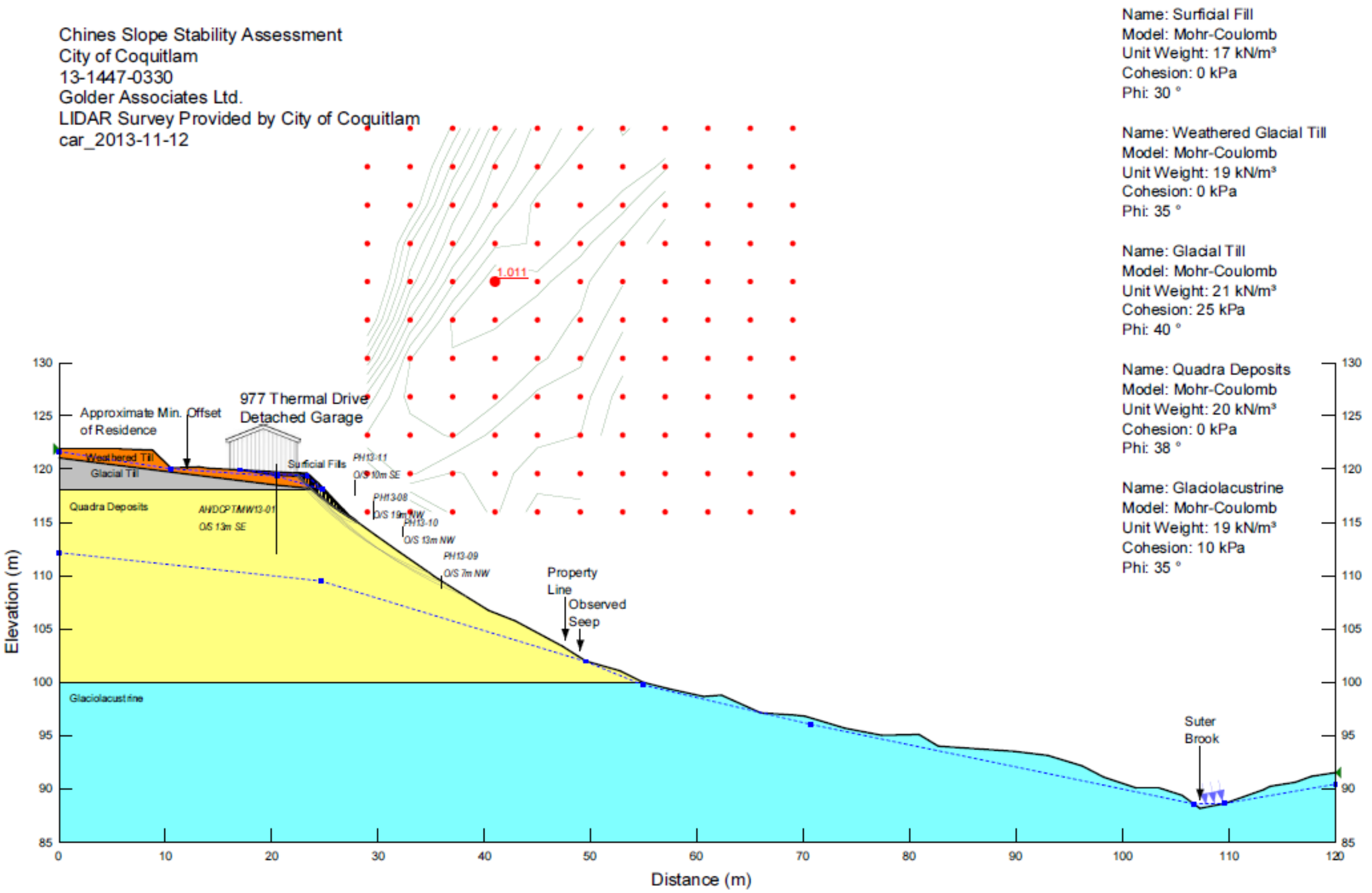
Name: Glaciolacustrine
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 10 kPa
Phi: 35 °

PROJECT
Chines Slope Stability
City of Coquitlam
Coquitlam, BC

TITLE
STATIC SLOPE STABILITY ANALYSIS SECTION A-A' RESIDENCE (DEEP FAILURE)

Golder Associates

PROJECT No.	13-1447-0330		PHASE No. 3000	
DESIGN	CAR	12NOV13	SCALE NTS	REV.
CADD			**FIGURE 4A**	
CHECK	MGB	29NOV13		
REVIEW	RCB	29NOV13		


Chines Slope Stability Assessment
City of Coquitlam
13-1447-0330
Golder Associates Ltd.
LIDAR Survey Provided by City of Coquitlam
car_2013-11-12

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Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
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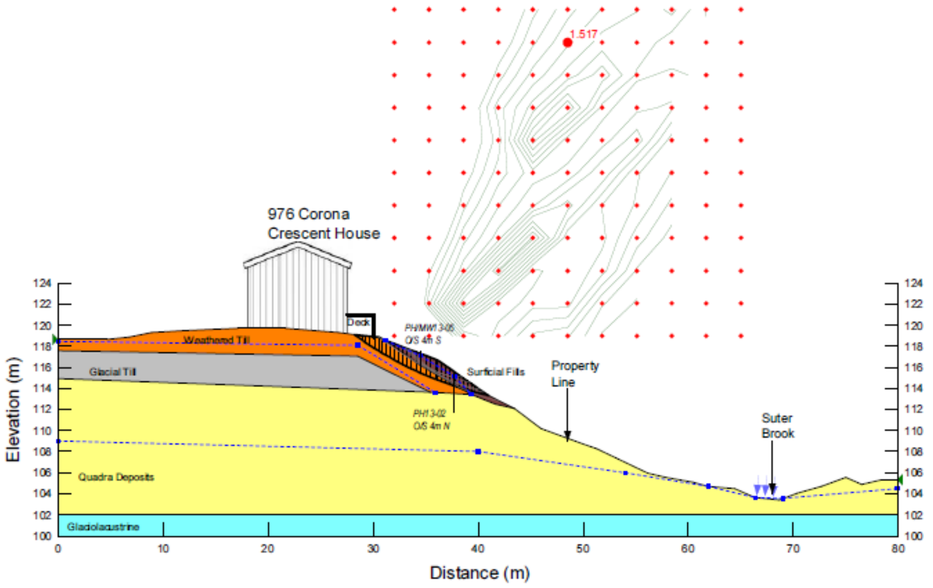
Unit Weight: 19 kN/m³
Cohesion: 10 kPa
Phi: 35 °

PROJECT	Chines Slope Stability City of Coquitlam Coquitlam, BC
TITLE	STATIC SLOPE STABILITY ANALYSIS SECTION A-A' GARAGE (SHALLOW FAILURE)

Golder Associates

PROJECT No.	13-1447-0330		PHASE No. 3000	
DESIGN	CAR	12NOV13	SCALE NTS	REV.
CADD			**FIGURE 4B**	
CHECK	MGB	29NOV13		
REVIEW	RCB	29NOV13		

Chines Slope Stability Assessment
City of Coquitlam
13-1447-0330
Golder Associates Ltd.
LIDAR Survey Provided by City of Coquitlam
car_2013-11-12



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Phi: 40 °

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Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 38 °

Name: Glaciolacustrine
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 10 kPa
Phi: 35 °

PROJECT

Chines Slope Stability
City of Coquitlam
Coquitlam, BC

TITLE

STATIC SLOPE STABILITY ANALYSIS
SECTION B-B’

PROJECT No.	13-1447-0330		PHASE No. 3000	
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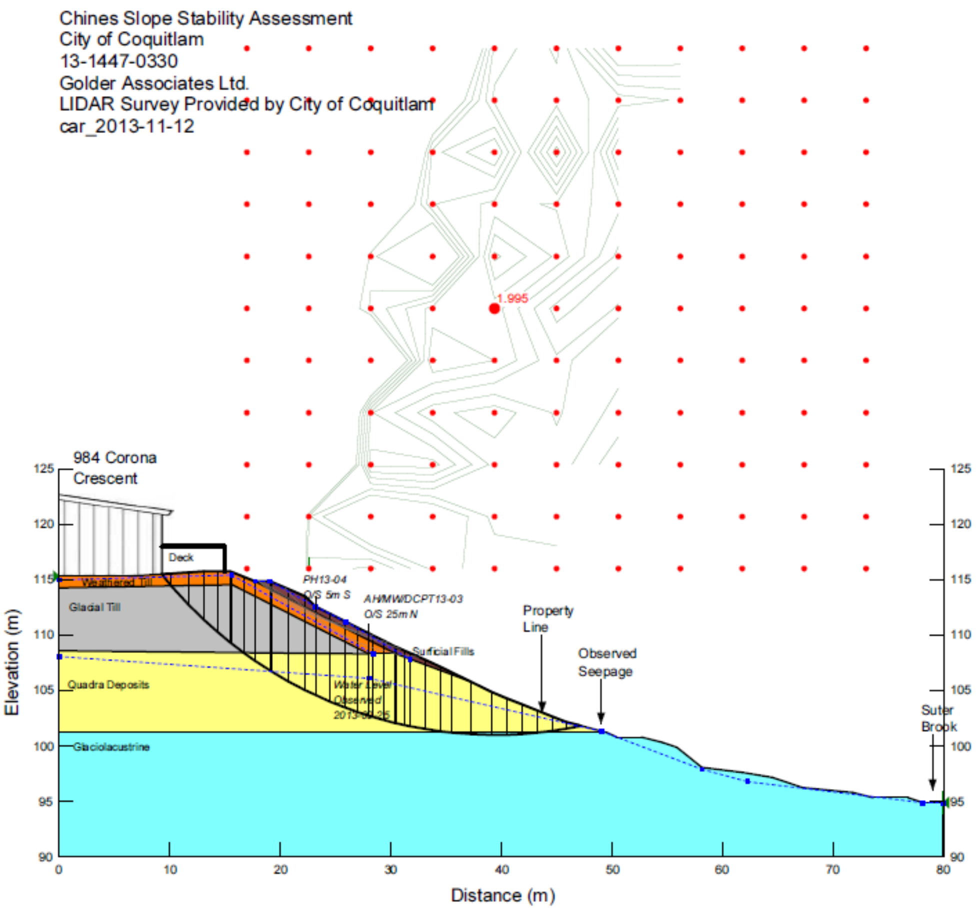
REVIEW	RCB	29NOV13		



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Cohesion: 0 kPa
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Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 10 kPa
Phi: 35 °

PROJECT

Chines Slope Stability
City of Coquitlam
Coquitlam, BC

TITLE

STATIC SLOPE STABILITY ANALYSIS
SECTION C-C’

Golder Associates

PROJECT No.	13-1447-0330		PHASE No. 3000	
DESIGN	CAR	12NOV13	SCALE NTS	REV.
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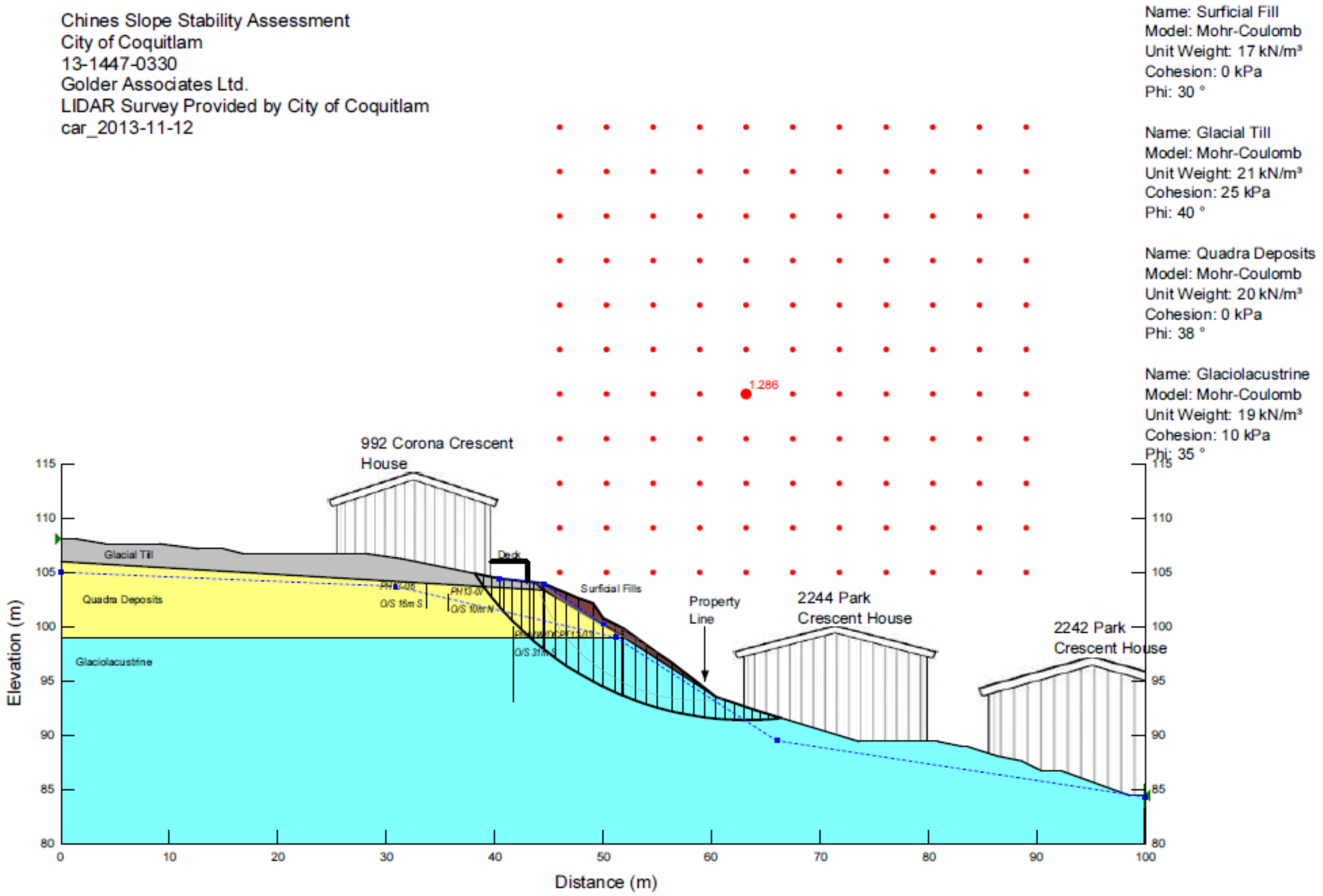
REVIEW	RCB	29NOV13		



Chines Slope Stability Assessment
City of Coquitlam
13-1447-0330
Golder Associates Ltd.
LIDAR Survey Provided by City of Coquitlam
car_2013-11-12

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Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 10 kPa
Phi: 35 °

