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Project No.: 5077-01

Geotechnical Investigation & Report

Proposed Residential Building – 1430 South Island Hwy – 19A, Campbell River, B.C.

Submitted to:

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1.0 INTRODUCTION

Terran Geotechnical Consultants Ltd. (Terran Geo) has completed this *Geotechnical Investigation Report for the Proposed Residential Building at* 1430 South Island Highway -19A in Campbell River, British Columbia. This report replaces the previous Geotechnical Investigation Report dated March 8, 2017 Revision 0.0. The purposes of this geotechnical investigation report were to conduct supplementary intrusive subsurface test holes, to assess the stability of the western slope on the property and to provide geotechnical recommendations pertinent to the proposed development. This report is for discussion purposes only. A Landslide Assessment Assurance Statement (Appendix D) will be submitted on finalization of this report.

This report has been prepared in accordance with standard geotechnical engineering principles and practices in British Columbia. The report has been prepared in accordance APEGBC's *Guidelines for Legislated Landslide Assessments for Proposed Residential Development in BC* (APEGBC, 2010), here after known as the Guidelines, where a level of landslide safety has not been adopted for this jurisdiction. This report does not address any environmental issues related to development of the project site.

The property is currently vacant and is located within the City of Campbell River's 'Steep Slope' Hazard area. The proposed six level multiple residential dwelling with covered parking is to be situated at the toe of the slope and has a building envelope of approximately 2,170 m^2.

2.0 SCOPE OF WORK

Terran Geo's scope of work includes:

- providing a background study,
- conducting a site reconnaissance and a subsurface soil investigation,
- assessing the slope stability of the slope,
- analyzing the soils information and stability results, and
- providing recommendations including, but not limited to soil bearing capacity, site drainage, and hazard mitigations.

3.0 BACKGROUND & DESKTOP STUDY

The background study involved reviewing past geotechnical investigation reports, site history, digital terrain model, surficial geology maps and air photos. This report utilized past geotechnical investigation's bore-hole data that were drilled on the property in 2006. GIS data contours were obtained from the City of Campbell River Online GIS open data catalogue. Digital terrain models were constructed using Global Mapper (v18.0.1) to visualize current and the pre-disturbance ground topographic surface. Past landslides and volume of the previous landslides could be estimated from comparing the before and after digital terrain models. Surficial geology map (Geological Survey of Canada, 1959) was reviewed to understand the natural soil deposition in the region. Air photos obtained through the UBC Geography Department were analyzed using stereoscopes to locate past landslides in the region.

4.0 Soils Investigation

A subsurface investigation and site reconnaissance were completed on February 9, 2017 and on April 11, 2017. Due to the steepness of the terrain, the supplementary subsurface investigation on the slope consisted of hand augers and soil outcrop mapping. Three bore-holes and two Dynamic Cone Penetrometer Tests (DCPTs) up to a depth of between 1.7 m below the existing ground surface in the slope were placed. Soils from the bore-holes were visually logged and collected for laboratory testing. The soil samples were tested for moisture and grain size composition. The DCPTs conducted were to provide consistency information of the soils at increasing depths. The locations of the bore-holes and DCPTs are illustrated in Figure 1.

A field assessment and traverse along the slope was completed to assess the stability of the slope and to note the slope inclination and vegetation. The water table were estimated in the bore-holes and in seepage zones noted on the slope.

5.0 Site characterization

5.1 General Topography

The property is situated to the southwest corner of the intersection of Rockland Road and South Island Hwy 19A, approximately 5 km south of the downtown core of Campbell River. The eastern portion of the property has been flattened and paved, whereas the western portion of the property consist of a slope that is approximately 22 m high, and varies between 27° and 32° in slope, dipping to the east. Due to the steepness of the slope, the property has been designated a “steep slope” under the Sustainable Official Community Plan (SOCP) (City of Campbell River, 2012). A buried sewer main utility runs adjacent to the top of slope (north and south), outside of the property, approximately 5 m to 17 m from the edge of the top of bank. There is an existing multifamily apartment and a single-family dwelling located north and south of the property, respectively; both developments are located at the toe of the slope.

Three single family residential dwellings lots are adjacent to the west property line on the top of slope. The original pre-disturbance landscape of the top of slope, consisting of mature coniferous and deciduous trees, has been cleared, graded flat, and replaced with a lawn.

Two past landslides have occurred on the property since the region had begun land development and are evident based on existing scarp and debris features, and lack of mature vegetation observed in the field.

The northwest land slide is the most recent, having failed in the late 1990’s, and is marked by a head scarp that runs approximately 50 m wide in an elliptical shape. The main failure mechanism appeared to have been shallow translational slide; however, the head portion of the slide may have been a 6 m deep rotational slide.

The southwest landslide is an older slide, at least three to four decades old. The edge of this landslide could not be located but is greater than 40 m. The main failure mechanism appears to be a shallow translation slide. These landslides are discussed in detail in the subsequent section.

Moderate to heavy seepage was observed from mid slope to the toe of slope. The seepage appears to be permanent and consistent throughout the year as indicated by well-established vegetation that typically grow in water saturated soil conditions. There are minor ravines that run uncontrolled from the top and mid slope to the bottom of the slope.

It is suspected the current toe of the slope has been cut back between 10 m to 15 m based on topographic interpolation from digital terrain models.

Due to the inaccessibility of the top slope and snowfall cover during the ground traverse, the condition of the ground surface could not be completely observed.

5.2 Site History

No natural landslides were observed on the west slope prior to development on the top of slope. Although the property was developed at the toe of the slope, air photo interpretation from 1946 and 1952 indicate there was minimal land grading work at the toe and the west slope was stable. Between 1964 and 1976, residential development occurred on the top of the slope, resulting in major vegetation clearing and land grading work that caused two pronounced ravines/gullies to develop in where the two existing landslides were observed.

A shallow translational landslide to the southwest is suspected to have developed between 1976 and 1982, as air photos indicate a clearing in vegetation on the slope where there is an existing gully.

It is understood from others, the northwest slope failed in 1998 due to land grading work at the toe where the bottom of the slope was undermined. The landslide debris were deposited along the slope and bottom, impacting the first storey of the building (motel). It was suggested the debris field was half a storey high at the bottom and filled in three suites. The slope toe was re-established and the debris material at the toe was removed; however, evidence of the landslide scarp is apparent in the topography.

Several buildings have been erected at the bottom of the slope since the mid twentieth century. The lot is currently vacant.

A compilation of air photos (City of Campbell River webmap) is presented in Appendix A.

5.3 Soil and Groundwater Conditions

The surficial soils on the property and surrounding upland and lowland areas have been deposited and influenced by the last glaciation during the Pleistocene Period. Typical soil conditions are glacio-marine deposits comprised of gravel and sandy marine-veneer deposits (typically up to 1.5 m deep) underlain by ground marine deposits such as dense till or clay.

Table 1 describes the general soil conditions on the slope. However, because of the past landslide failures, vegetation and varying deposition nature of the marine sediments, the thickness of the soil may vary. The head of the landslide surface where the rupture surface is exposed is expected to have minimal top soil thicknesses and is closer to the till layer, while the toe of the landslide where the debris field has been deposited is expected to have a much larger thickness of looser materials such as top soils and sands. Till outcrop consisting of dense sand is exposed in areas of the slope at the head scarp of previously landslide has occurred (see Photo 1 and 2 in Appendix A). This is supported based on the auger soil logs that were completed in various location of the landslide. Detailed soil and DCPT logs are provided in Appendix B.

Table 1– Soil Stratigraphy on the slope

Thickness (m)	Soil Description (top to bottom)
0.2 – 1.3	TOPSOIL, organic silt with rootlets, woody debris, very loose
1.0 – 1.5	SAND, some silt and gravels, loose to very loose (GLACIO-MARINE VENEER DEPOSITS)
-	Lenses of sand, silt, gravel, dense or hard and very firm clay (TILL)

Table 2 describes the general soil conditions at the bottom of slope, where the property has been developed in the past.

Table 2– Soil Stratigraphy at the bottom of the slope

Thickness (m)	Soil Description (top to bottom)
0.1	Asphalt
0.5	SAND & GRAVEL, compact (FILL)
0 - 1.0	SAND, some silt and gravels, loose to very loose (GLACIO-MARINE VENEER DEPOSITS)
-	Lenses of sand, silt, gravel, dense (TILL)

Very firm to hard clay soil outcrop was observed at the existing toe of the slope near the south property line. The hard clay layer was observed to be approximately 4.5 m thick, and cut vertically by mechanical means during past site grading work (see Photo 3 and 4 in Appendix A). The hard clay is considered to be associated with the marine till deposit. This soil layer is considered impermeable and any groundwater from the slope is draining overtop through the sand veneer and topsoil.

The soil conditions are supported by published surficial geology maps, past geotechnical investigations and our understanding of the surficial geology of the area. Moderate to heavy seepage was observed along the bottom half of the slope. The water table, perched above the impervious till, was observed close to the ground surface in the bore-holes that were hand-augered mid slope.

5.4 SEISMICITY

The Site Classification for the property is 'C' – Very dense soil and soft rock according to the 2012 B.C. Building Code. This is based on DCPT readings completed to 6.5 meters below ground surface (mbgs) and dense to compact sand and silt till observed in previous site investigation performed by others (Lewkowich, 2007). As interpolated from the 2015 National Building Code Seismic Hazard Calculation for the coordinates 49.987° N, 125.227° W with a 2% in 50 years probability of exceedance, the Peak Ground

Acceleration can be taken as 0.285g. A detailed summary of the spectral acceleration response values are provided in Appendix C of this report.

The acceleration and velocity based site coefficients, F_a and F_v, may both be taken as 1.0. There is negligible probability of liquefaction of the subgrade at this site during the design earthquake due to the shallow and dense till soil conditions.

6.0 Slope Stability Assessment

Slope stability assessment consist of the following processes:

- Complete a back analysis of the past northwest landslide to estimate soil strengths and soil/groundwater parameters;
- Construct a static and pseudo static limit equilibrium models for two representative cross sections of the slope using back analyses output, geotechnical investigation, digital terrain models, and the proposed building plans;
- Complete a landslide risk analysis by determining the runout distance of the landslide and its probability to cause fatalities. Compare the factor of safety for landslides that may cause fatality to the *Natural Hazards Risk Tolerance Criteria* that has been adopted by the District of North Vancouver and among other countries such as Australia, Hong Kong, and the UK.

A back analysis was completed for a known past translational landslide in the northwest slope of the property to estimate soil strength parameters. A static and pseudo-static slope stability model was completed for two sections on the slope to estimate the size of potential shallow and deep seated landslides during normal conditions and in a designated earthquake. The stability model was completed using a limit equilibrium model, Morgensten Price Method, analyzed with GeoStudio Slope/w (Version 8.16.1.13452) and completed in accordance to Method 2 (Pseudo-static analysis using a slope displacement based seismic coefficient for a 2% probability of failure occurring in a 50 year period) as recommended in the Guideline (APEGBC, 2010). Run out distance of the potential slides were estimated based on past landslides and volume of the slides.

6.1 Back analysis

The northwest landslide was back analyzed assuming a translational slide where the rupture surface exits at the toe of the slope due to undermining activity that occurred at the toe of the slope (attributed as the main cause for the failure) and a high-water table. The stability model representing the back analysis is provided in Figure 1. The dimension of the landslide mass is approximately 2,700 m^3, that spans 20 m to 30 m wide and 50 m in length with a runout distance estimated to be 20 m.

Soil properties of the surficial soils are provided in Table 3 and are estimated based on typical soil properties and from the back analysis.

TABLE 3– SOIL PARAMETERS

Soil Type	Unit Weight	Friction Angle	Cohesion
Top Soil	12 kN/m^3	20°	3 kPa
Sand Veneer (glacio-marine deposits)	19 kN/m^3	36°	5 kPa
Sand and Gravel Till	20 kN/m^3	40°	30 kPa
Hard Clay	21 kN/m3	18°	200 kPa

6.2 Static and Pseudo Static Stability Models

Two types of models were generated for three cross sections (Section A, Section B, and Section C) along the western slope. The models represent the current slope topography and groundwater conditions with the proposed building, but without the toe berm or proposed fill between the building and the slope.

The static condition refers to the case where we have drained conditions on the slope. The pseudo static condition refers to the seismic case where we have horizontal ground acceleration from a designed magnitude earthquake.

A typical method to analyze and assess slope stability in the event of a seismic event, the pseudo static condition, is to use Method 2 Pseudo-static limit equilibrium analysis using a slope displacement based seismic coefficient (APEGBC, 2010). This Method suggest using a seismic coefficient, k_{15}, that would represent a 15 cm of slope displacement along the slip surface, deemed the maximum allowable displacement threshold allowed in a design earthquake. K_{15} is estimated from the following equation below:

$$K_{15} = (0.006 + 0.038\ M) \times S(T) - 0.026;\ S<1.5g$$

where M is the moment magnitude of the modal earthquake (note APEGBC's Task Force on Seismic Slope Stability recommends a modal magnitude of M = 7 since modal magnitudes for BC sites are rarely much larger than this value); and S(T) is the spectral response acceleration, where the spectral period is computed from the following equation below:

$$S(T)=S(1.5xTs) \text{ and } Ts = 4 \times \text{Height /Average Shear Wave Velocity.}$$

The spectral response for a 2% probability of exceedance in 50 years (0.000404 per annum) event can be estimated from the 2015 National Building Code Seismic Hazard Calculation (See Appendix C). K_{15} is estimated to be 0.14 for a spectral acceleration of Sa(0.3)=0.620 which is based on an average shear wave velocity of 450 m/s.

The static and pseudo static models were analyzed for both Section A, Section B, Section C. The results are summarized in Table 4 and in Figure 2 to 9.

TABLE 4– SLOPE STABILITY RESULTS

Scenario	Factor of Safety	Comments
Static – Section A	1.09	Mid slope to toe slip surface with high water table (Figure 2)
Seismic – Section A	0.72	Mid slope to toe slip surface with high water table (Figure 3)
Static – Section B	1.14	Mid slope to toe slip surface with high water table (Figure 4)
	~1	Top of slope to toe slip surface with high water table (Figure 5)
Seismic – Section B	0.68	Top of slope to toe slip surface with high water table (Figure 6)
	0.81	Mid slope to toe surface with high water table (Figure 7)
Static – Section C	1.13	Top slope to mid slope slip surface with high water table (Figure 8)
Seismic – Section C	0.93	Top of slope to mid slope slip surface with high water table (Figure 9)

Failure mechanisms for the modeled landslides for Section A, Section B, and Section C are mainly translational shallow translational slides. However, based on experience of past landslides on the property, landslides that may start as a shallow translational landslides at the toe or bottom half of the slope and develop into slightly deeper rotational landslide at the top of the slope. For this reason, landslides were modelled for the top of slope and at the bottom of slope (only for Section B where the top of slope has not failed).

Based on the slope stability results, the slope is expected to fail during a design earthquake.

Runout distance and velocities of potential landslides can be determined by applying the Center of Mass approach and energy budget calculation for simple Coulomb frictional models (Firmansyah, S., Tohari, A, Latief, F.D.E., 2003). The runout distances were estimated for large translational landslides (entire slope) in each cross section with factor of safety less than 1.5 for static cases and factor of safety less than 1.0 for pseudo static conditions are summarized in Table 5 below.

TABLE 5– RUN OUT DISTANCE RESULTS

Scenario	Cross Sectional Area of design landslide (m^2)	Run-out Distance from Toe of Slope[1,2] (m)	Velocity of landslide at toe[2] (m/s)
Static – Section A	73	2	~0
Seismic – Section A[3]	70	1	~0
Static – Section B	60	13	1.8
Seismic – Section B[3]	66	8	0.9
Static – Section C	39	7	1.4
Seismic – Section C[3]	39	7	1.4

Notes:

1) Refers to the new toe of slope with the toe buttress(fill).
2) Run-out distance and velocity depends on the Center of Mass of the landslide, its height from the toe and residual friction angle (assumed to 15°).

3) Seismic (pseudo static) scenario refers to a ground acceleration where the slope displaces a maximum of 15 cm. The run out model above assumes the landslide fails completely, resulting in mass movement. Full run-out distance may not actually be achieved.

6.3 Hazard/Risk Assessment

The property and surrounding steep slopes are prone to landslides based on historical observations and air photo interpretation. In particular, the two landslides that have occurred on this property within the last four decades have been caused by human caused factors such as the following:

- Development at the top of the slope where the natural vegetation has been removed, which has caused higher water infiltration into the soil and surface water runoff and thus resulted in shallower perched water table and seepage in the slopes;
- Gullies forming from surface water runoff from the top of slope, thus resulting in erosion of the soil. The past landslides have occurred in air photo observed developed gullies;
- Land grading and removal of soils (undermining) at the toe of the slope, thus creating unstable slope conditions; and
- Changes in vegetation. The original mature vegetation, deep rooted, on the slope has been replaced by immature shallow rooted vegetation.

There is potential for future landslides on the existing western slope where failures have occurred in the past under static and seismic conditions. Landslide failure mechanisms may start as shallow translational landslide at the toe and progress in to the upper rotational slide at the top of slope.

The following risk analysis for the proposed building and land grading (with toe berm) is presented in Table 6. This is based on the stability results from Table 4.

Table 6– Risk Analysis

		Hazard		Consequence	
Type of Event	Runout Distance	Probability for landslide	Rating	Value	Rating
Shallow Compound Landslides, high velocity, <3000 m^3 mass	Up to 13 m from the new toe of slope (Geotechnical offset - See Drawing 3)	1>100	Very High	Potential for loss of life, property damage	Very High

A level of landslide slide safety has not been adopted by the City of Campbell River. This report uses the Natural Hazards Risk Tolerance Criteria (District of North Vancouver, 2009) shown in Table 7 to evaluate the level of risk for the proposed development. Based on slope stability assessment presented in the above, <u>the proposed development does not meet the required criteria under current conditions and engineering solutions will be required to make the proposed development safe.</u>

Table 7– Risk Tolerance Criteria[1] without Engineering Measures

Type of Application	Hazard		Action
	Probability for Fatality 1:100,000	Slope FOS>1.5	
New Development (Section B, C)	Not pass	Not Pass	Requires engineering options to mitigate hazards and/or passive mitigation measures

Note: 1) Taken from the Natural Hazards Risk Tolerance Criteria (District of North Vancouver, 2009)

7.0 DISCUSSION AND RECOMMENDATIONS

It is our opinion that the proposed residential building is feasible, but would require implementation of landslide mitigation measures to reduce the risk, and other recommendations with regards to soil bearing capacity, foundation types, slope maintenance and site drainage, provisions for soil stockpiles, landscaping, and stipulations on storm water management.

7.1 LANDSLIDE MITIGATION MEASURES

Terran Geo recommends the following passive mitigation measure due to landslide risks from stability modelling and landslide run out zones:

- No habitable buildings or auxiliary buildings shall reside within the geotechnical offset (ranging from 5 m to 15 m offset – See Drawing 3) from the new toe of the slope after the proposed fill to approximately 7.0 masl (meters above sea level) has been constructed unless reviewed from a qualified geotechnical engineer specializing in slope stability. Engineering mitigation measures will be required if a developer in the future proposes to build within the geotechnical offset. For this proposed development, engineering mitigation measures is required as the proposed building is within the geotechnical offset defined within Zone 2 of Drawing 3.

For this proposed development, engineering slope stability mitigation and risk reduction measures are required since the back portion of the proposed apartment development (Zone 2) is located within the geotechnical offset. These measures are as follows:

- Horizontal drainage pipes drilled into toe and mid slope (within the sandy veneer) to reduce the water level and reduce seepage;
- Interceptor ditches located mid slope on an existing natural bench to collect surface water runoff that can be directed into drainage pipes and discharged at the toe of the slope;
- Revegetation of the slope that is bare of vegetation;
- Designated landslide run-out zone in the rear portion of the building; and
- No habitable areas in the rear portion of the building (southwest) facing upslope on the second floor and no openings in the foundation wall below 9.50 m (See Zone 2 - Drawing 3).

A reduction in the water table and control of surface water runoff will significantly improve the stability of the slope as can be shown in Figure 8, Figure 9, and Figure 10 (with drainage control in place). The results of the stability model analysis with the lowered water table and the associated Risk Tolerance is summarized in Table 8 and Table 9, respectively.

Table 8– Summary of Stability Modelling with a Lowered Water Table

Scenario	FS	Comment
Section A – static	>1.5	For landslide exiting at the toe.
Section B - Static	1.4	Mid slope to lower slope translational failures.
Section C - Static	~1.4	For landslide exiting above toe buttress (translational)

Table 9– Risk Tolerance Criteria[1]

Type of Application	Hazard	
	Probability for Fatality 1:100,000	Static Slope FOS>1.5
New Development Zone 1 (Section A)	Pass	Pass
New Development Zone 2 (Section B and C)	Pass	Marginal[2]

Note:

1) Taken from the Natural Hazards Risk Tolerance Criteria (District of North Vancouver, 2009)

2) Although the static stability for Section B and C marginally do not meet factor of safety requirement of 1.5, there is very low probability of fatalities and low risk to the structural component of the building if the measures described above are undertaken (particularly to no habitable space and closing of foundation wall within Zone 2).

Based on the improved stability of the slope from lowered water table, run-out zone, limits on habitable space and building requirement the landslide hazard and risks have been reduced to satisfy the Natural Hazard Risk Tolerance Criteria.

7.2 Site Preparation

Areas of the building footing and slab area should be stripped and cleared of the asphalt, organic debris and rootlets, and loose wet soil subgrade. The subgrade shall be approved by the Geotechnical Engineer prior to backfilling.

When site-grading and/or structural fill is required, it should consist of a clean granular engineered fill, such as a (75 mm) minus pit run sand and gravel or an approved equivalent. All engineered fills should be placed and compacted as approved by the Geotechnical Engineer to at least 95% of the material's Standard Proctor Maximum Dry Density (SPMDD) value in lifts no thicker than 300 mm.

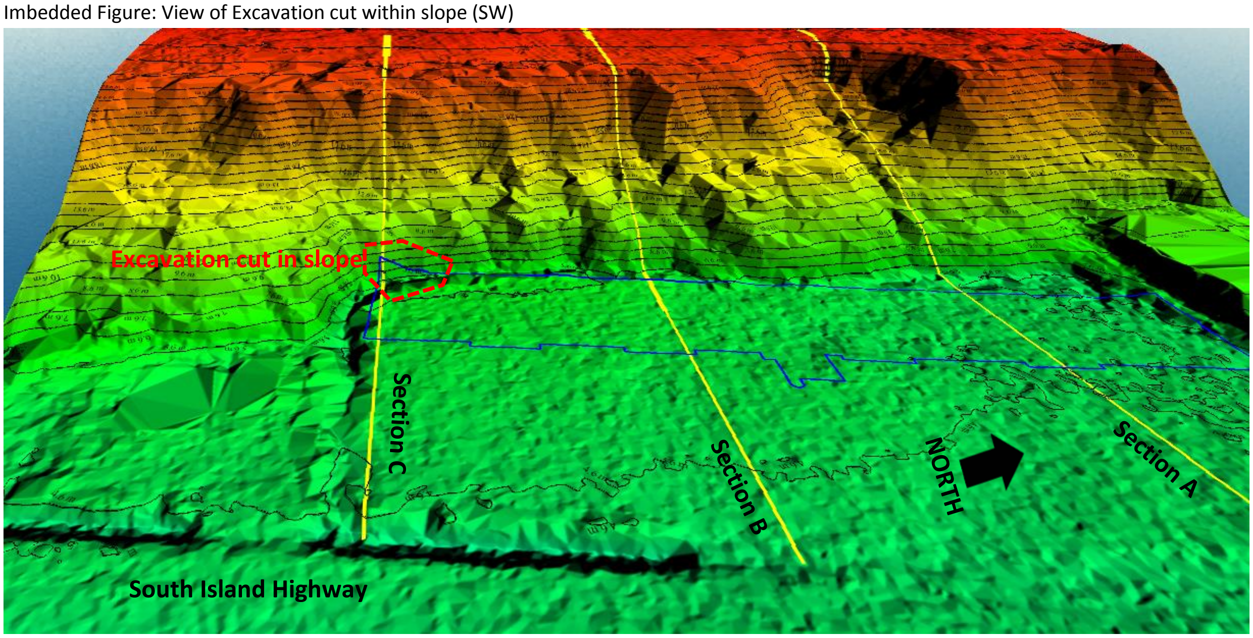
During construction, no soil stockpiles shall be placed on the slope. Stockpiles shall be sloped at 1H:1V.