PROJECT
Chines Slope Stability
City of Coquitlam
Coquitlam, BC

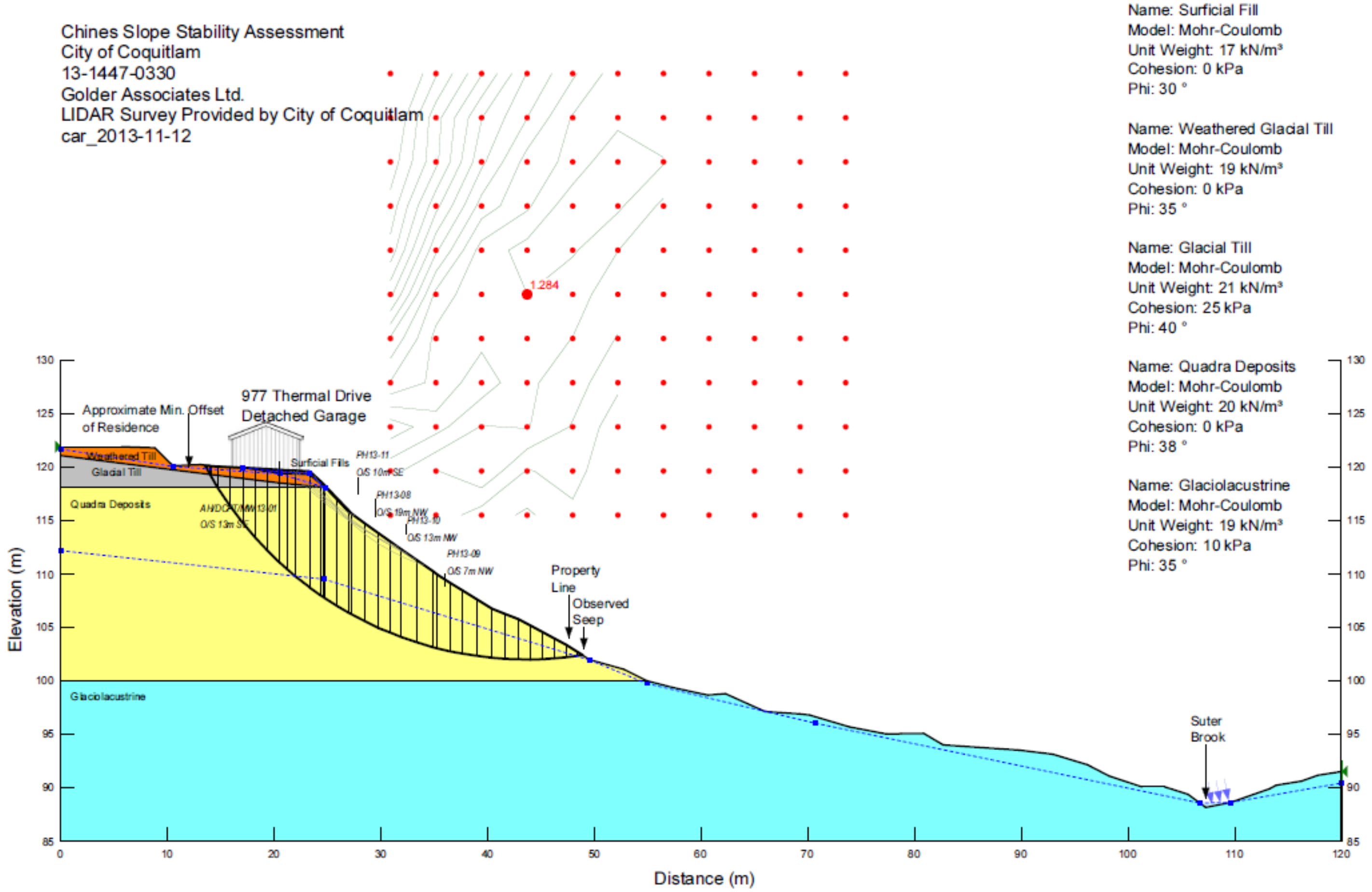
TITLE

STATIC SLOPE STABILITY ANALYSIS
SECTION D-D'

Golder Associates

PROJECT No.	13-1447-0330		PHASE No. 3000	
DESIGN	CAR	12NOV13	SCALE NTS	REV.
CADD			**FIGURE 7**	
CHECK	MGB	29NOV13		
REVIEW	RCB	29NOV13		

Chines Slope Stability Assessment
City of Coquitlam
13-1447-0330
Golder Associates Ltd.
LIDAR Survey Provided by City of Coquitlam
car_2013-11-12



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Cohesion: 10 kPa
Phi: 35 °

PROJECT

Chines Slope Stability
City of Coquitlam
Coquitlam, BC

TITLE

SEISMIC SLOPE STABILITY ANALYSIS SECTION A-A’ RESIDENCE (DEEP FAILURE)

Golder Associates

PROJECT No.	13-1447-0330		PHASE No. 3000	
DESIGN	CAR	12NOV13	SCALE NTS	REV.
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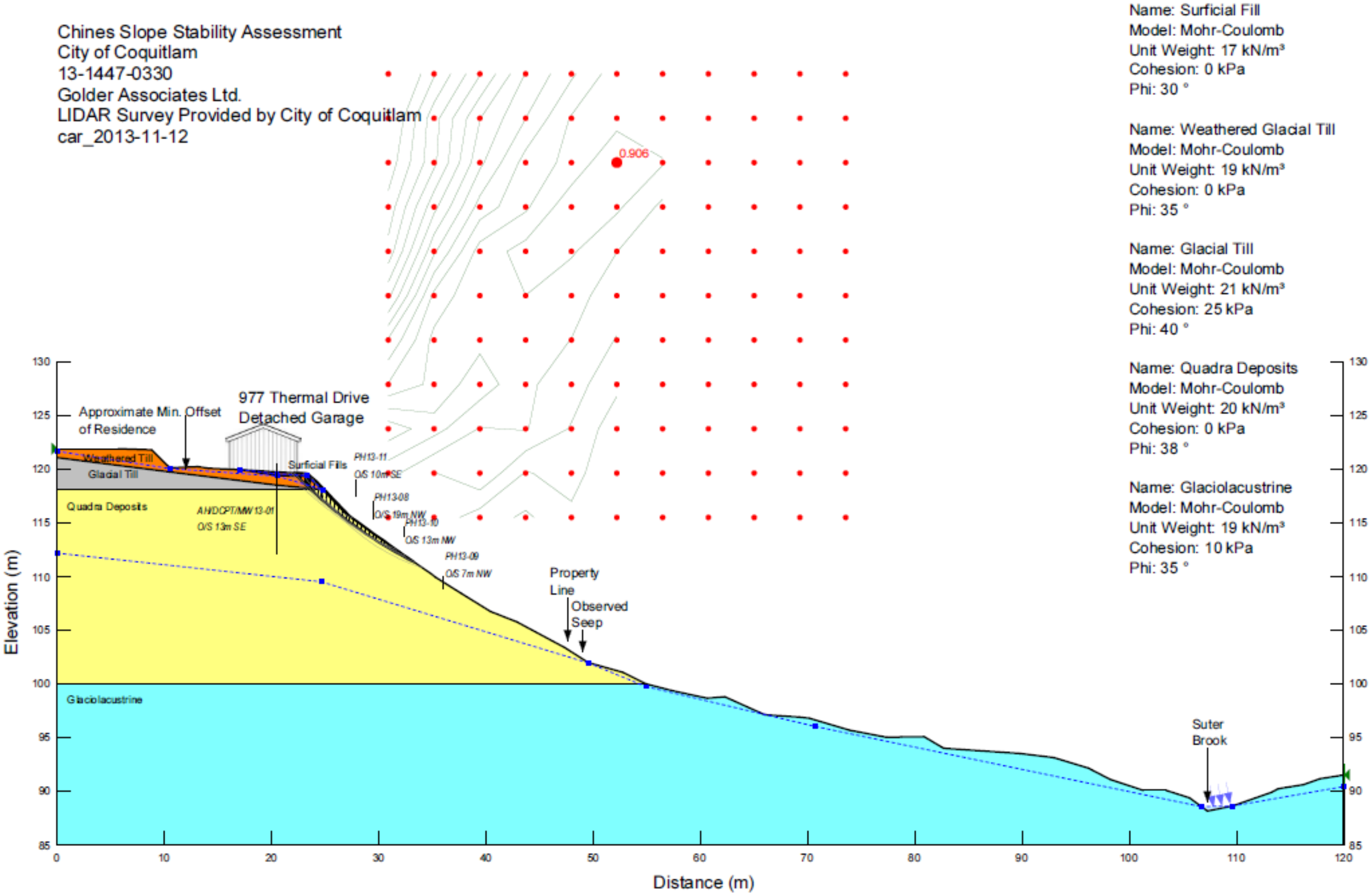
REVIEW	RCB	29NOV13		



Chines Slope Stability Assessment
City of Coquitlam
13-1447-0330
Golder Associates Ltd.
LIDAR Survey Provided by City of Coquitlam
car_2013-11-12

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Phi: 35 °

PROJECT
Chines Slope Stability
City of Coquitlam
Coquitlam, BC

TITLE

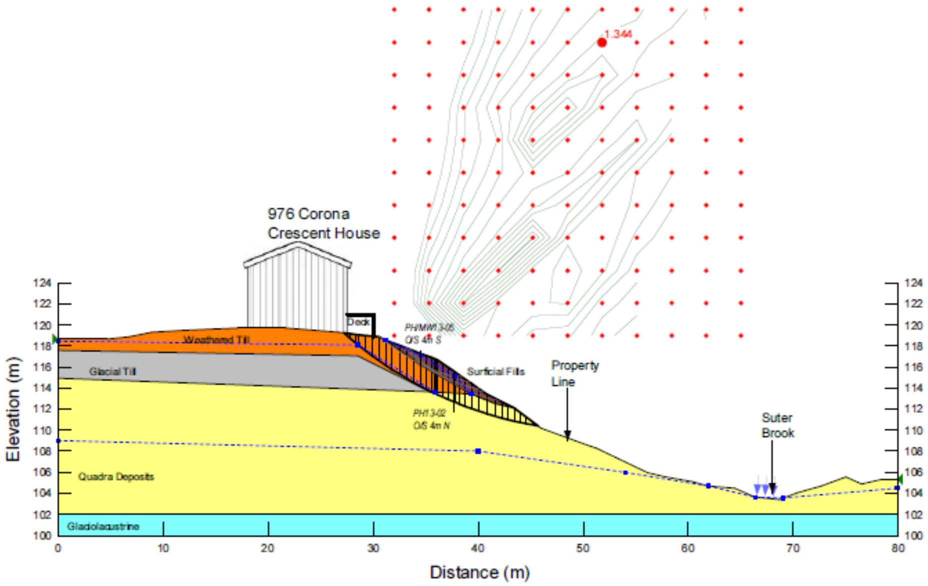
SEISMIC SLOPE STABILITY ANALYSIS SECTION A-A’ GARAGE (SHALLOW FAILURE)

Golder Associates

PROJECT No.	13-1447-0330	PHASE No. 3000	
DESIGN	CAR	12NOV13	SCALE NTS	REV.
CADD			
CHECK	MGB	29NOV13	
REVIEW	RCB	29NOV13	

FIGURE 8B

Chines Slope Stability Assessment
City of Coquitlam
13-1447-0330
Golder Associates Ltd.
LIDAR Survey Provided by City of Coquitlam
car_2013-11-12



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PROJECT

Chines Slope Stability
City of Coquitlam
Coquitlam, BC

TITLE

SEISMIC SLOPE STABILITY ANALYSIS
SECTION B-B’

Golder Associates

PROJECT No.	13-1447-0330		PHASE No. 3000
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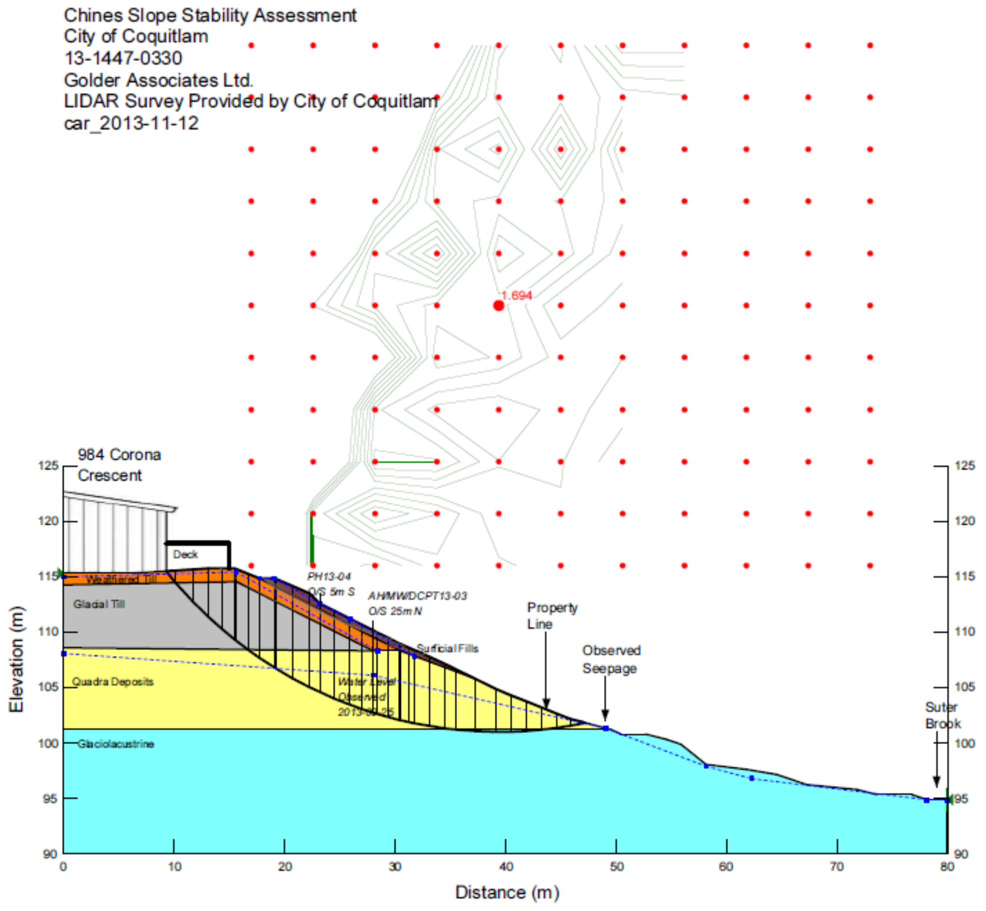

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PROJECT

Chines Slope Stability
City of Coquitlam
Coquitlam, BC

TITLE

SEISMIC SLOPE STABILITY ANALYSIS
SECTION C-C’