7.3 Temporary Excavation Cut

The proposed building requires temporary excavation in close proximity to the existing toe of the slope in the southwest corner of the proposed building. The proposed building requires cutting into the slope by approximately 4 m and 3 to 5 m in height. Most of the cut will occur within the hard clay layer; however, surficial soils and top soil will need to be scaled back. Detailed Temporary excavation and shoring design must be completed prior to construction and may involve the following:

- Unwatering the slope and managing slope seepage;
- Scaling back of excavation cut and slope;
- Anchoring system that may consist of helical piles or shotcrete and soil anchors;
- Temporary retaining walls;
- Time restriction on when temporary excavation cut can be completed; and/or
- Staged excavation and backfill.

Imbedded Figure: View of Excavation cut within slope (SW)



7.4 Foundation

The native sand silt till at this site is competent to support the footing and floor loads associated with typical apartment buildings on conventional strip footings and slab on grade. The boreholes placed in the building footprint indicates a slight dip of the silt till of about 14% and should be evaluated during subgrade preparation to mitigate differential settlement of the upper sand stratum.

It is recommended a 100 mm thick bedding of 19 mm crushed gravel is placed over the structural drainage fill (see the subsequent section). The maximum allowable soil bearing capacity for the sand and silt till shall not exceed 150 kPa (approximately 3133 psf) for design of the footings. Footings should be designed for equal contact pressure of nearly equal sizes to minimize potential total and differential settlement to less than 1 inch total and ½ inch differential. Adjacent footings placed at different elevations should be constructed no closer than or be stepped at no more than a line projected at 2H:1V from the lower footing. Footings should be placed at least 450 mm below the finished ground surface for frost protection.

7.5 Lateral Wall Pressure

Lateral loadings on foundation walls, assuming leveled backfill slope, have been provided for the proposed fill, consisting of free draining gravel material. The lateral earth pressure coefficients have been provided for At-Rest Pressure (k_0), Active Pressure (K_A), and Passive Pressure (K_P). Coulomb's theory was used to calculate the active and passive pressures, while a Mononobe-Okabe solution was used to calculate an earthquake induced active pressure. A summary of lateral earth pressure coefficients is provided in Table 9.

Table 10– Summary of Lateral Earth Pressure Coefficients

Pressure Coefficient	Symbol	Value
At-Rest Pressure	k_0	0.5
Active Pressure	K_A	0.3
Passive Pressure	K_P	3.0
Seismic Pressure	Delta K_{ae}	0.25

The coefficients were determined assuming a level, free draining backfill with a unit weight of 19 kN/m^3.

Lateral loadings on temporary retaining walls that is supporting the slope are different than those coefficients provided in Table 10 for foundation walls due to the varying angle in the backslope and hydrostatic ground pressure. A Geotechnical Engineer must be consulted on retaining wall design that is supporting a sloped backfill.

7.6 Permanent Drainage

Footing drains should be evaluated along the western side of the building. Consideration of a drainage layer comprising of 3 inch minus gravel with a minimum thickness of 300 mm shall be placed on the subgrade to allow water at the toe of the slope to drain east below the building.

Open areas shall be vegetated and allow for rain water to infiltrate into the ground. For areas that are paved, water shall not be concentrated and allowed to flow onto the slope.

Permanent drainage of the slope shall be designed as part of the engineering measures for landslide mitigation measures.

7.7 Commitments for Field Reviews

Terran Geo recommends the following field review:

- Review the installation of horizontal drainage pipe, interceptor ditches, run out zone and slope drainage and inspect the slope.
- Bearing capacity review; and

- Structural fill and drainage bed backfill review.

To ensure commitment of field reviews, Terran Geo must be notified when the construction work comments to facilitate the necessary field reviews. Terran Geo cannot accept responsibility or liability for the adequacy of its recommendations when the recommendations are used in the filed without Terran Geo being retained to review and approve the recommendations during construction.

7.0 Closure & Limitations

The proposed building constructed on this property can be used safely for the intended use, based on the Level of Landslide Safety presented in this report and provided the above landslide engineering mitigation measures; recommendations for soil bearing capacity, foundation types, slope maintenance and site drainage, provisions for soil stockpiles, landscaping, stipulations on storm water management are implemented.

This report was completed for the exclusive use of Campbell Shore Holdings Ltd. and its agents, in addition to the City of Campbell River to support the construction of the subject site. Any use of the materials contained in this letter for other than the intended purpose must first be verified by Terran Geo.

Stratigraphic variations in the ground conditions are expected due to its historic nature, therefore, all exploratory work involves an element of risk that some conditions will not be detected. This report has been prepared with the care exercised by reasonable, prudent and competent professionals trained in the discipline of geotechnical engineering and in accordance with geotechnical practices for this region and time. No other warranty, expressed or implied is made.

We trust that this information meets your present requirements. If you require additional information, or if you have any questions, please do not hesitate to contact the undersigned.

Sincerely,

Terran Geotechnical Consultants Ltd.

Dylan Lee, P.Eng.
Project Manager | Geological Engineer

Thanh Le, P. Eng.
Principal | Geotechnical Engineer

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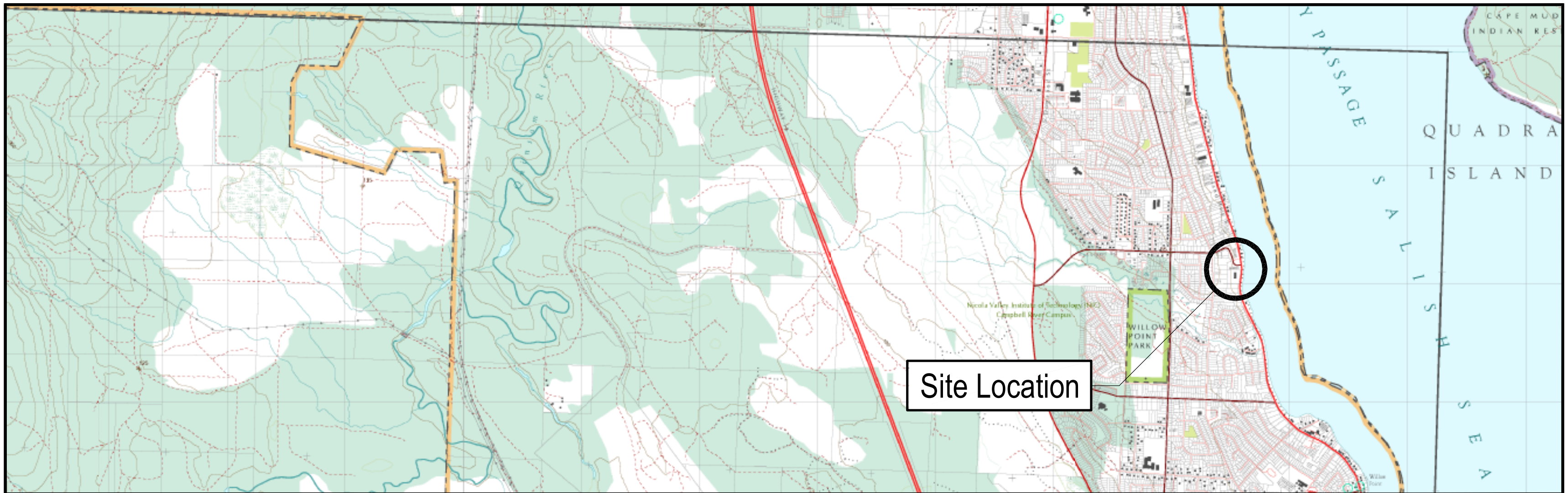
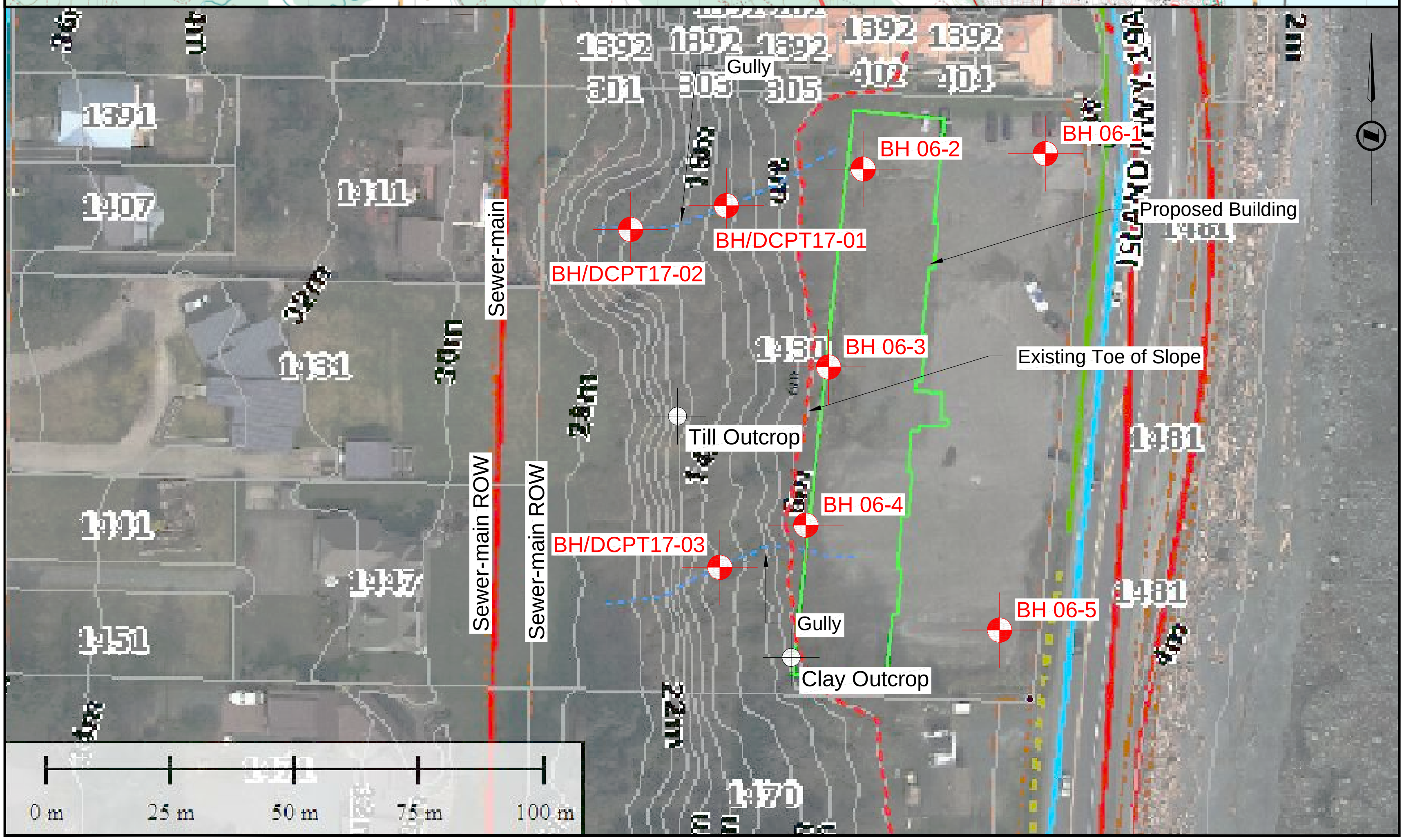
DRAWINGS





TERRAN
GEOTECHNICAL

PROFESSIONAL SEAL

PREPARED FOR

Campbell Shore Holdings Ltd.

Proposed Residential Building

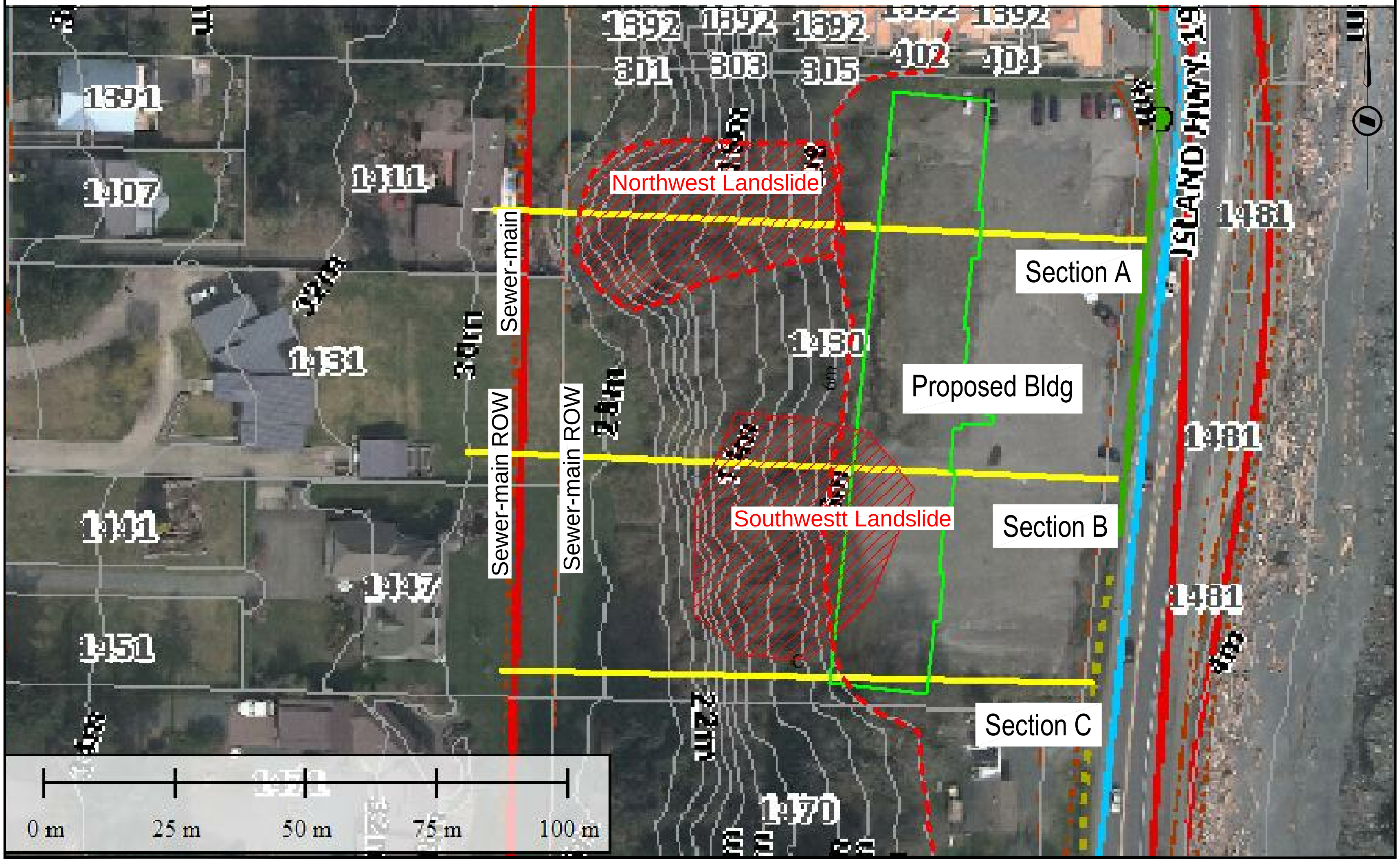
1430 South Island Highway, Campbell River, B.C.

Project Number: 5077-01

Geotechnical Investigation
Borehole / DCPT Plan

Sheet Number:	1
Date Created:	2017-04-10
Date Revised:	2017-04-27
Drawn By:	J. Simihag
Reviewed By:	D. Lee
Scale:	As Shown

5077-01-DWG-01	2.0



TERRAN
GEOTECHNICAL

PROFESSIONAL SEAL

PREPARED FOR

Campbell Shore Holdings Ltd.

Proposed Residential Building

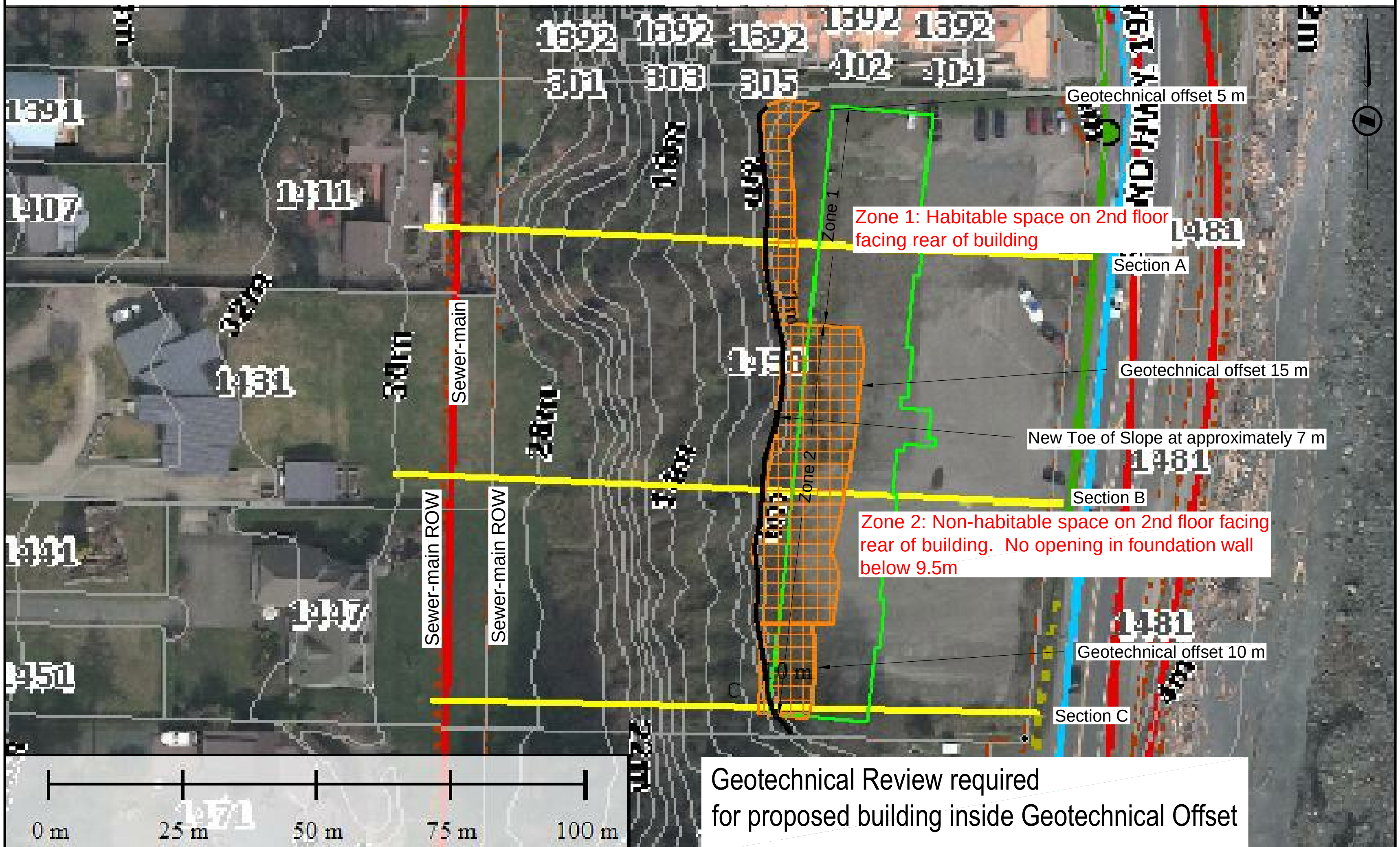
1430 South Island Highway, Campbell River, B.C.

Project Number: 5077-01

Geotechnical Investigation
Previous Landslides

Sheet Number:	2
Date Created:	2017-02-17
Date Revised:	2017-02410
Drawn By:	J. Simihag
Reviewed By:	D. Lee
Scale:	As shown

5077-01-DWG-02	2.0



TERRAN
GEOTECHNICAL

PROFESSIONAL SEAL

PREPARED FOR

Campbell Shore Holdings Ltd.

Proposed Residential Building

1430 South Island Highway, Campbell River, B.C.

Project Number: 5077-01

Geotechnical Investigation
Geotechnical Offset

Sheet Number:	3
Date Created:	2017-02-17
Date Revised:	2017-04-10
Drawn By:	J. Simihag
Reviewed By:	D. Lee
Scale:	As shown

5077-01-DWG-03	1.0

FIGURES

Figure 1: Back Analysis of Northwest Landslide

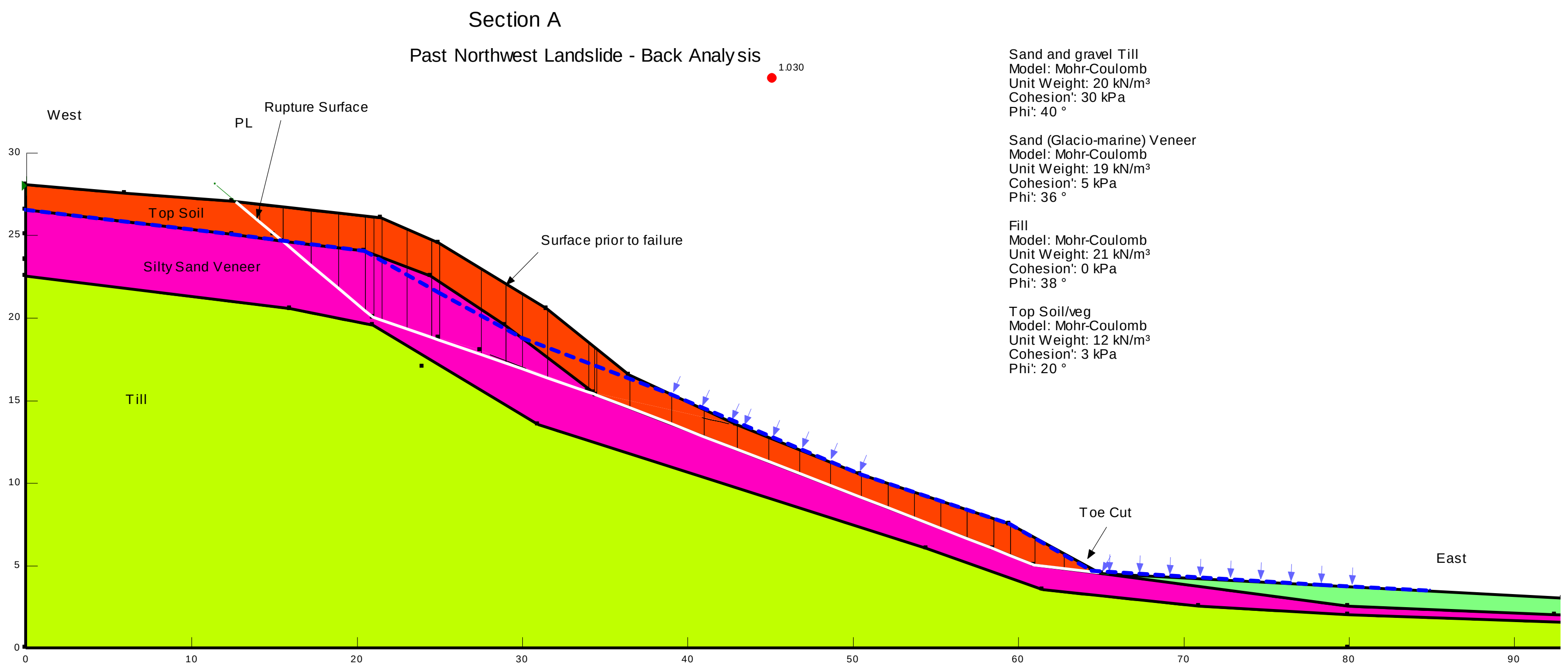
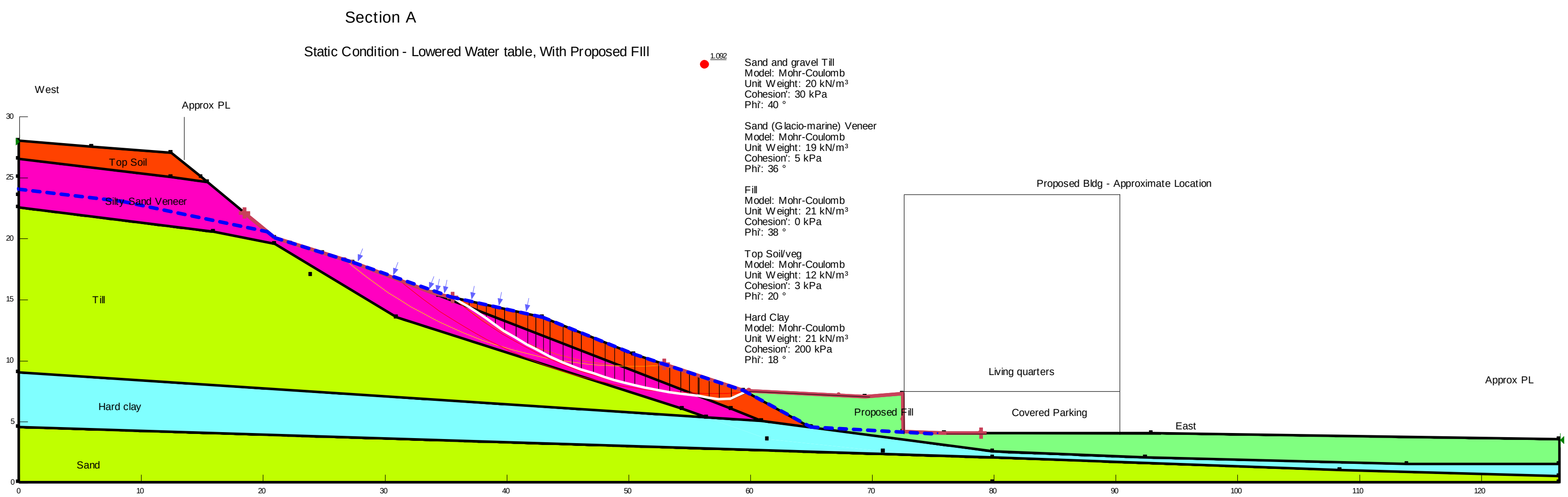