Golder Associates

PROJECT No.	13-1447-0330		PHASE No. 3000	
DESIGN	CAR	12NOV13	SCALE NTS	REV.
CADD			**FIGURE 10**	
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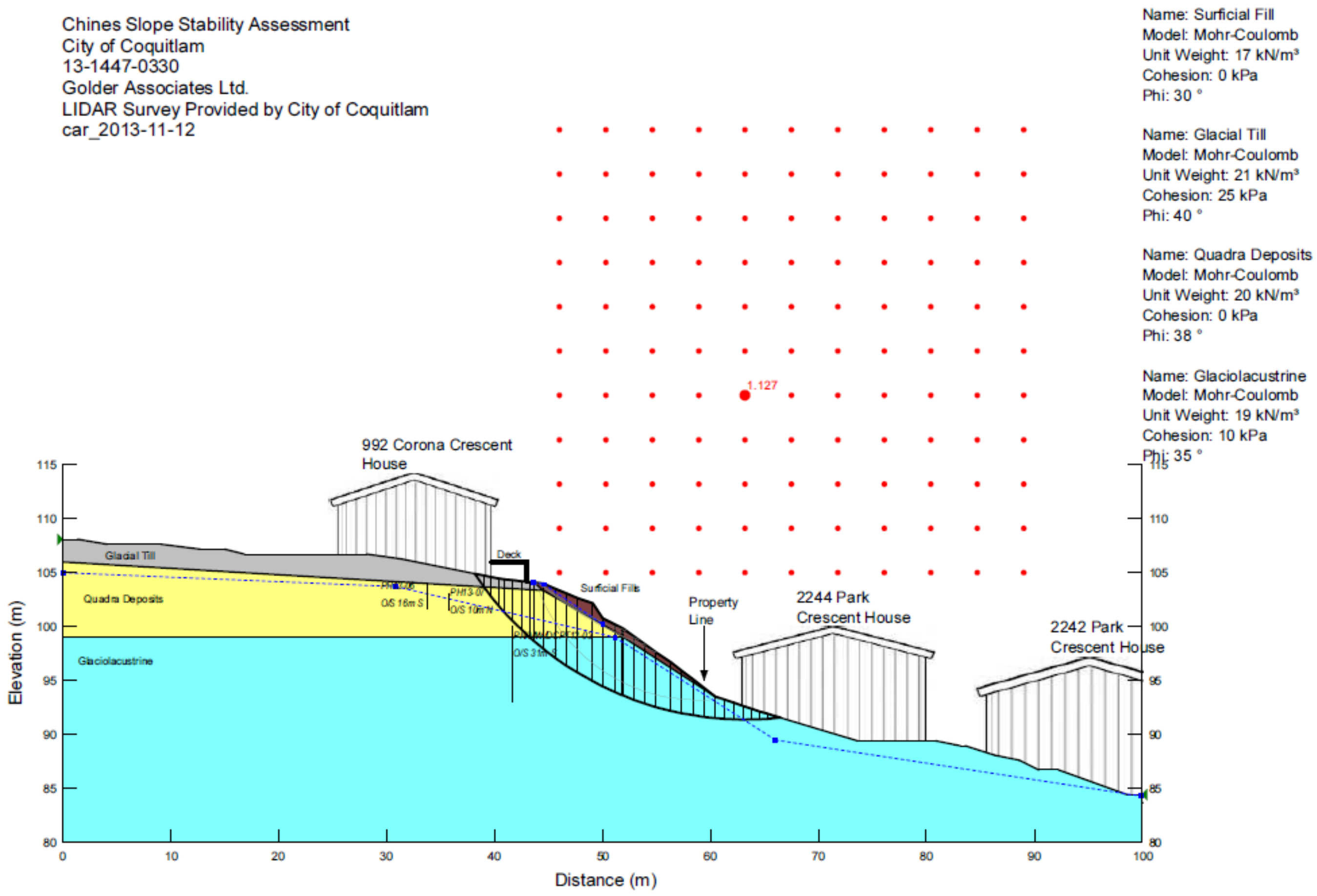
REVIEW	RCB	29NOV13		



PROJECT

Chines Slope Stability
City of Coquitlam
Coquitlam, BC

TITLE

SEISMIC SLOPE STABILITY ANALYSIS
SECTION D-D’

Golder Associates

PROJECT No.	13-1447-0330		PHASE No. 3000	
DESIGN	CAR	12NOV13	SCALE NTS	REV.
CADD			**FIGURE 11**	
CHECK	MGB	29NOV13		
REVIEW	RCB	29NOV13		

APPENDIX A

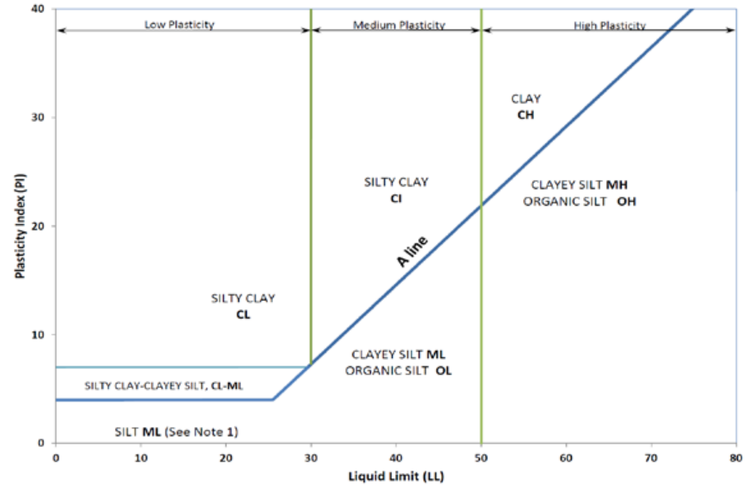
Record of Testhole Logs

METHOD OF SOIL CLASSIFICATION

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10}xD_{60}}$	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content ≤30% by mass)	COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm)	GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm)	Gravels with ≤12% fines (by mass)	Poorly Graded	<4	≤1 or ≥3	≤30%	GP	GRAVEL
				Well Graded	≥4	1 to 3		GW	GRAVEL
			Gravels with >12% fines (by mass)	Below A Line	n/a			GM	SILTY GRAVEL
				Above A Line	n/a			GC	CLAYEY GRAVEL
		SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm)	Sands with ≤12% fines (by mass)	Poorly Graded	<6	≤1 or ≥3		SP	SAND
				Well Graded	≥6	1 to 3		SW	SAND
			Sands with >12% fines (by mass)	Below A Line	n/a			SM	SILTY SAND
				Above A Line	n/a			SC	CLAYEY SAND

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators					Organic Content	USCS Group Symbol	Primary Name
				Dilatancy	Dry Strength	Shine Test	Thread Diameter	Toughness (of 3 mm thread)			
INORGANIC (Organic Content ≤30% by mass)	FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	Dull	3mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
				Slow to very slow	Low to medium	Dull to slight	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
			Liquid Limit ≥50	Slow to very slow	Low to medium	Slight	3mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
				None	Medium to high	Dull to slight	1 mm to 3 mm	Medium to high	5% to 30%	OH	ORGANIC SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30% **(see Note 2)**	CL	SILTY CLAY
			Liquid Limit 30 to 50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium		CI	SILTY CLAY
			Liquid Limit ≥50	None	High	Shiny	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)		Peat and mineral soil mixtures							30% to 75%	PT	SILTY PEAT, SANDY PEAT
		Predominantly peat, may contain some mineral soil, fibrous or amorphous peat							75% to 100%		PEAT



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.

Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.

For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.

For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.

A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to ~~or~~ indicate~~s~~ a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (*i.e.,* SAND and GRAVEL, SAND and CLAY)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
> 5 to 12	some
≤ 5	trace

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.).

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size
TP	Thin-walled, piston – note size
WS	Wash sample

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

Term	SPT 'N' (blows/0.3m)[1]
Very Loose	0 - 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects.
2. Definition of compactness descriptions based on SPT 'N' ranges from Terzaghi and Peck (1967) and correspond to typical average N_{60} values.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1] (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index $= (w_l – w_p)$
w_s	shrinkage limit
I_L	liquidity index $= (w – w_p) / I_p$
I_C	consistency index $= (w_l – w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} – e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90^{o} angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN	Joint
FLT	Fault
SH	Shear
VN	Vein
FR	Fracture
SY	Stylolite
BD	Bedding
FO	Foliation
CO	Contact
AXJ	Axial Joint
KV	Karstic Void
MB	Mechanical Break

PL	Planar
CU	Curved
UN	Undulating
IR	Irregular
K	Slickensided
PO	Polished
SM	Smooth
SR	Slightly Rough
RO	Rough
VR	Very Rough

PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF AUGERHOLE: AH/MW/DCPT13-01

SHEET 1 OF 1

CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457425 E: ~512285
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

DATUM: Local

DRILLING DATE: September 10, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

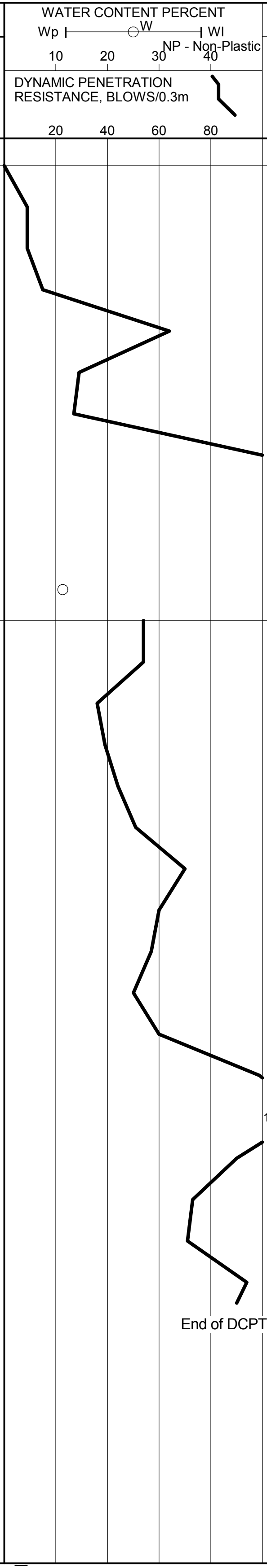
INCLINATION: -90°

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

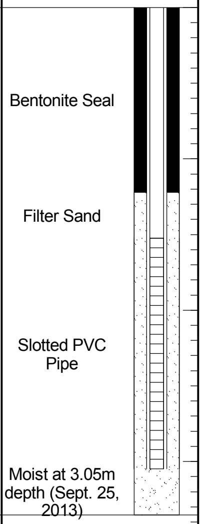
DEPTH SCALE METRES: 0 – 10

BORING METHOD: Bobcat MT52 Auger Rig, Solid Stem Auger

SOIL PROFILE – DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	WATER CONTENT PERCENT	GRAVEL	SAND	FINES	SILT	CLAY	PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING
Ground Surface														
TOPSOIL														
FILL - (SM) SILTY SAND, fine to coarse, trace fine to coarse subangular gravel, contains rootlets; light brown, moist to dry, loose to compact.	0.05	1	AS											
(CI) SILTY CLAY; light brown, w<PL, very stiff.	0.91													
(SM) SILTY SAND, fine to coarse, trace fine subangular gravel, contains rootlets; grey-brown, moist, compact.	1.52	2	AS											
(SM) SILTY SAND, fine to medium, fine to coarse subangular gravel; grey, moist, very dense. (Till-like)	1.98													
(SM) SAND, fine to medium, some silt to silty; brown-grey, moist, very dense.	2.44	3	AS			○	0	70	30					
End of Augerhole. (Refusal)	3.35													



PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CR
CHECKED: RCB

PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF AUGERHOLE: AH13-02

SHEET 1 OF 1

CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457482 E: ~512396
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

DRILLING DATE: September 11, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

DATUM: Local

INCLINATION: -90°

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES				WATER CONTENT PERCENT Wp ├──○W──┤ Wl NP - Non-Plastic 10 20 30 40	GRADATION %					PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RECOVERY %		GRAVEL	SAND	FINES	SILT	CLAY				
		Ground Surface																
0	Bobcat MT52 Auger Rig Solid Stem Auger	TOPSOIL - (SM) SILTY SAND, fine to coarse, contains rootlets; brown, moist.		0.00														
		FILL - (SM) SILTY SAND, fine to coarse, some fine subangular gravel; light brown, moist, very loose.		0.61														
1					1	AS												
		End of Augerhole. (Refusal on concrete slab)		1.22														
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CR
CHECKED: RCB

File:GINT_GAL_NATIONALIM Output Form:BC_BOREHOLE_GRADATION (AUTO) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB bdrozdiak 11/19/13

PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF AUGERHOLE: AH/MW/DCPT13-03

SHEET 1 OF 1

CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457519 E: ~512378
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

DATUM: Local

DRILLING DATE: September 12, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

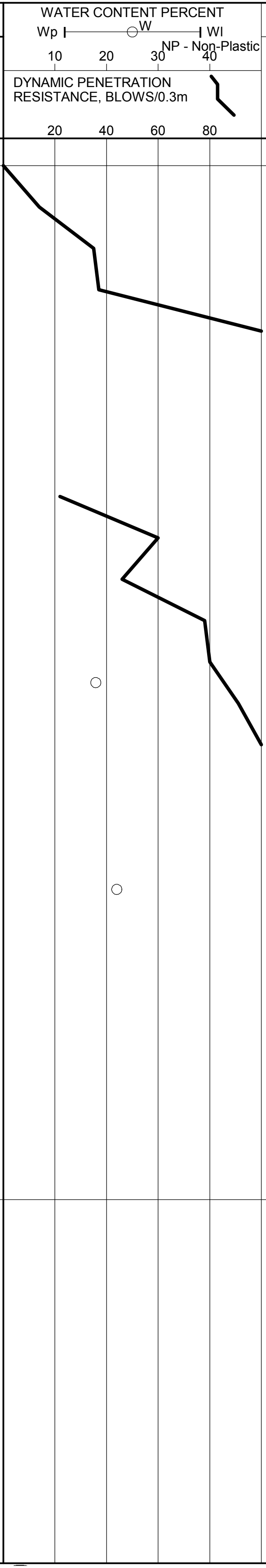
INCLINATION: -90°

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

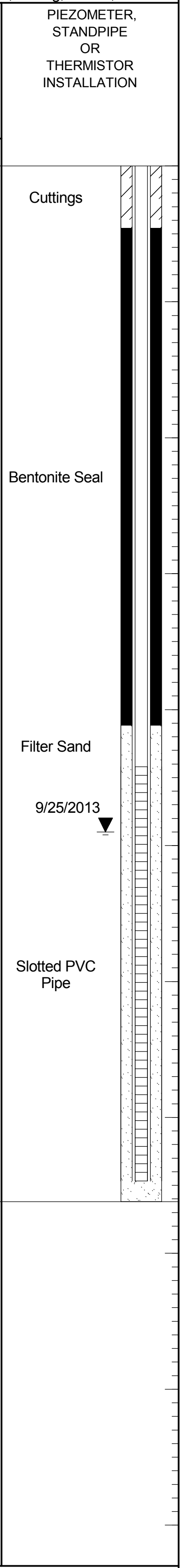
BORING METHOD: Bobcat MT52 Auger Rig, Solid Stem Auger