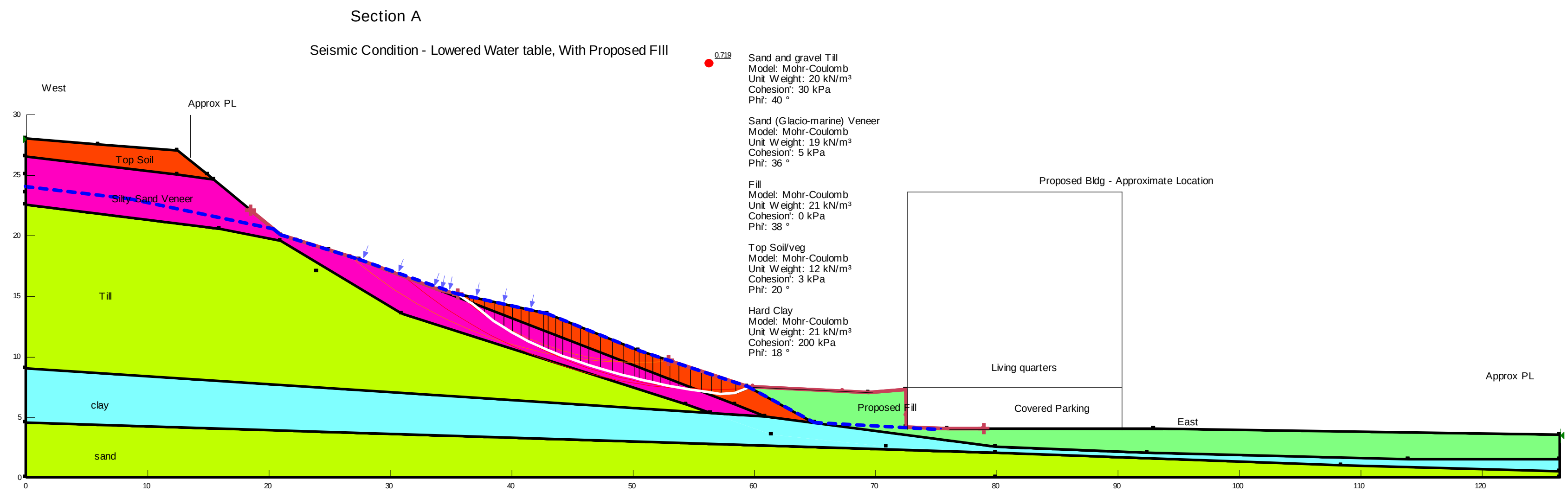
Figure 2: Section A Static Conditions / current Water Table



Notes:

1) Slip surfaces less than FS<1.5 are shown.
2) Section corresponds to Northwest landslide

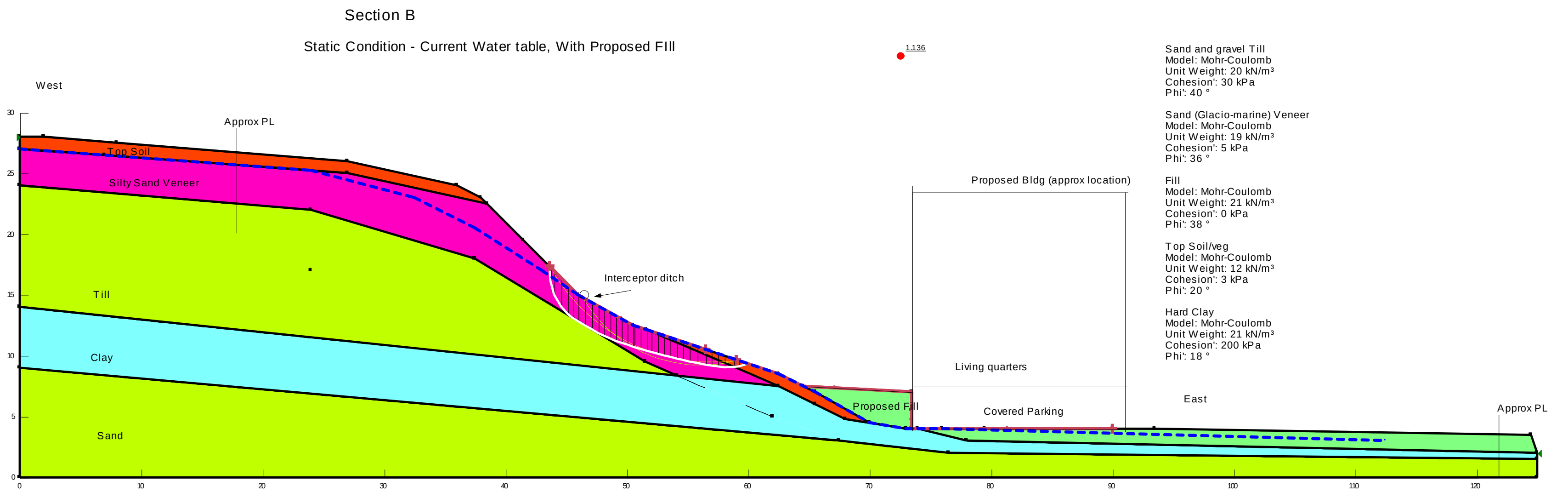
Figure 3: Section A Seismic Conditions / current Water Table



Notes:

1) Slip surfaces less than FS<1.0 are shown.
2) Section corresponds to Northwest landslide

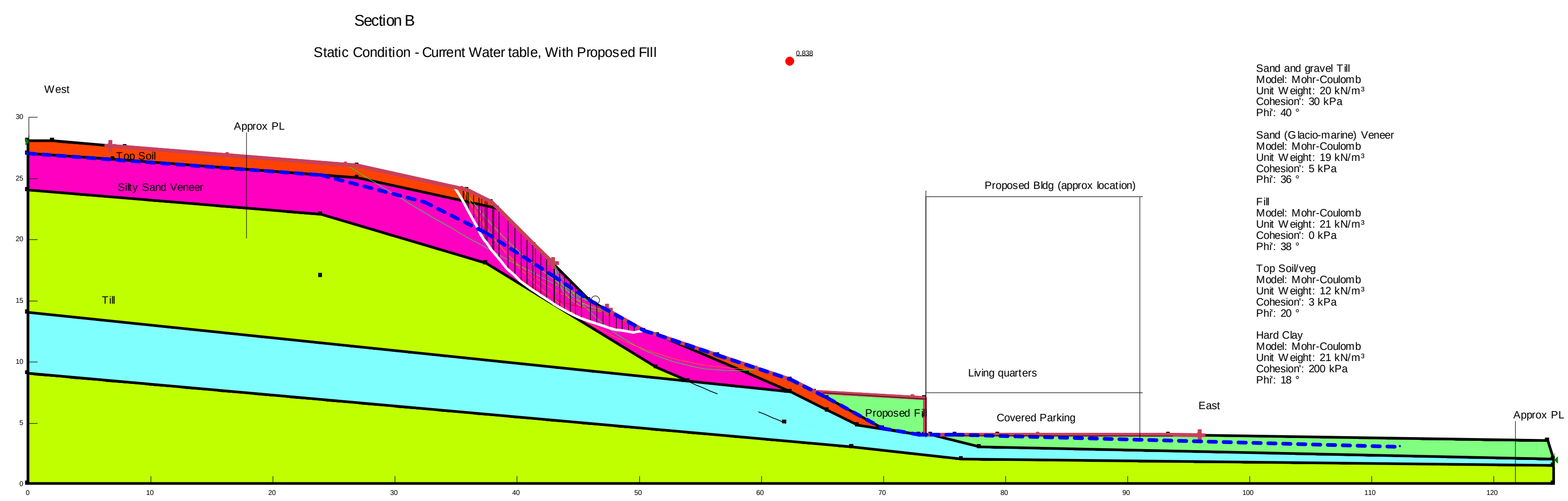
Figure 4: Section B Static Conditions (failures lower half of slope) / current water table



Notes:

1) Slip surfaces less than FS<1.5 are shown.
2) Section corresponds to southwest landslide

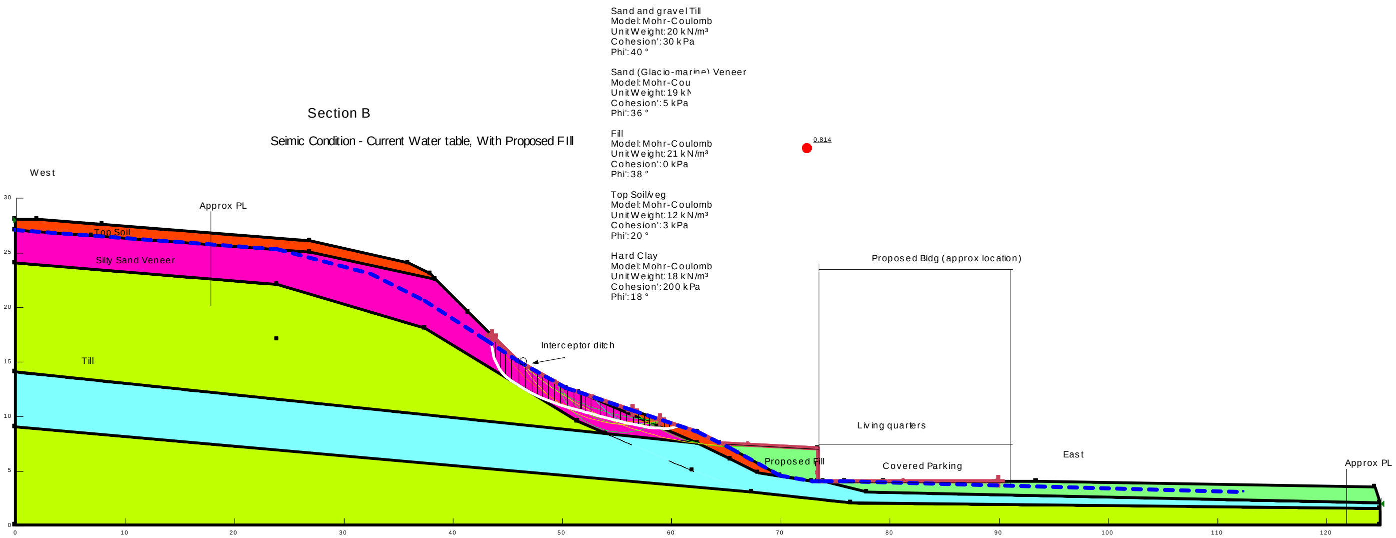
Figure 5: Section B Static Conditions (failures upper half of slope) / current water table



Notes:

1) Slip surfaces less than FS<1.5 are shown.
2) Section corresponds to southwest landslide

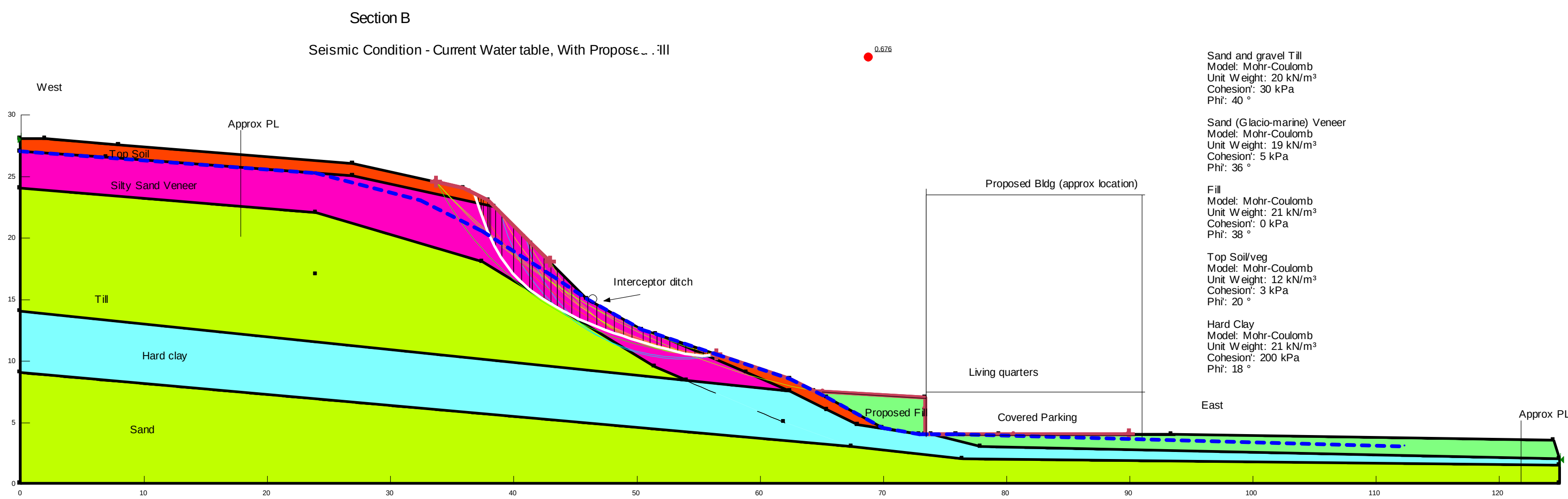
Figure 6: Section B Seismic Conditions (failures lower half of slope) / current water table



Notes:

1) Slip surfaces less than FS<1.0 are shown.
2) Section corresponds to southwest landslide

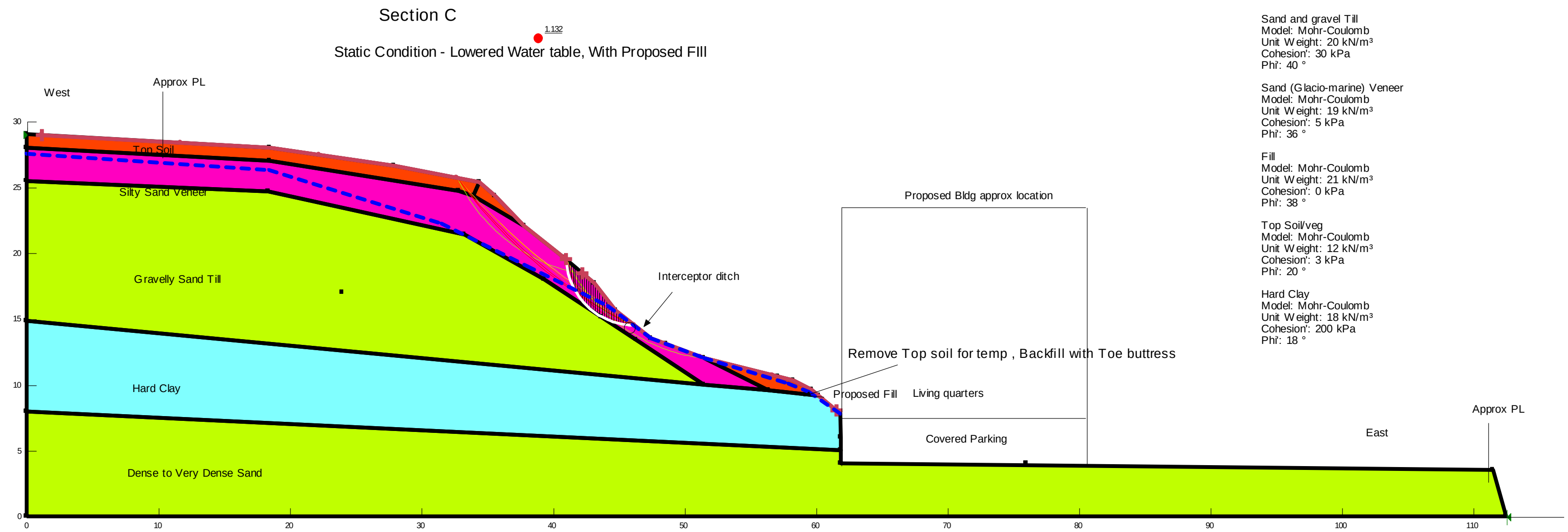
Figure 7: Section B Seismic Conditions (failures upper half of slope) / current water table



Notes:

1) Slip surfaces less than FS<1.0 are shown.
2) Section corresponds to southwest landslide.

Figure 8: Section C Static Condition (failures upper half of slope) / current water table



Notes:

1) Slip surfaces less than FS<1.5 are shown.

Figure 9: Section C Seismic Conditions (failures upper half of slope) / current water table

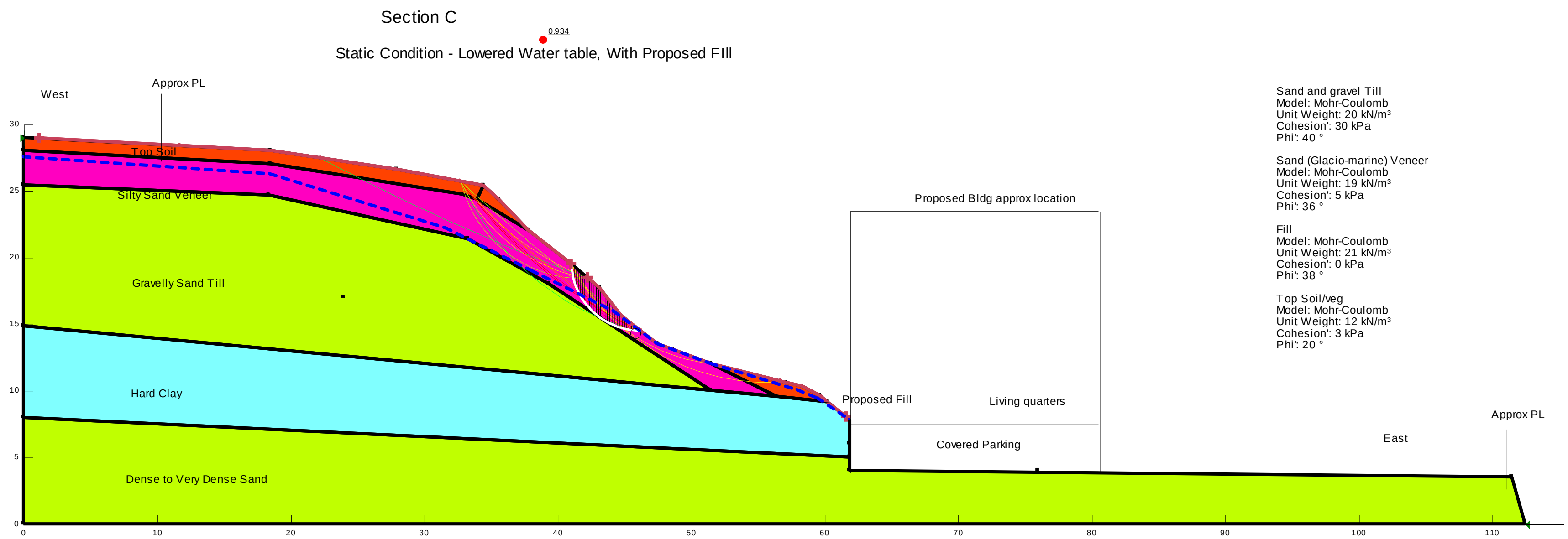
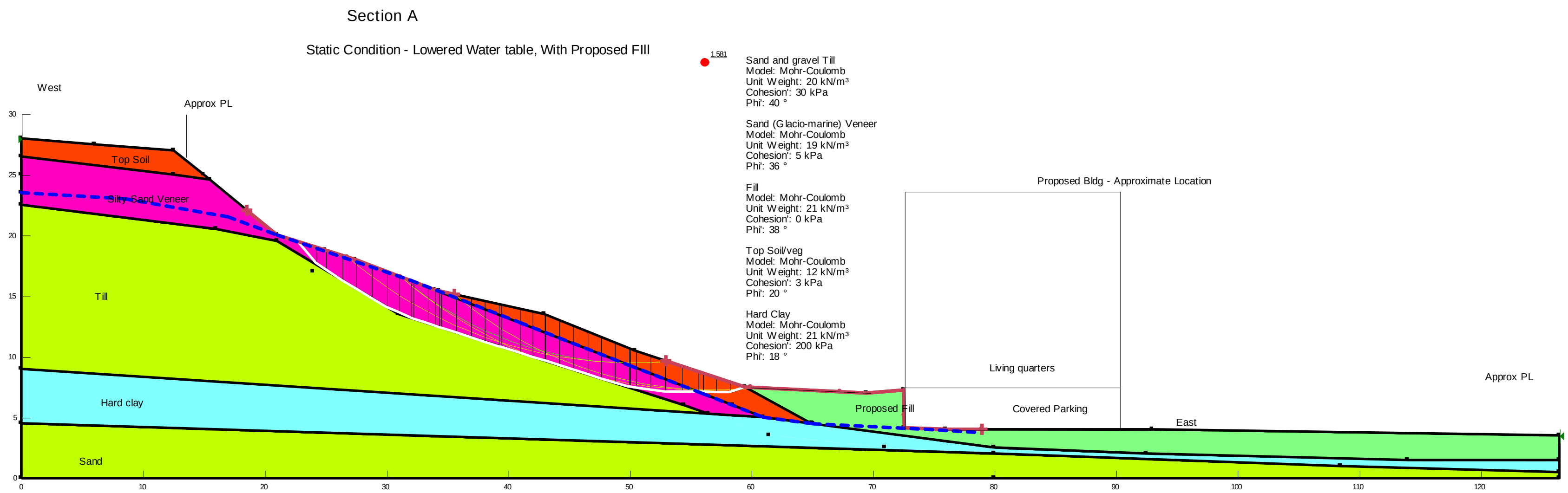


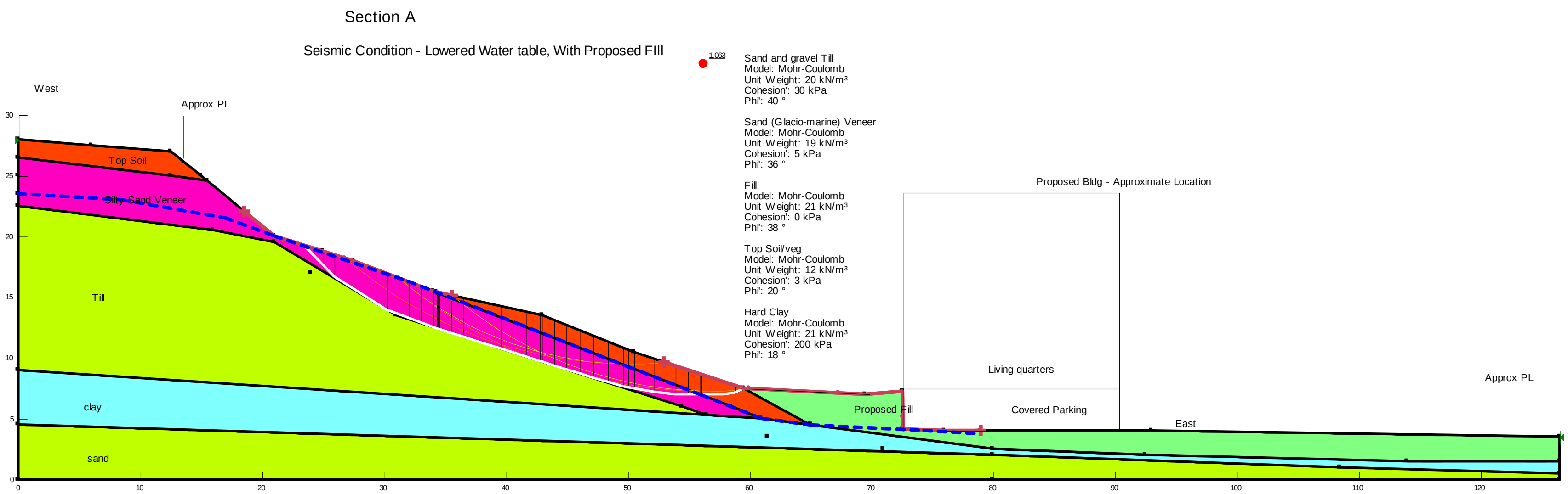
Figure 10: Section A Static Case, lowered water table with drain pipes and interceptor ditches



Notes:

1) Lowest Factor of Safety shown in figure.
2) Section corresponds to northwest landslide.