SOIL PROFILE – DESCRIPTION	ELEV. DEPTH (m)
Ground Surface	
TOPSOIL - (SM) SILTY SAND, fine to coarse, contains rootlets and woody debris; brown, moist, loose.	0.00
Possible FILL - (SW) gravelly SAND, fine to coarse sand, fine to coarse subangular to angular gravel, trace silt; red-brown, moist, compact.	0.30
(SW-SM) gravelly SAND, fine to coarse sand, fine to coarse subangular gravel, some silt, contains rootlets; very dense. - from 1.22m to 1.83m depth: becoming gravel with cobbles. - from 2.13m to 2.74m depth: cobbles and gravel.	0.91
(SM) SILTY SAND, fine to medium; brown-grey with some red staining, moist, dense to very dense. - at 4.57m depth: becoming grey and wet. - at approx. 6.1m depth: becoming silt and sand.	2.74
End of Augerhole. (Refusal)	7.62

SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	GRAVEL	SAND	FINES	SILT	CLAY
1	AS							
2	AS							
3	AS							
4	AS			0	80	20		
5	AS							



PLASTICITY INDEX % | ORGANIC CONTENT % | ADDITIONAL LAB. TESTING



DEPTH SCALE
1 : 50

LOGGED: CR
CHECKED: RCB

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PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF BOREHOLE: PH13-01

SHEET 1 OF 1

CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457473 E: ~512396
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

DRILLING DATE: September 13, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

DATUM: Local

INCLINATION: -90°

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES				WATER CONTENT PERCENT Wp ├──○W──┤ Wl 10 20 30 40 NP - Non-Plastic	GRADATION %					PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RECOVERY %		GRAVEL	SAND	FINES	SILT	CLAY				
		Ground Surface																
0	Pionjar Portable Hammer Drill 50mm Split Spoon	FILL - (SM) SILTY SAND, fine to coarse, trace fine angular gravel, contains rootlets; brown, moist.	▨	0.00	1	SS												
		(SM) SILTY SAND, fine to coarse, some fine to coarse subangular to angular gravel; brown-grey, moist. (Till-like)	⁘	0.61 0.76	2	SS												
1		End of Borehole. (Refusal)																
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CR
CHECKED: RCB

PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF BOREHOLE: PH13-02

SHEET 1 OF 1

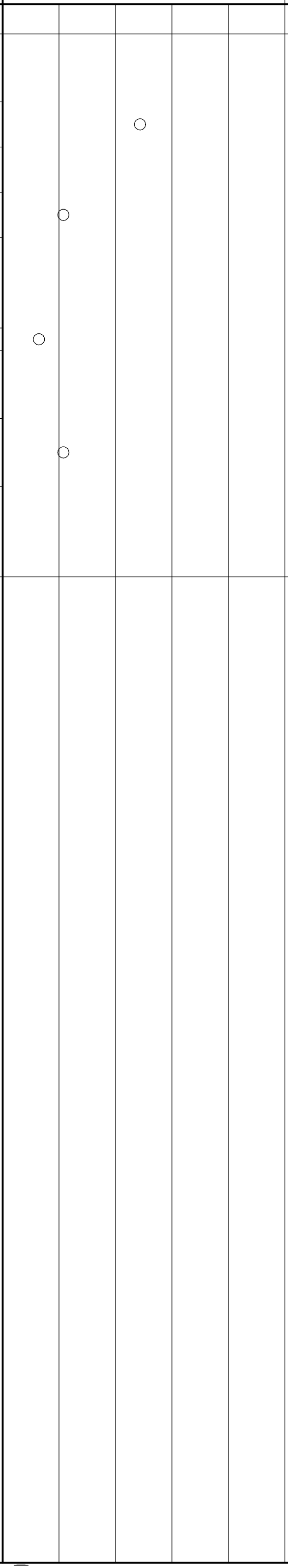
CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457466 E: ~512401
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

DRILLING DATE: September 11, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

INCLINATION: -90°

DATUM: Local

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	SAMPLES RECOVERY %	WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 10 20 30 40 NP - Non-Plastic	GRADATION % GRAVEL	GRADATION % SAND	GRADATION % FINES	GRADATION % SILT	GRADATION % CLAY	PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		Ground Surface																
0	Pionjar Portable Hammer Drill 50mm Split Spoon	FILL - (SM) SILTY SAND, fine to coarse, some fine subangualr gravel, contains rootlets and decayed wood debris; brown, moist.		0.00	1	SS			○									
1		FILL - (ML) SILT, trace fine sand; grey, dry.		1.07	2	SS			○									
		FILL - (SM) SILTY SAND to SILT, fine to coarse sand, trace fine subrounded gravel; red-brown, moist to dry. - layer of brown SILTY SAND, contains rootlets at 1.68m depth.		1.37														
2		FILL - (SP) SAND, fine to coarse, some silt, some fine to coarse subangular gravel; grey, dry. - becoming silty and grey-brown at 2.44m depth. - broken glass at 2.59m depth.		1.98	3	SS			○									
3		(SP-SM) SAND, fine to coarse, some silt, trace fine gravel; red-grey, moist. - fibrous organic layers approx. 2cm thick at 3.11m and 3.20m depths.		2.59	4	SS			○	4	89	7						
4 5 6 7 8 9 10		End of Borehole. (Refusal)		3.66														



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CR
CHECKED: RCB

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PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF BOREHOLE: PH/MW/DCPT13-03

SHEET 1 OF 1

CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457523 E: ~512340
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

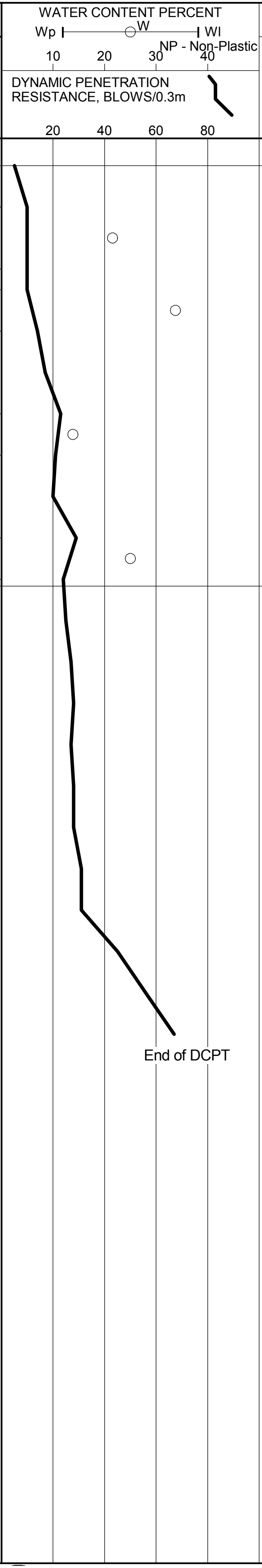
DATUM: Local

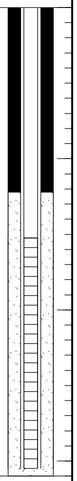
DRILLING DATE: September 13, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

INCLINATION: -90°

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	GRAVEL	SAND	FINES	SILT	CLAY	PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		Ground Surface														
0	Pionjar Portable Hammer Drill 50mm Split Spoon	TOPSOIL - (SM) SILTY SAND, fine to coarse, contains rootlets; brown, moist, loose.	0.00 0.10													
		(SP-SM) SAND, fine to medium, some silt, some fine subangular gravel, contains rootlets from 0.1m to 0.61m depth; brown-grey with some staining, loose.		1	SS											Bentonite Seal
1		(ML) SILT, low plasticity; grey with orange staining, w<PL, moist, firm. - becoming fine to coarse subangular gravel at 1.22m depth.	0.91	2	SS											
2		(SP-SM) SAND, fine to medium, some silt to silty; grey, moist, compact. - orange staining from 1.68m to 1.83m depth. - very thinly interlayered with brown sand, some silt at 1.83m depth.	1.37	3	SS			0	80	20						Filter Sand Slotted PVC Pipe
3		- orange staining at 2.74m depth. - SILT and fine SAND from 2.74m to 2.90m depth.		4	SS											
		End of Borehole. (Refusal)	3.10													Dry Sept. 25/13





DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CR
CHECKED: RCB

PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF BOREHOLE: PH13-04

SHEET 1 OF 1

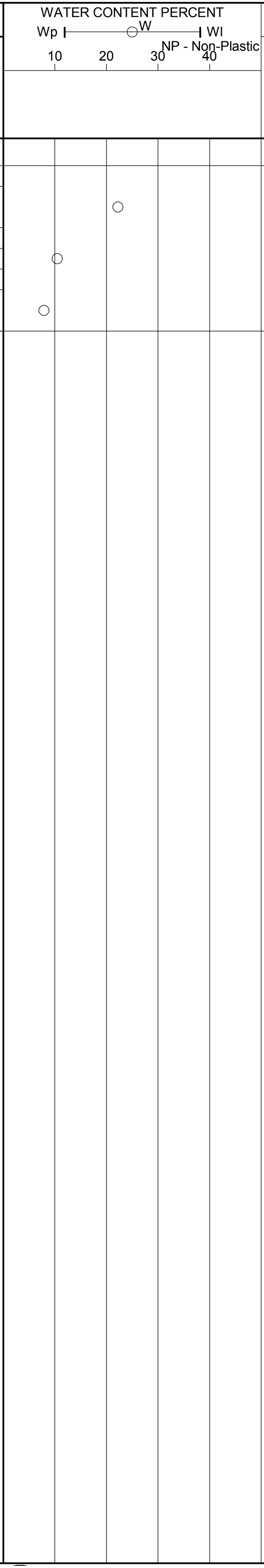
CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457490 E: ~512389
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

DATUM: Local

DRILLING DATE: September 12, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

INCLINATION: -90°

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	SAMPLES: RECOVERY %	GRADATION %: GRAVEL	GRADATION %: SAND	GRADATION %: FINES	GRADATION %: SILT	GRADATION %: CLAY	PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		Ground Surface															
0	Pionjar Portable Hammer Drill 50mm Split Spoon	FILL - (SM) SILTY SAND, fine to coarse, some fine to coarse subangular gravel, contains rootlets; red-brown, moist.	☒	0.00	1	SS											
		(SM) gravelly SILTY SAND, fine to coarse, fine to coarse subangular gravel; grey, moist. (Till-like) - orange staining and fibrous organics from 0.46m to 0.61m depth.		0.30	2	SS											
1					3	SS			15	54	31						
		End of Borehole. (Refusal)		1.22													
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	



DEPTH SCALE
1 : 50

LOGGED: CR
CHECKED: RCB

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PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF BOREHOLE: PH/MW13-05

SHEET 1 OF 1

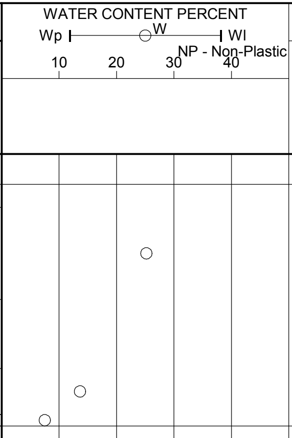
CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457460 E: ~512407
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

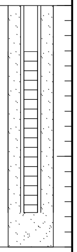
DATUM: Local

DRILLING DATE: September 12, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

INCLINATION: -90°

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	GRAVEL	SAND	FINES	SILT	CLAY	PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		Ground Surface														
0	Pionjar Portable Hammer Drill 50mm Split Spoon	FILL - Yard Waste	0.00													
		FILL - (SM) SILTY SAND, fine to coarse, contains rootlets; brown, moist.	0.15	1	SS											Filter Sand
1																Slotted PVC Pipe
		(SM) SILTY SAND, fine to coarse, some fine to coarse subangular gravel, contains rootlets; grey-brown, moist.	1.22	2	SS											
				3	SS			26	52	22						
		(SM) gravelly SILTY SAND, fine to coarse sand, fine to coarse, subangular gravel; grey, moist. (Till-like)	1.60													Dry Sept. 25/13
2																
		End of Borehole. (Refusal)														
3																
4																
5																
6																
7																
8																
9																
10																





DEPTH SCALE
1 : 50

LOGGED: CR
CHECKED: RCB

PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF BOREHOLE: PH13-06

SHEET 1 OF 1

CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457537 E: ~512349
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

DRILLING DATE: September 13, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

DATUM: Local

INCLINATION: -90°

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	WATER CONTENT PERCENT Wp —○W— Wl (NP - Non-Plastic) 10 20 30 40	GRADATION % GRAVEL	SAND	FINES	SILT	CLAY	PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		Ground Surface																
0	Pionjar Portable Hammer Drill 50mm Split Spoon	TOPSOIL - (SM) SILTY SAND, fine to coarse, contains rootlets and wood debris; brown, moist.		0.00														
		(SM) SILTY SAND, fine to coarse; brown-grey with orange staining.		0.61														
1																		
		(SP-SM) SAND, fine, some silt to silty; grey with orange staining, moist.		1.22														
2		- roots at 1.83m depth.			1	SS												
		End of Borehole.		2.29														
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CR
CHECKED: RCB

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PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF BOREHOLE: PH13-07

SHEET 1 OF 1

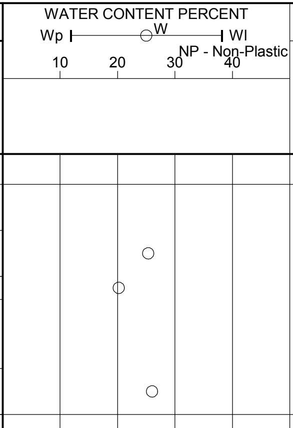
CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457563 E: ~512351
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

DRILLING DATE: September 13, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

DATUM: Local

INCLINATION: -90°

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	GRADATION %: GRAVEL	SAND	FINES	SILT	CLAY	PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		Ground Surface															
0	Pionjar Portable Hammer Drill 50mm Split Spoon	TOPSOIL - (SM) SILTY SAND, trace fine to coarse angular gravel, contains rootlets and leaf litter; brown, moist.		0.00													
		(SM) SILTY SAND, some fine subangular gravel; grey, moist, dense. - contains rootlets and orange staining from 0.3m to 0.61m depth.		0.30	1 2	SS SS											
1		(ML) sandy SILT, fine to coarse sand, trace fine subangular gravel; grey with orange staining, moist. (Till-like)		0.91	3	SS			0	17	83	61	22				
		End of Borehole. (Refusal)		1.52													
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CR
CHECKED: RCB

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PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF BOREHOLE: PH13-08

SHEET 1 OF 1

CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457448 E: ~512261
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

DATUM: Local

DRILLING DATE: September 13, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