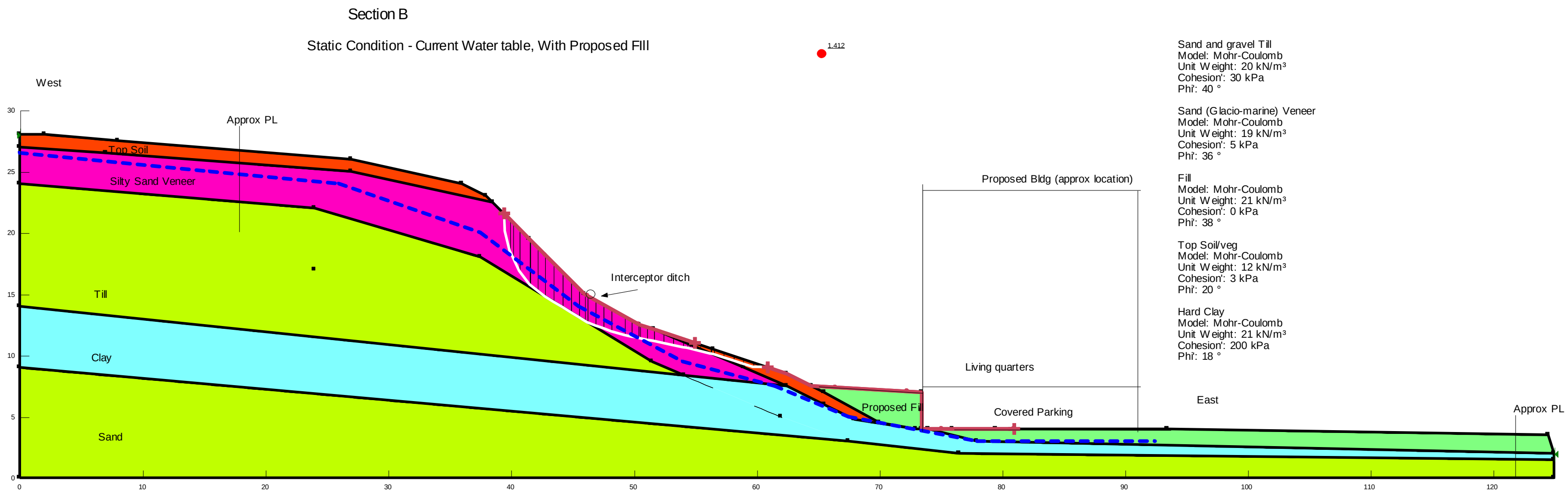
Figure 11: Section A Seismic Case, lowered water table with drain pipes and interceptor ditches



Notes:

1) Lowest Factor of Safety shown in figure.
2) Section corresponds to northwest landslide.

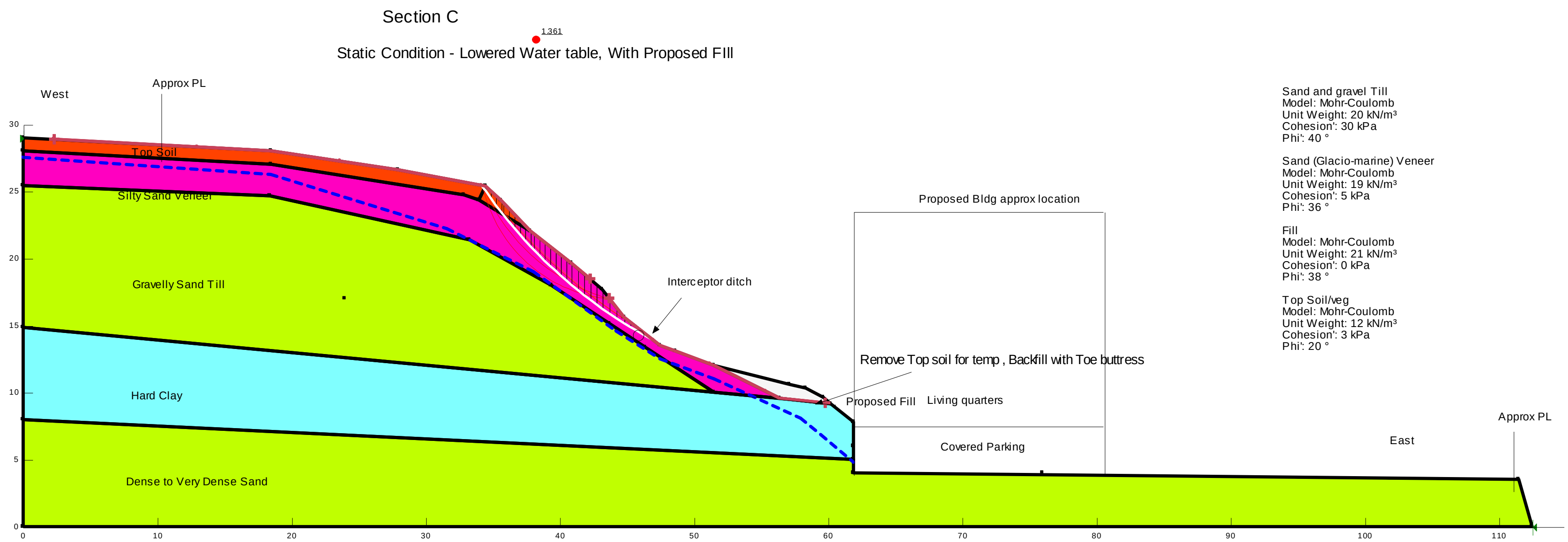
Figure 12: Section B Static Case, lowered water table with drain pipes and interceptor ditches



Notes:

1) Factor of Safety less than 1.5 shown or lowest FS.
2) Section corresponds to southwest landslide.

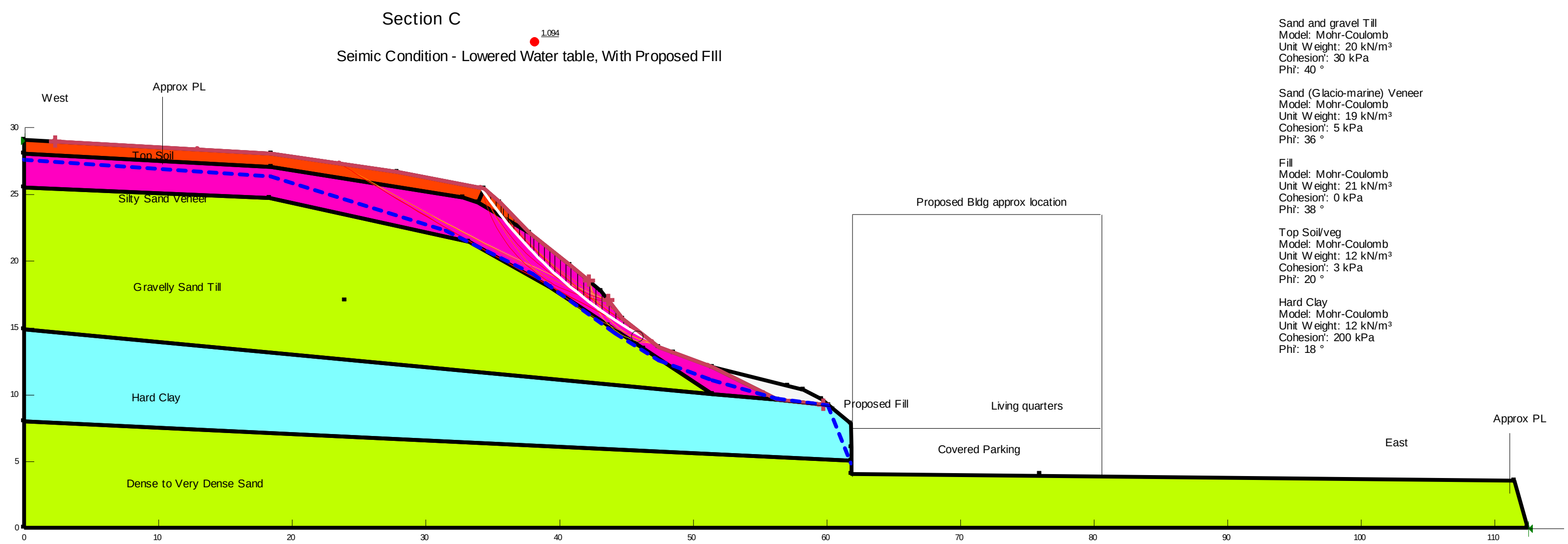
Figure 13: Section C Static Case, lowered water table with drain pipes and interceptor ditches



Notes:

1) Factor of Safety less than 1.5 shown or lowest FS.

Figure 14: Section C Seismic Case, lowered water table with drain pipes and interceptor ditches



Notes:

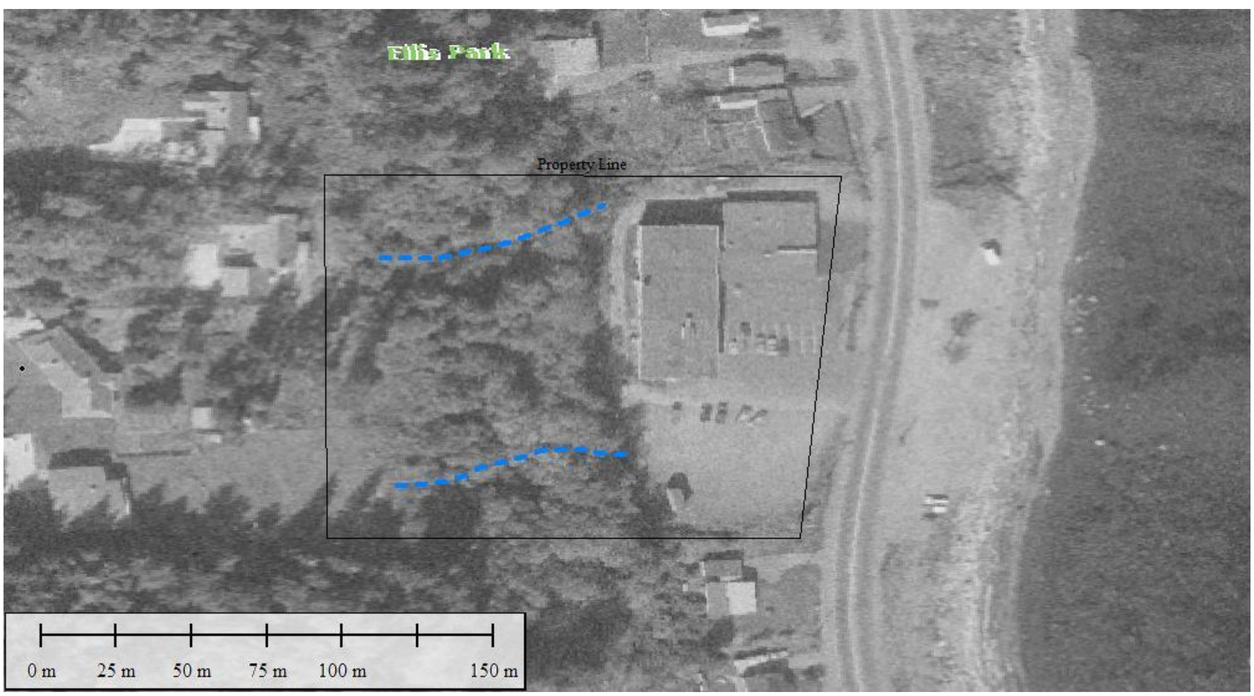
1) Factor of Safety less than 1.5 shown or lowest FS.