INCLINATION: -90°

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES				WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl NP - Non-Plastic 10 20 30 40	GRADATION %					PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RECOVERY %		GRAVEL	SAND	FINES	SILT	CLAY				
		Ground Surface																
0	Pionjar Portable Hammer Drill 50mm Split Spoon	TOPSOIL - (ML) sandy SILT, contains rootlets; brown, dry.		0.00														
		(ML/SM) SILT and SAND, contains rootlets; grey-brown, moist.		0.30	1	SS			○									
1		- layer of decayed woody organics at 0.91m depth.																
		(ML) SILT, trace fine sand; grey, moist.		1.37	2	SS			○	0	1	99	85	14				
2		End of Borehole. (Refusal)		1.68														
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CR
CHECKED: RCB

PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF BOREHOLE: PH13-09

SHEET 1 OF 1

CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457448 E: ~512274
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

DRILLING DATE: September 13, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

DATUM: Local

INCLINATION: -90°

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES				WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl NP - Non-Plastic 10 20 30 40	GRADATION %					PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RECOVERY %		GRAVEL	SAND	FINES	SILT	CLAY				
		Ground Surface																
0	Pionjar Portable Hammer Drill 50mm Split Spoon	TOPSOIL - (SM) SILTY SAND and decomposed fibrous organics, contains rootlets.		0.00														
1		(SP) SAND, fine to medium, trace silt; grey, moist, very dense.		0.61	1	SS												
		End of Borehole. (Refusal)		1.07														
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CR
CHECKED: RCB

PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF BOREHOLE: PH13-10

SHEET 1 OF 1

CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457448 E: ~512267
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

DATUM: Local

DRILLING DATE: September 13, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

INCLINATION: -90°

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES				WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl NP - Non-Plastic 10 20 30 40	GRADATION %					PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RECOVERY %		GRAVEL	SAND	FINES	SILT	CLAY				
		Ground Surface																
0	Pionjar Portable Hammer Drill 50mm Split Spoon	TOPSOIL - (ML) SILT, some fine to medium sand, contains rootlets and woody debris; brown, moist.		0.00														
		(ML) SILT, some fine sand, contains rootlets and woody debris; brown-grey with orange staining throughout, moist.		0.15	1	SS												
		(SP-SM) SAND, fine to medium, trace coarse sand, some silt; grey with orange staining, moist.		0.76														
1																		
		End of Borehole. (Refusal)																
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CR
CHECKED: RCB

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PROJECT No.: 13-1447-0330 / 3000 / 3002

RECORD OF BOREHOLE: PH13-11

SHEET 1 OF 1

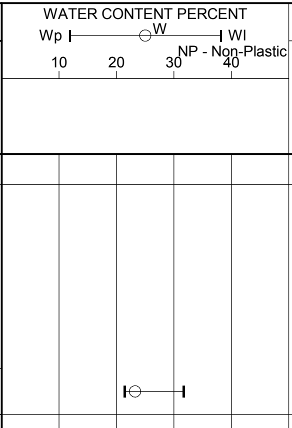
CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457433 E: ~512286
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

DRILLING DATE: September 13, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

DATUM: Local

INCLINATION: -90°

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	WATER CONTENT PERCENT (Wp ⊢ ○W ⊣ Wl; NP - Non-Plastic)	GRAVEL	SAND	FINES	SILT	CLAY	PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		Ground Surface															
0	Pionjar Portable Hammer Drill 50mm Split Spoon	TOPSOIL - (SM) SILTY SAND, fine to coarse, contains rootlets and woody debris; brown, moist.	0.00														
		(SM) SILTY SAND, fine to coarse, some fine to coarse angular to subrounded gravel, contains rootlets; light brown, moist.	0.30														
1		(CI) SILTY CLAY, some fine sand; grey with some orange staining, moist.	0.91														
				1	SS			⊢○——⊣						11			
		End of Borehole. (Hole collapsed)	1.52														
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CR
CHECKED: RCB

PROJECT No.: 13-1447-0330 / 3000 / 300

RECORD OF DYNAMIC CONE PENETRATION TEST: DCPT13-01

SHEET 1 OF 1

CLIENT: City of Coquitlam
PROJECT: Chines Slope Stability
LOCATION: Coquitlam, B.C.
N: ~5457473 E: ~512401
Note: Northing and Easting Coordinates have been determined by GPS in the field and are approximate only.

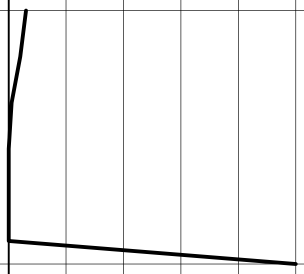
DRILLING DATE: September 11, 2013
DRILLING CONTRACTOR: Rocky Mountain Soil Sampling Inc.

DATUM: Local

INCLINATION: -90°

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES				WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl, 10 20 30 40, NP - Non-Plastic / DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m, 20 40 60 80	GRADATION %					PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RECOVERY %		GRAVEL	SAND	FINES	SILT	CLAY				
		Ground Surface																
0	Bobcat MT52 Auger Rig Solid Stem Auger	.		0.00														
1																		
		End of Dynamic Cone Penetration Test. (Refusal on concrete slab)		1.68														
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		



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DEPTH SCALE
1 : 50

LOGGED: CR
CHECKED: RCB

APPENDIX B

Laboratory Testing Results

PARTICLE SIZE ANALYSIS OF SOILS

Reference(s)
ASTM C136

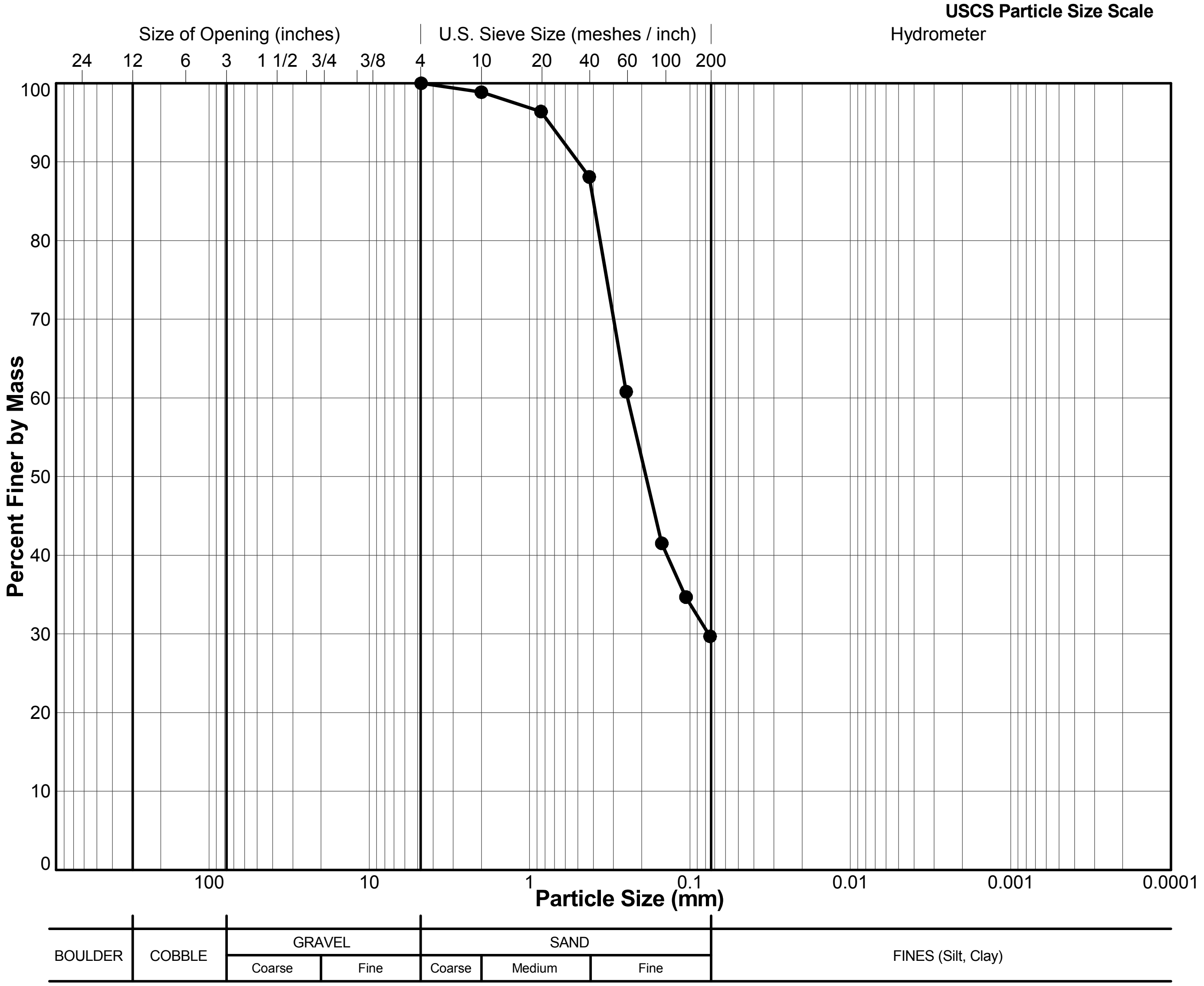
Client: City of Coquitlam	**Augerhole ID: AH/MW/DCPT13-01**
Project: Chines Slope Stability	**Sample No.: 3**
Location: Coquitlam, BC	**Depth Interval (m):** 3.05 to 3.20
Project No.: 13-1447-0330 **Phase:** 3000 **Task:** 3002	**Lab Schedule No.:** 200

Other Remarks: **N/A**

Specific Gravity (assumed): 2.70 | **Shape:**

Max. Particle Size Passing (mm): 4.75

Method: Split, Washed



DC	**9/23/2013**	**LP**	**9/25/2013**
Tech	Date	Checked	Date

File:GINT_GAL_NATIONALIM Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB mmiller 9/26/13

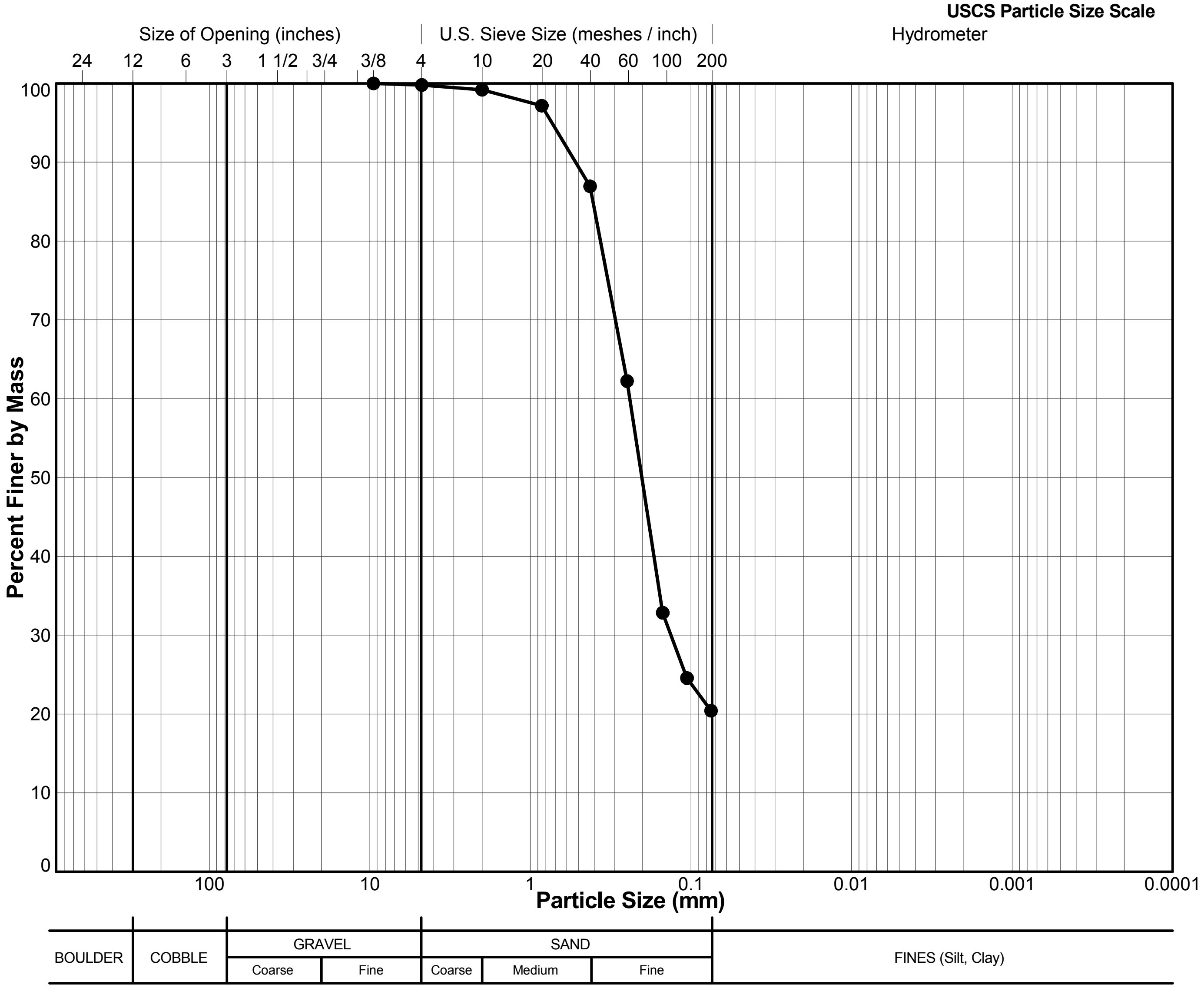
PARTICLE SIZE ANALYSIS OF SOILS	Reference(s) **ASTM C136**
Client: City of Coquitlam	**Augerhole ID: AH/MW/DCPT13-03**
Project: Chines Slope Stability	**Sample No.: 4**
Location: Coquitlam, BC	**Depth Interval (m):** 3.66 to 3.96
Project No.: 13-1447-0330 **Phase:** 3000 **Task:** 3002	**Lab Schedule No.:** 200

Other Remarks: **N/A**

Specific Gravity (assumed): 2.70 **Shape:**

Max. Particle Size Passing (mm): 9.5

Method: Split, Washed



DC/OA	9/23/2013	LP	9/25/2013
Tech	Date	Checked	Date

File:GINT_GAL_NATIONALIM Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB mmiller 9/26/13

Golder Associates

PARTICLE SIZE ANALYSIS OF SOILS

Reference(s)
ASTM C136

Client:	City of Coquitlam	**Borehole ID: PH/MW/DCPT13-03**
Project:	Chines Slope Stability	**Sample No.: 3**
Location:	Coquitlam, BC	**Depth Interval (m):** 1.83 to 2.13
Project No.:	13-1447-0330 **Phase:** 3000 **Task:** 3002	**Lab Schedule No.:** 200

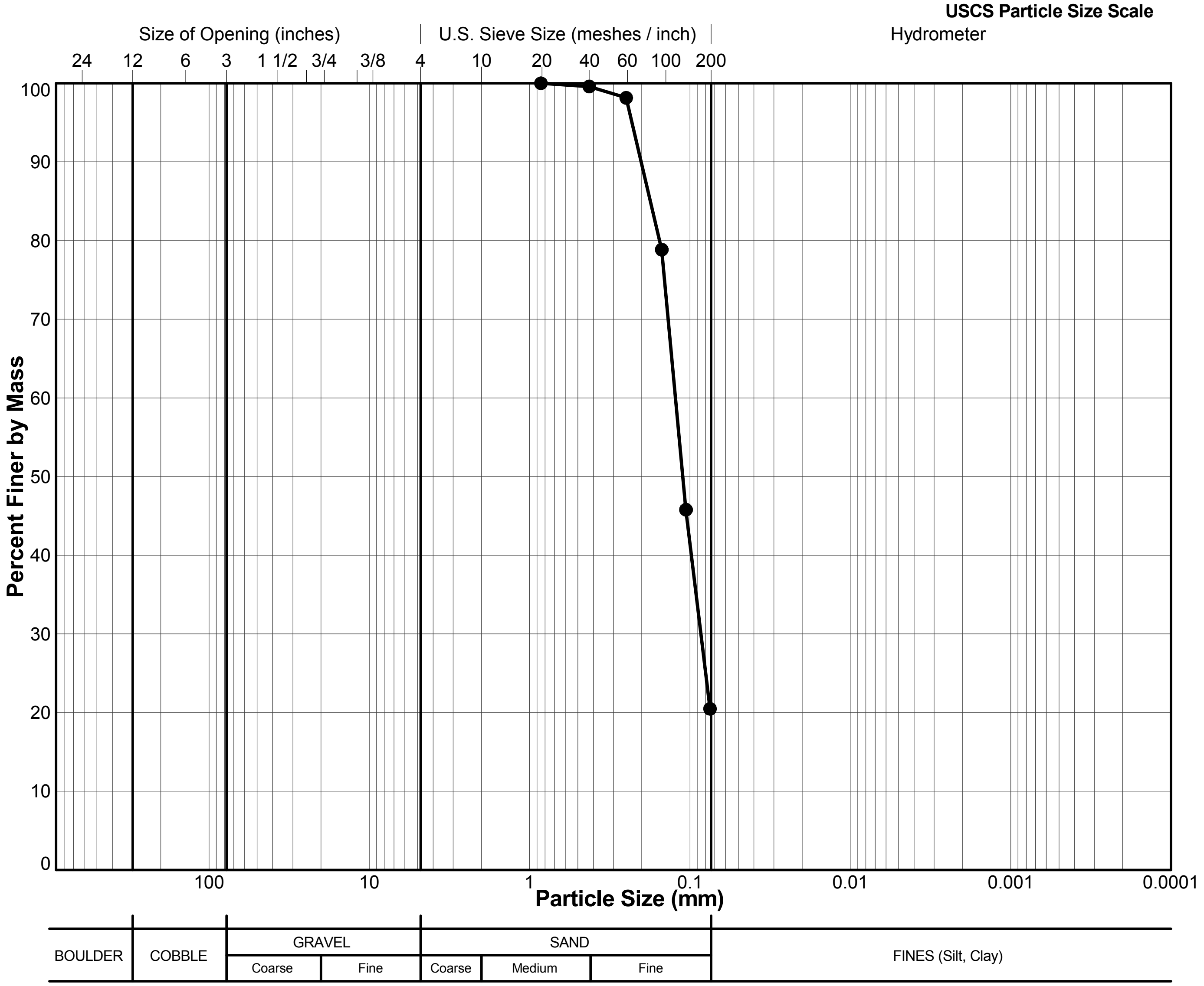
Other Remarks: **N/A**

Specific Gravity (assumed): 2.70

Shape:

Max. Particle Size Passing (mm): 0.85

Method:



DC/OA	**9/23/2013**	**LP**	**9/25/2013**
Tech	Date	Checked	Date

File:GINT_GAL_NATIONALIM Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB mmiller 9/26/13

PARTICLE SIZE ANALYSIS OF SOILS

Reference(s)
ASTM C136

Client:	City of Coquitlam	**Borehole ID: PH/MW13-05**
Project:	Chines Slope Stability	**Sample No.: 3**
Location:	Coquitlam, BC	**Depth Interval (m):** 1.52 to 1.60
Project No.:	13-1447-0330 **Phase:** 3000 **Task:** 3002	**Lab Schedule No.:** 200

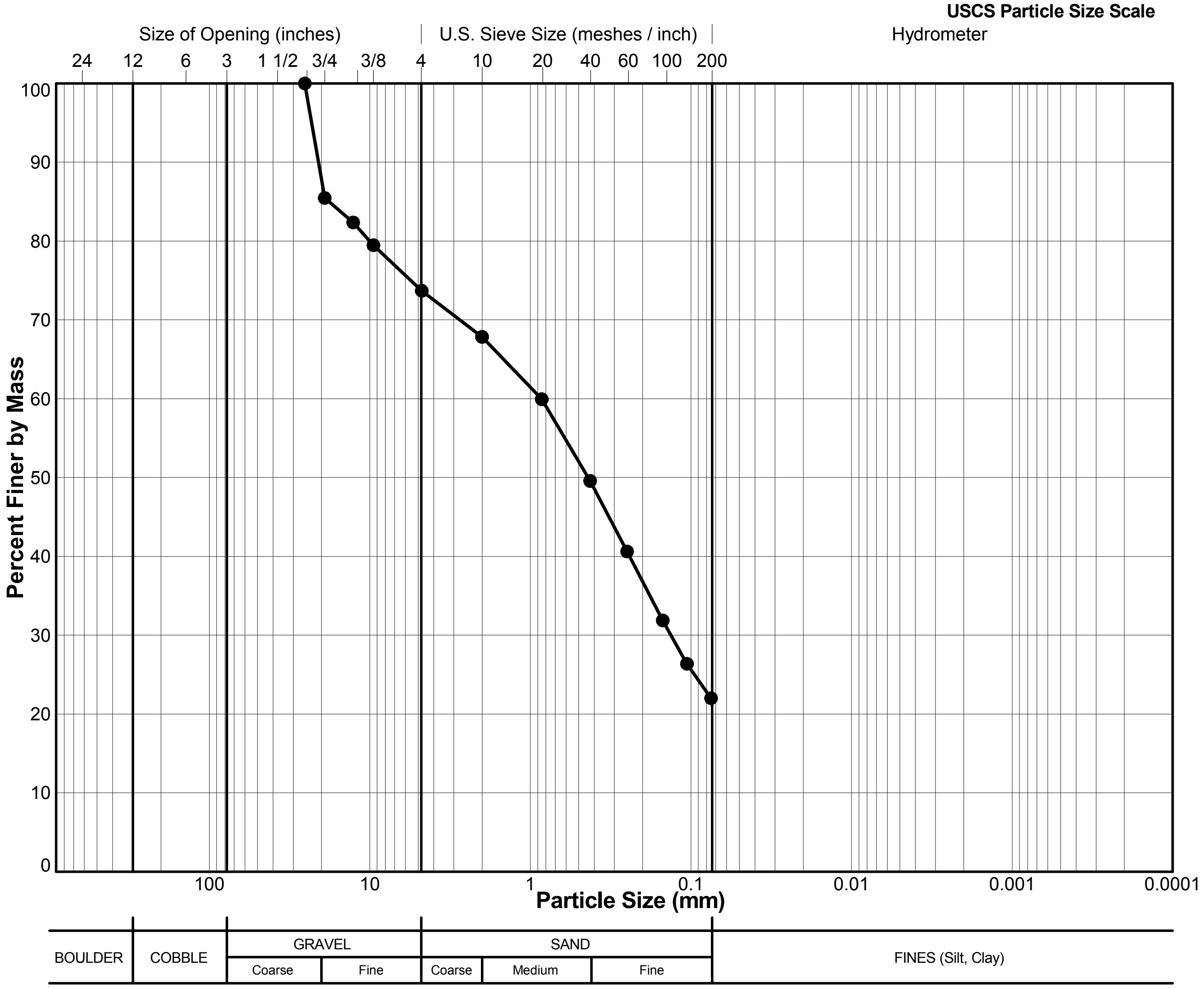
Other Remarks: **N/A**

Specific Gravity (assumed): 2.70

Shape:

Max. Particle Size Passing (mm): 25.4

Method: Combined, Washed



DC/OA	**9/23/2013**	**LP**	**9/25/2013**
Tech	Date	Checked	Date

File:GINT_GAL_NATIONALIM Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB mmiller 9/26/13

PARTICLE SIZE ANALYSIS OF SOILS

Reference(s)
ASTM C136

Client: City of Coquitlam

Project: Chines Slope Stability

Location: Coquitlam, BC

Project No.: 13-1447-0330 **Phase:** 3000 **Task:** 3002

Borehole ID: PH13-02

Sample No.: 4

Depth Interval (m): 2.59 to 3.05

Lab Schedule No.: 200

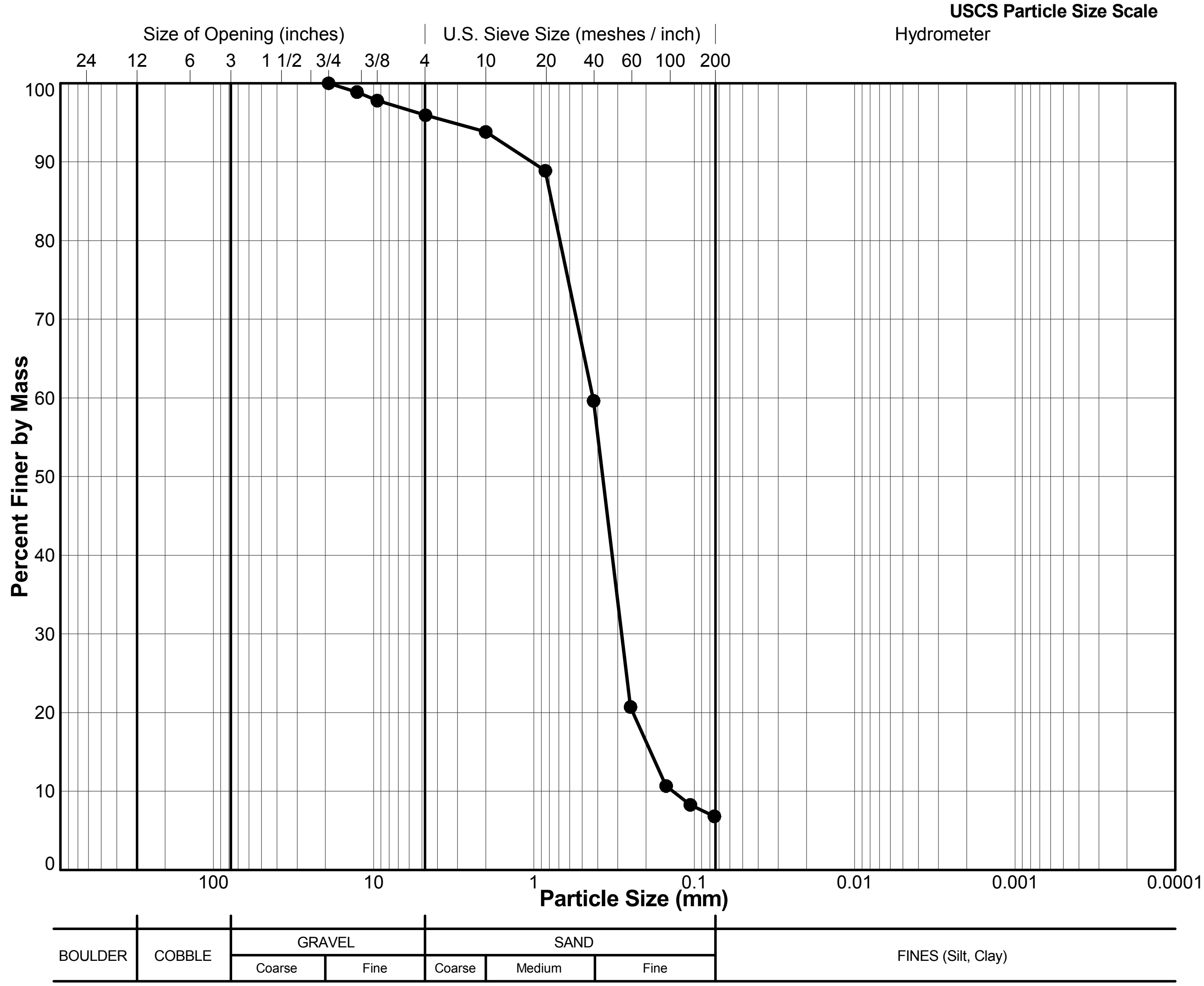
Other Remarks: N/A

Specific Gravity (assumed): 2.70

Shape:

Max. Particle Size Passing (mm): 19.1

Method: Split, Washed



DC/OA	**9/23/2013**	**LP**	**9/25/2013**
Tech	Date	Checked	Date

File:GINT_GAL_NATIONALIM Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB mmiller 9/26/13

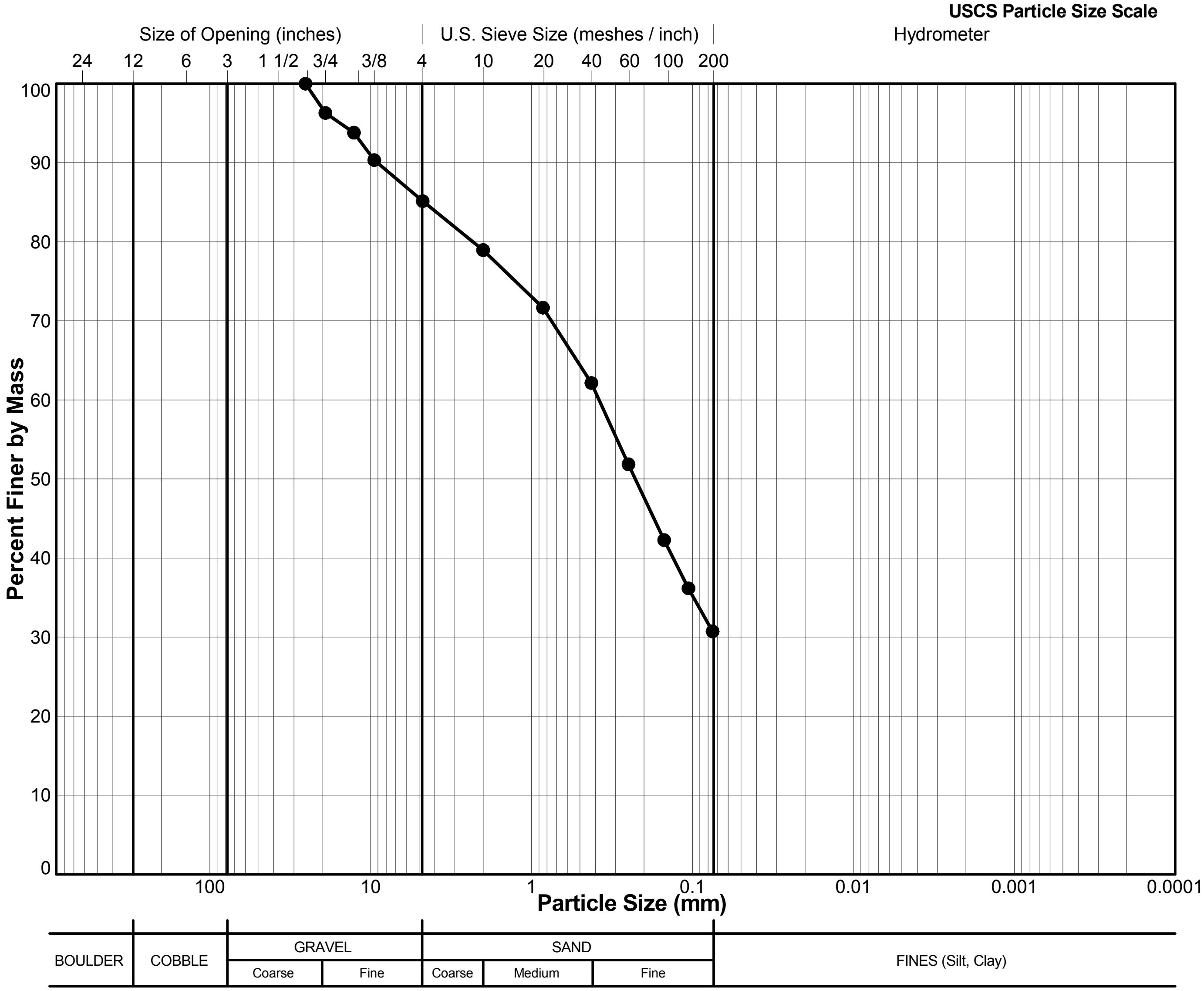
PARTICLE SIZE ANALYSIS OF SOILS	Reference(s) **ASTM C136**
Client: City of Coquitlam	**Borehole ID: PH13-04**
Project: Chines Slope Stability	**Sample No.: 3**
Location: Coquitlam, BC	**Depth Interval (m):** 0.91 to 1.22
Project No.: 13-1447-0330 **Phase:** 3000 **Task:** 3002	**Lab Schedule No.:** 200

Other Remarks: **N/A**

Specific Gravity (assumed): 2.70	**Shape:**

Max. Particle Size Passing (mm): 25.4

Method: Split, Washed



DC/OA	**9/23/2013**	**LP**	**9/25/2013**
Tech	Date	Checked	Date

File:GINT_GAL_NATIONALIM Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB mmiller 9/26/13

Golder Associates

PARTICLE SIZE ANALYSIS OF SOILS

Reference(s)
ASTM D 422

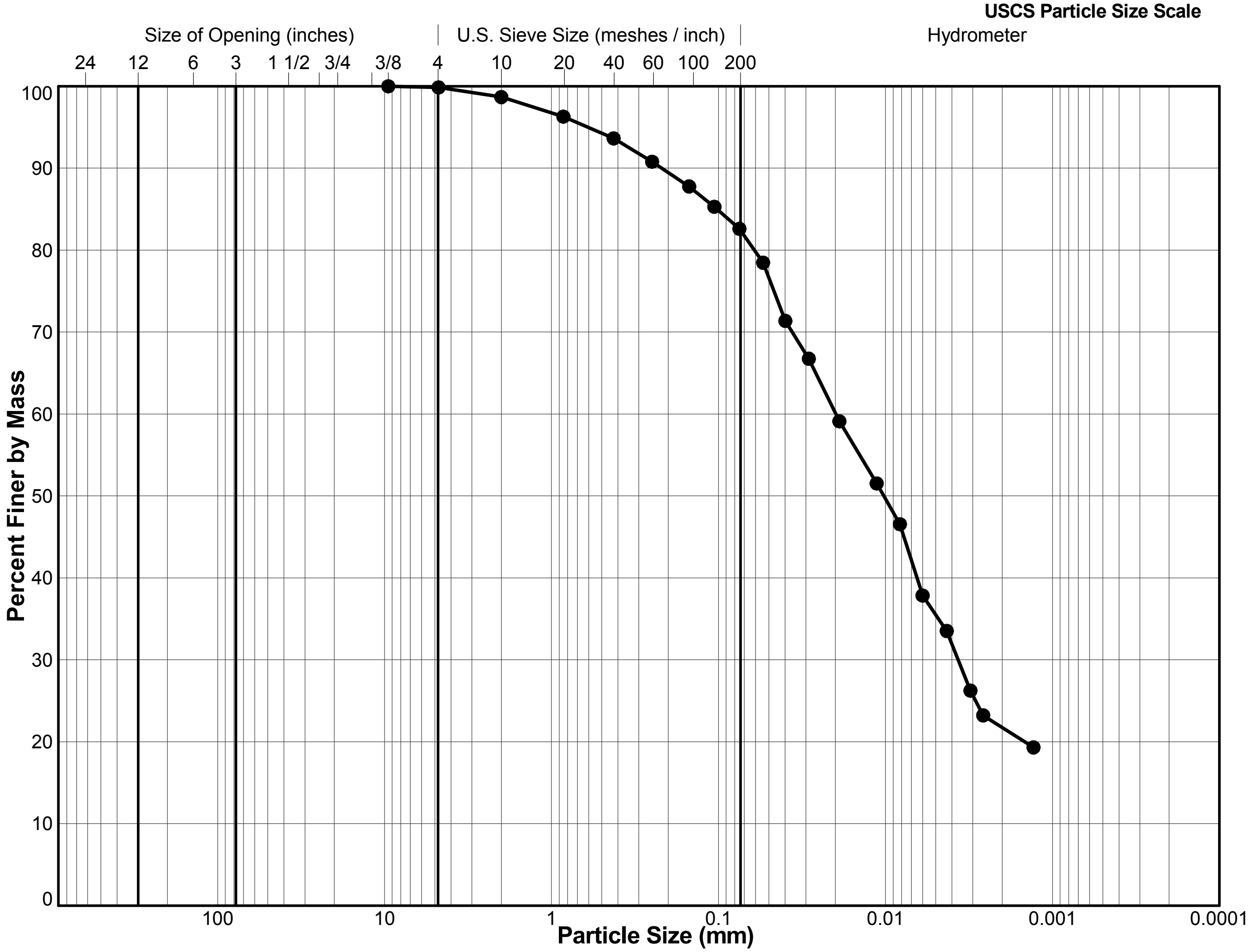
Client:	City of Coquitlam	**Borehole ID: PH13-07**
Project:	Chines Slope Stability	**Sample No.: 3**
Location:	Coquitlam, BC	**Depth Interval (m):** 1.22 to 1.52
Project No.:	13-1447-0330 **Phase:** 3000 **Task:** 3002	**Lab Schedule No.:** 200

Other Remarks: **N/A**

Specific Gravity (assumed): 2.70	**Shape:**
Max. Particle Size Passing (mm): 9.5	**Dispersion Method: Stirring**
Method: Split, Washed	**Dispersion Period (min): 1**

Hydrometer ID: BURNABY - 541360_4%_2010-07-13

USCS Particle Size Scale



BOULDER	COBBLE	GRAVEL		SAND			FINES (Silt, Clay)
		Coarse	Fine	Coarse	Medium	Fine	

MM/BM	**9/25/2013**	**LP**	**9/25/2013**
Tech	Date	Checked	Date

File:GINT_GAL_NATIONALIM Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB mmiller 9/26/13

Golder Associates

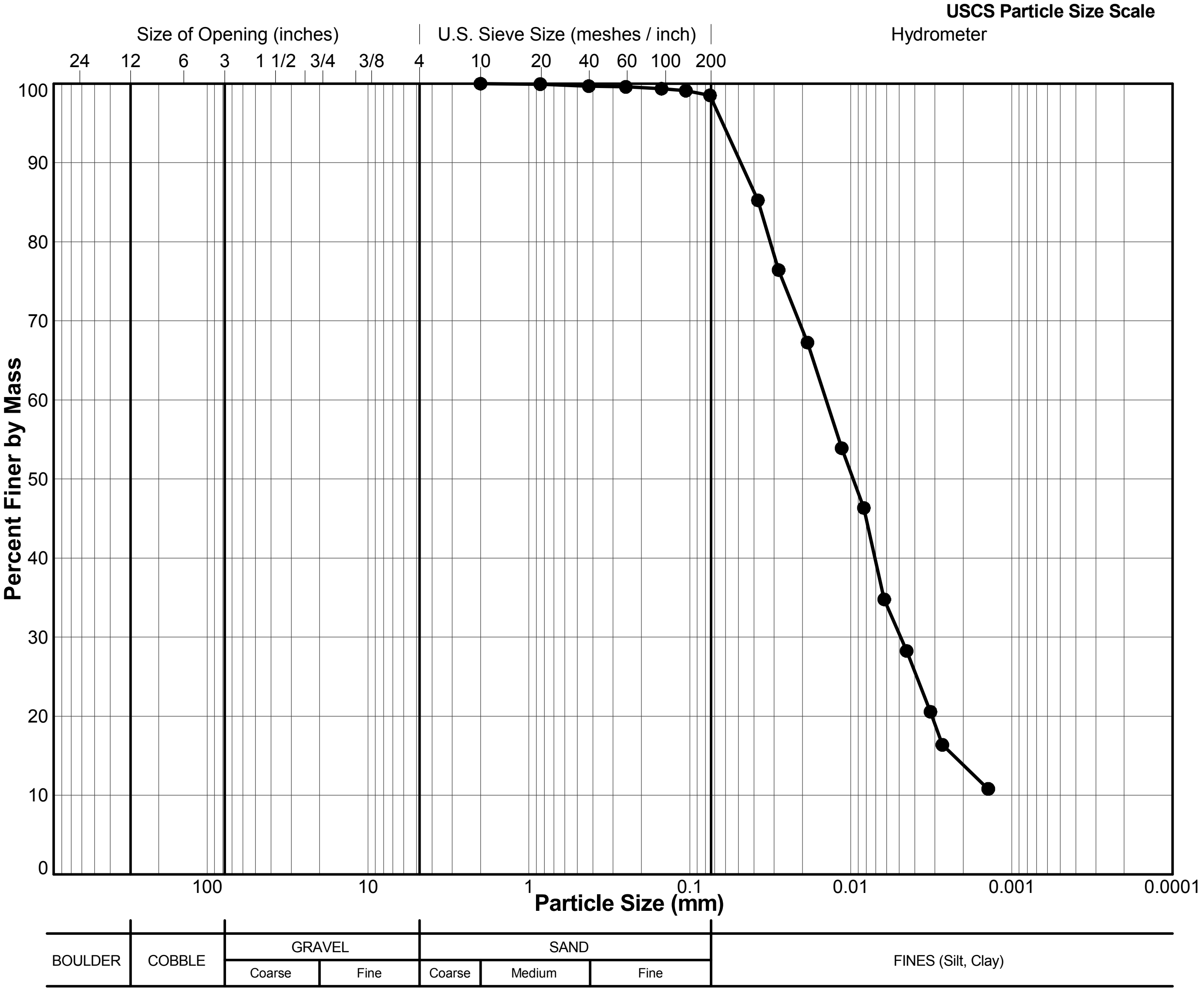
PARTICLE SIZE ANALYSIS OF SOILS

Reference(s)
ASTM D 422

Client:	City of Coquitlam	**Borehole ID: PH13-08**
Project:	Chines Slope Stability	**Sample No.: 2**
Location:	Coquitlam, BC	**Depth Interval (m):** 1.37 to 1.52
Project No.:	13-1447-0330 **Phase:** 3000 **Task:** 3002	**Lab Schedule No.:** 200

Other Remarks: **N/A**

Specific Gravity (assumed): 2.70	**Shape:**
Max. Particle Size Passing (mm): 2	**Dispersion Method: Stirring**
Method: Split, Washed	**Dispersion Period (min): 1**
Hydrometer ID: BURNABY - 87024_4%_2009-04-03	



MM/BM	**9/25/2013**	**LP**	**9/25/2013**
Tech	Date	Checked	Date

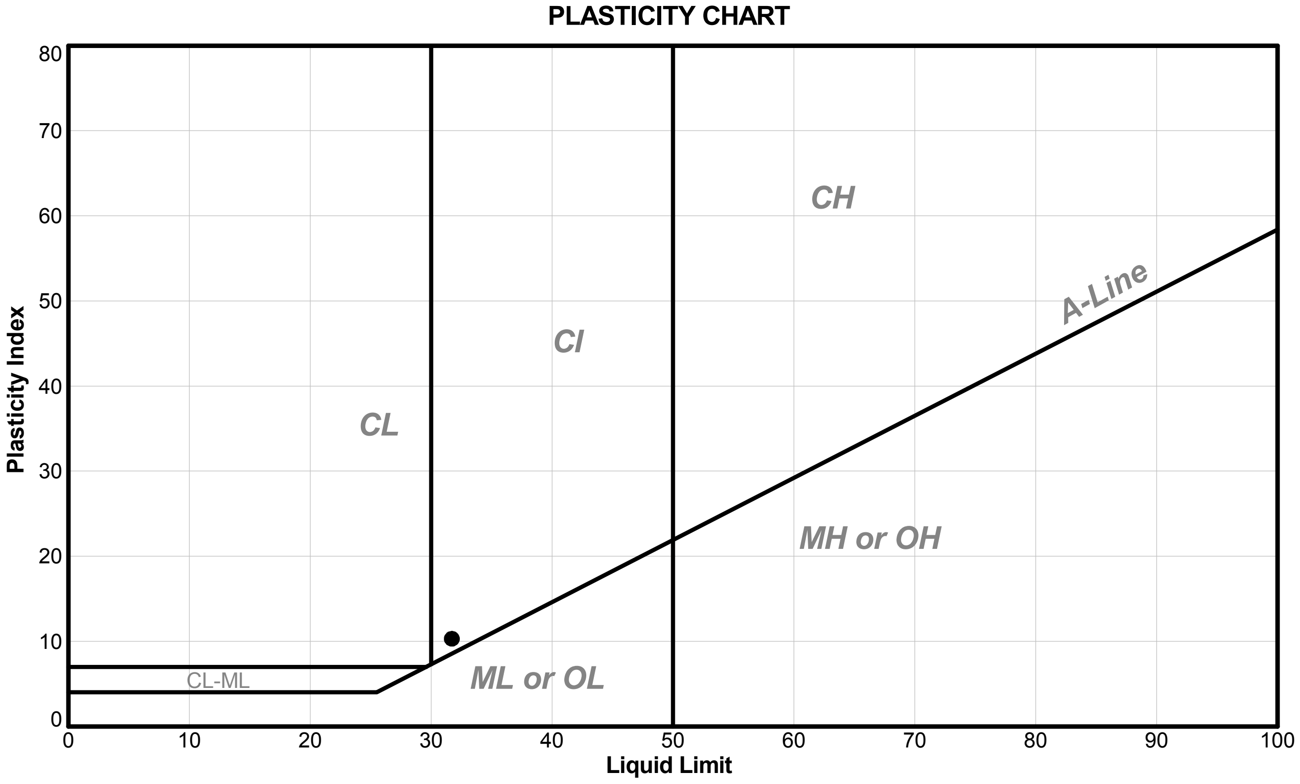
File:GINT_GAL_NATIONALIM Output Form:_LAB_PARTICLE SIZE (SINGLE) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB mmiller 9/26/13

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS	Reference(s) **ASTM D 4318-10**
Client: City of Coquitlam	**Borehole ID: PH13-11**
Project: Chines Slope Stability	**Sample No.: 1**
Location: Coquitlam, BC	**Depth Interval (m):** 1.22 to 1.52
Project No.: 13-1447-0330 **Phase:** 3000 **Task:** 3002	**Lab Schedule No.:** 200

Classification and Definition: CI - Inorganic SILTY CLAY of medium plasticity, sandy or gravelly SILTY CLAY.

Other Remarks: N/A

Test Method: A-Multi Point | **Preparation Method: Wet**



Sym.	Sample Location	Sample Number	Depth (m)	Bottom (m)	Percent Passing #40 Sieve (%)	Liquid Limit	Plastic Limit	Plasticity Index	Natural Water Content (%)	Liquidity Index
●	PH13-11	1	1.22	1.52	ND	32	21	11	23.2	0.2

NP - NON-PLASTIC RESULT ND - NOT DETERMINED

Note: The test data given herein pertain to the sample provided only. This report constitutes a testing service only.

MM	**9/20/2013**	**LP**	**9/25/2013**
Tech	Date	Checked	Date

File:GINT_GAL_NATIONALIM Output Form:_LAB_ATTERBERG CASAGRANDE (SINGLE) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB mmiller 9/26/13

WATER CONTENT DETERMINATION

Reference(s)
ASTM D 4959

Client: City of Coquitlam

Project No.: 13-1447-0330 **Phase:** 3000 **Task:** 3002

Project: Chines Slope Stability

Lab Schedule No.: 200

Location: Coquitlam, BC

Sample Location	Sample No.	Sample Interval		Water Content (%)
		Depth (m)	Bottom (m)	
AH/MW/DCPT13-01	**3**	3.05	3.20	**11.3**
AH/MW/DCPT13-03	**4**	3.66	3.96	**17.9**
AH/MW/DCPT13-03	**5**	5.18	5.49	**22.0**
PH/MW/DCPT13-03	**1**	0.30	0.76	**21.6**
PH/MW/DCPT13-03	**2**	0.91	1.22	**33.8**
PH/MW/DCPT13-03	**3**	1.83	2.13	**13.8**
PH/MW/DCPT13-03	**4**	2.74	3.05	**25.0**
PH/MW13-05	**1**	0.15	0.76	**25.2**
PH/MW13-05	**2**	1.22	1.52	**13.6**
PH/MW13-05	**3**	1.52	1.60	**7.5**
PH13-02	**1**	0.46	0.76	**24.3**
PH13-02	**2**	1.07	1.37	**10.8**
PH13-02	**3**	1.98	2.13	**6.4**
PH13-02	**4**	2.59	3.05	**10.8**
PH13-04	**1**	0.15	0.46	**22.2**
PH13-04	**2**	0.61	0.76	**10.5**
PH13-04	**3**	0.91	1.22	**7.9**
PH13-07	**1**	0.30	0.61	**25.3**
PH13-07	**2**	0.61	0.76	**20.2**
PH13-07	**3**	1.22	1.52	**26.0**
PH13-08	**1**	0.46	0.76	**24.7**
PH13-08	**2**	1.37	1.52	**22.9**
PH13-11	**1**	1.22	1.52	**23.2**

File:GINT_GAL_NATIONALIM Output Form:_LAB_WATER CONTENT (REPORT) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB mmiller 9/26/13

LP	9/25/2013
Checked	Date

APPENDIX C

Existing Landslide Likelihood, Consequence, and Risk Estimates

Landslide Likelihood Estimates - Existing Conditions

Suter Brook Ravine Pslide(average) = 0.0012

Source Area	Angle (o)		Loose Soil		Water		Deformation	Gravel Score	Adjustment Factor	Pslide(lot)
	Estimation	score	Condition	score	Condition	score				
977 Thermal Drive	39-42	1.25	<1m deep at crest and <2m deep below crest	0.5	Plus full roof	1	1	1	0.625	7.4E-04
976 Corona Crescent	33-37	1	>2 m deep at or below crest	1	Plus full roof	1	2	1	2	2.4E-03
980 Corona Crescent	35	1	<2 m deep at and below crest	0.5	Assume plus full roof	1	2	1	1	1.2E-03
984 Corona Crescent	32	0.8	<1m deep at crest and <2m deep below crest	0.35	Plus full roof	1	2	1	0.56	6.6E-04
988 Corona Crescent	33-35	0.8	<1m deep at crest and <2m deep below crest	0.35	Plus full roof	1	1	1	0.28	3.3E-04
990 Corona Crescent	33	0.8	>2 m deep at or below crest	1	Assume plus full roof	1	1	1	0.8	9.4E-04
992 Corona Crescent	31	0.8	<1m deep at crest and <2m deep below crest	0.35	Assume plus full roof	1	2	1	0.56	6.6E-04
998 Corona Crescent	<35	0.8	<2 m deep at and below crest	0.5	Assume plus full roof	1	2	1	0.8	9.4E-04
1000 Corona Crescent	<35	0.8	<2 m deep at and below crest	0.5	Assume plus full roof	1	1	1	0.4	4.7E-04
1004 Corona Crescent	<35	0.8	<1m deep at crest and <2m deep below crest	0.35	Assume plus full roof	1	1	1	0.28	3.3E-04
1008 Corona Crescent	<35	0.8	<1m deep at crest and <2m deep below crest	0.35	Plus full roof	1	2	1	0.56	6.6E-04
1012 Corona Crescent	~36	1	<2 m deep at and below crest	0.5	Assume plus full roof	1	2	1	1	1.2E-03
1016 Corona Crescent	<35	0.8	<1m deep at crest and <2m deep below crest	0.35	Assume plus full roof	1	2	1	0.56	6.6E-04
1020 Corona Crescent	<35	0.8	<2 m deep at and below crest	0.5	Plus driveway	1.5	2	1	1.2	1.4E-03
1024 Corona Crescent	<35	0.8	<1m deep at crest and <2m deep below crest	0.35	Plus driveway	1.5	1	1	0.42	4.9E-04
1028 Corona Crescent	<35	0.8	<1m deep at crest and <2m deep below crest	0.35	Plus driveway	1.5	2	1	0.84	9.9E-04

Landslide Consequence and Risk - Existing Conditions
Crest Properties - Suter Brook Ravine

Source Area	Distance from Crest					Spatial Probability	Temporal Probability	Vulnerability	Element	Expected Number of Fatalities	Pslide(lot)	Societal Risk per Year
	Houses <3m	Houses 3-6m	Houses 6-9 m	Houses 9-12m	Houses>12m	P{s:h}	P{t:s}	V	E	N		
977 Thermal Drive	0	0	0	1	0	0.290	0.007	0.50	4	0.004	7.4E-04	3.0E-06
976 Corona Crescent	0	1	0	0	0	0.670	0.007	0.50	4	0.009	2.4E-03	2.2E-05
980 Corona Crescent	0	0	1	0	0	0.400	0.007	0.50	4	0.006	1.2E-03	6.5E-06
984 Corona Crescent	0	0	0	1	0	0.290	0.007	0.50	4	0.004	6.6E-04	2.7E-06
988 Corona Crescent	0	0	1	0	0	0.400	0.007	0.50	4	0.006	3.3E-04	1.8E-06
990 Corona Crescent	0	0	0	0	1	0.200	0.007	0.50	4	0.003	9.4E-04	2.6E-06
992 Corona Crescent	0	1	0	0	0	0.670	0.007	0.50	4	0.009	6.6E-04	6.1E-06

Individual Risk Values
Most at Risk Individuals

Residence present in this range

Source Area	Individual Risk Values				
	<3m	3-6m	6-9m	9-12m	>12m
977 Thermal Drive	3.8E-06	1.3E-08	2.8E-11	4.2E-14	4.3E-17
976 Corona Crescent	1.2E-05	4.2E-08	8.8E-11	1.3E-13	1.4E-16
980 Corona Crescent	6.1E-06	2.1E-08	4.4E-11	6.7E-14	6.9E-17
984 Corona Crescent	3.4E-06	1.2E-08	2.5E-11	3.7E-14	3.9E-17
988 Corona Crescent	1.7E-06	5.9E-09	1.2E-11	1.9E-14	1.9E-17
990 Corona Crescent	4.9E-06	1.7E-08	3.5E-11	5.3E-14	5.6E-17
992 Corona Crescent	3.4E-06	1.2E-08	2.5E-11	3.7E-14	3.9E-17

Landslide Consequence and Risk - Existing Conditions
Downslope Properties - Suter Brook Ravine

Source Area	Angle from Crest (o)				Spatial Probability	Temporal Probability	Vulnerability	Element	Expected Number of Fatalities	Pslide(lot)	Societal Risk per Year
	Houses >25	Houses >23	Houses >21	Houses >19-21	P{s:h}	P{t:s}	V	E	N		
977 Thermal Drive	0	0	0	0	0.000	0.5	0.29	4	0.000	7.4E-04	0.0E+00
976 Corona Crescent	0	0	0	0	0.000	0.5	0.29	4	0.000	2.4E-03	0.0E+00
980 Corona Crescent	0	0	0	0	0.000	0.5	0.29	4	0.000	1.2E-03	0.0E+00
984 Corona Crescent	0	0	0	0	0.000	0.5	0.29	4	0.000	6.6E-04	0.0E+00
988 Corona Crescent	0	0	0	0	0.000	0.5	0.29	4	0.000	3.3E-04	0.0E+00
990 Corona Crescent	0	0	0	0	0.000	0.5	0.29	4	0.000	9.4E-04	0.0E+00
992 Corona Crescent	1	1	0	2	0.839	0.5	0.29	4	0.487	6.6E-04	3.2E-04
998 Corona Crescent	0	0	0	0	0.000	0.5	0.29	4	0.000	9.4E-04	0.0E+00
1000 Corona Crescent	0	0	0	1	0.003	0.5	0.29	4	0.001	4.7E-04	6.8E-07
1004 Corona Crescent	0	0	0	3	0.008	0.5	0.29	4	0.004	3.3E-04	1.4E-06
1008 Corona Crescent	0	0	0	0	0.000	0.5	0.29	4	0.000	6.6E-04	0.0E+00
1012 Corona Crescent	0	0	0	0	0.000	0.5	0.29	4	0.000	1.2E-03	0.0E+00
1016 Corona Crescent	0	0	0	0	0.000	0.5	0.29	4	0.000	6.6E-04	0.0E+00
1020 Corona Crescent	0	0	0	0	0.000	0.5	0.29	4	0.000	1.4E-03	0.0E+00
1024 Corona Crescent	0	0	0	0	0.000	0.5	0.29	4	0.000	4.9E-04	0.0E+00
1028 Corona Crescent	0	0	0	0	0.000	0.5	0.29	4	0.000	9.9E-04	0.0E+00

Individual Risk Values
Most at Risk Individuals

Residence present in this range

Source Area	Individual Risk Values			
	Houses >25	Houses >23	Houses >21	Houses >19-22
977 Thermal Drive	9.5E-05	2.4E-05	1.2E-05	3.6E-07
976 Corona Crescent	3.0E-04	7.6E-05	3.8E-05	1.1E-06
980 Corona Crescent	1.5E-04	3.8E-05	1.9E-05	5.7E-07
984 Corona Crescent	8.5E-05	2.1E-05	1.1E-05	3.2E-07
988 Corona Crescent	4.2E-05	1.1E-05	5.3E-06	1.6E-07
990 Corona Crescent	1.2E-04	3.0E-05	1.5E-05	4.5E-07
992 Corona Crescent	8.5E-05	2.1E-05	1.1E-05	3.2E-07
998 Corona Crescent	1.2E-04	3.0E-05	1.5E-05	4.5E-07
1000 Corona Crescent	6.1E-05	1.5E-05	7.6E-06	2.3E-07
1004 Corona Crescent	4.2E-05	1.1E-05	5.3E-06	1.6E-07
1008 Corona Crescent	8.5E-05	2.1E-05	1.1E-05	3.2E-07
1012 Corona Crescent	1.5E-04	3.8E-05	1.9E-05	5.7E-07
1016 Corona Crescent	8.5E-05	2.1E-05	1.1E-05	3.2E-07
1020 Corona Crescent	1.8E-04	4.6E-05	2.3E-05	6.8E-07
1024 Corona Crescent	6.4E-05	1.6E-05	7.9E-06	2.4E-07
1028 Corona Crescent	1.3E-04	3.2E-05	1.6E-05	4.8E-07

Landslide Societal Risk - Existing Conditions
Suter Brook Ravine

Source Area	N at Base	N at Crest	Pslide(lot)	Total Fatalities	Societal Risk (per year)
977 Thermal Drive	0.00	0.00	7.35E-04	0.004	2.96E-06
976 Corona Crescent	0.00	0.01	2.35E-03	0.009	2.19E-05
980 Corona Crescent	0.00	0.01	1.18E-03	0.006	6.54E-06
984 Corona Crescent	0.00	0.00	6.59E-04	0.004	2.65E-06
988 Corona Crescent	0.00	0.01	3.29E-04	0.006	1.83E-06
990 Corona Crescent	0.00	0.00	9.41E-04	0.003	2.61E-06
992 Corona Crescent	0.49	0.01	6.59E-04	0.496	3.27E-04
998 Corona Crescent	0.00	#N/A	9.41E-04	0.000	0.00E+00
1000 Corona Crescent	0.00	#N/A	4.71E-04	0.001	6.82E-07
1004 Corona Crescent	0.00	#N/A	3.29E-04	0.004	1.43E-06
1008 Corona Crescent	0.00	#N/A	6.59E-04	0.000	0.00E+00
1012 Corona Crescent	0.00	#N/A	1.18E-03	0.000	0.00E+00
1016 Corona Crescent	0.00	#N/A	6.59E-04	0.000	0.00E+00
1020 Corona Crescent	0.00	#N/A	1.41E-03	0.000	0.00E+00
1024 Corona Crescent	0.00	#N/A	4.94E-04	0.000	0.00E+00
1028 Corona Crescent	0.00	#N/A	9.88E-04	0.000	0.00E+00

TOTAL FOR ALL PROPERTIES: 3.67E-04
(fatalities/year)
2722
(years/fatality)

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