APPENDIX A

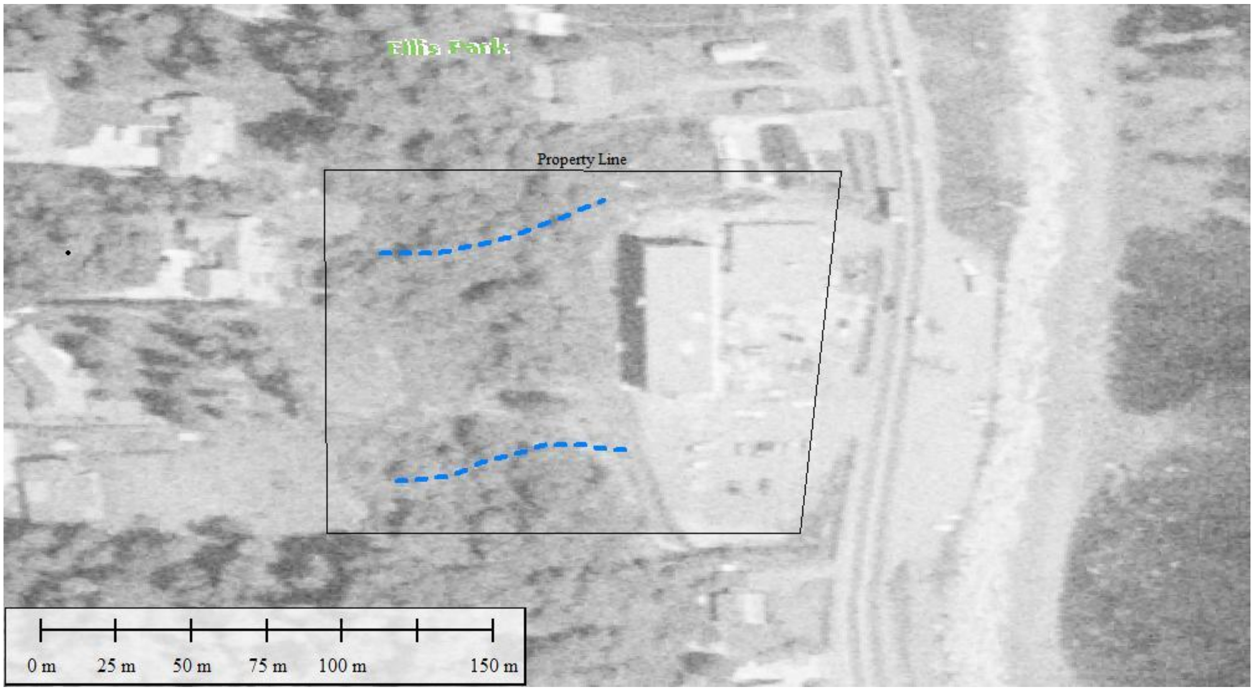
1964


Ellis Park
Property Line
0 m
25 m
50 m
75 m
100 m
150 m

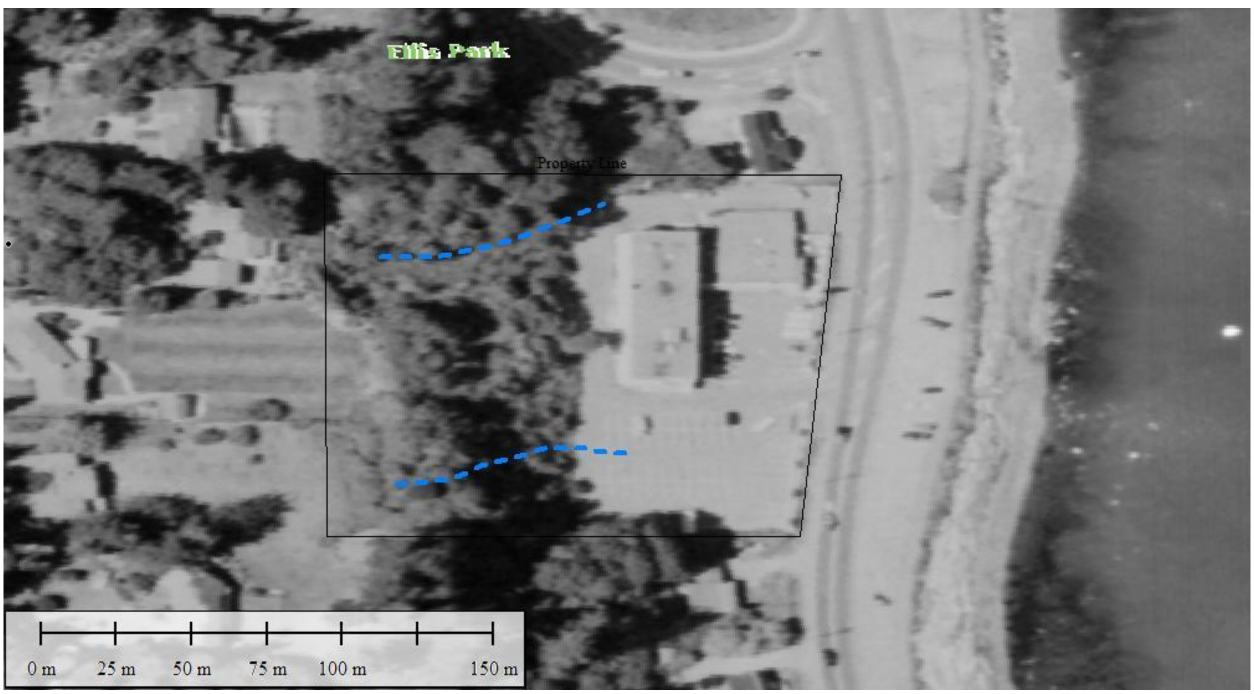
1976


Ellis Park
Property Line
0 m
25 m
50 m
75 m
100 m
150 m

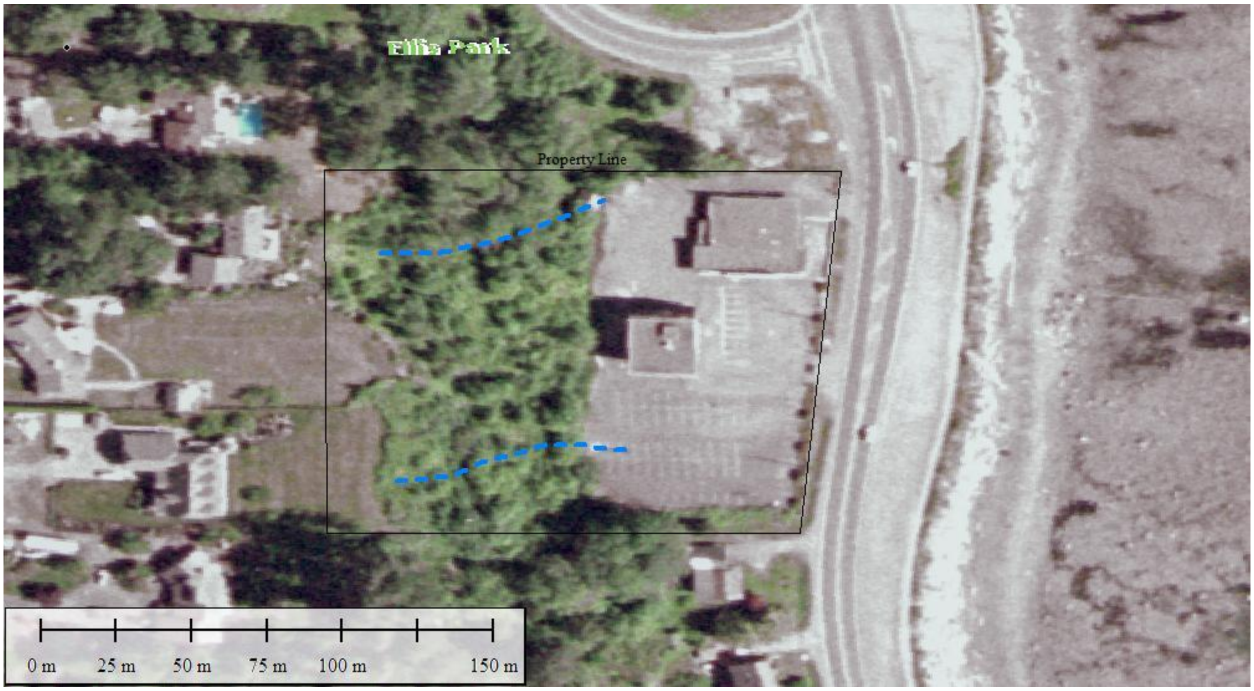
1980


Ellis Park
Property Line
0 m
25 m
50 m
75 m
100 m
150 m

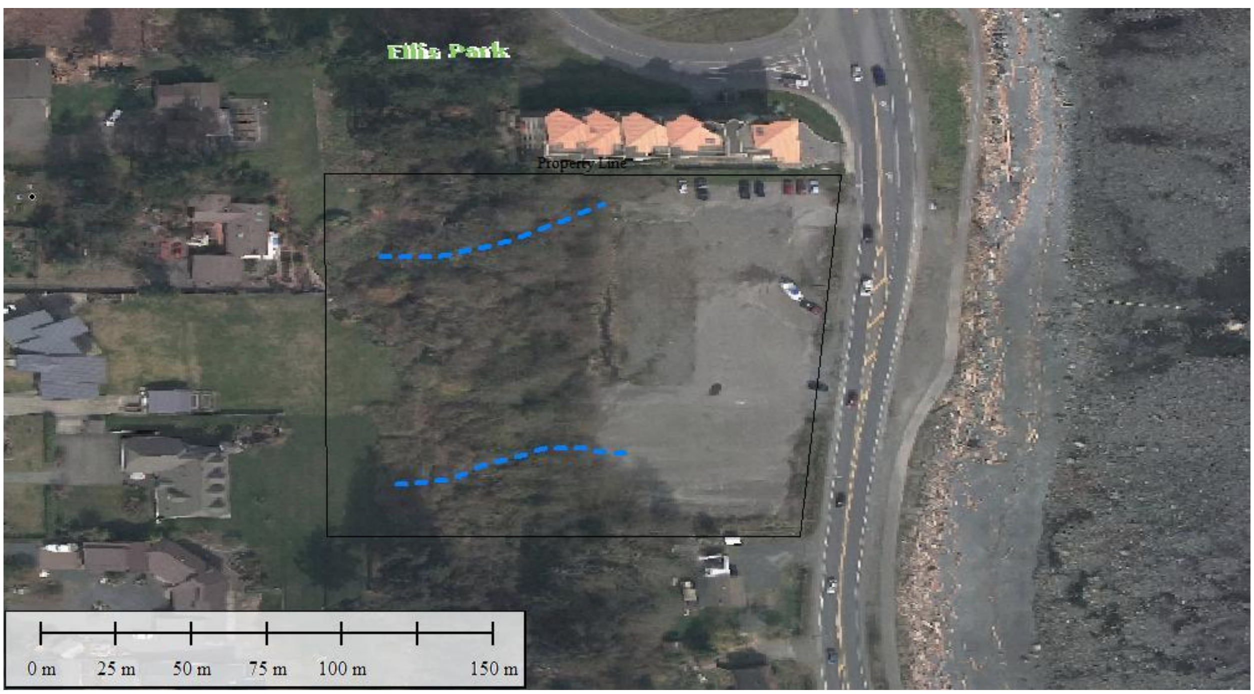
2002


Ellis Park
Property Line
0 m
25 m
50 m
75 m
100 m
150 m

2007



2016



Historical Air photos (City of Campbell River Webmap)

Photo 1: Exposed Till layer outcrop (2/3 up slope near section B)

Photo 2: Close up of exposed Till layer outcrop (2/3 up slope near section B)

Photo 3: Exposed Hard Clay layer at the toe of slope at Section C

Photo 4: Exposed Hard Clay layer at the toe of slope at Section C

APPENDIX B

SOIL LOG: BH06-1

PROJECT NAME: Grand Coastals Resort & SPA	GROUND SURFACE ELEVATION AND UTM: Existing Grade
PROJECT #: G4778 — CLIENT: Island Coastal Resorts Ltd.	DATE STARTED: 11/20/2006 — DATE FINISHED: 11/20/2006
DRILLING CONTRACTOR: Lewkowich — DRILLING METHOD: Auger Drill	END OF TEST HOLE (m): 7.6 — MEASURING POINT: Top of Grade
DRILLING EQUIPMENT: Truck Mounted Auger	DEPTH TO WATER (m): 0.8
SAMPLING METHOD:	LOGGED BY: DD — PROJECT ENGINEER: TC

Moisture Content (%) ●
Plasticity Limit (%) ◆
Liquidity Limit (%) ▲
20 40 60 80

Surface Elevation: Existing Grade

DEPTH (m)	DEPTH (ft)	Sample	Classification	DESCRIPTION	Notes
0.0	0.0		AS	Asphalt	
			HP FI	Sand & Gravel (SW): fine to medium grained, some crushed gravel to 25 mm diameter, trace silt, compact, brown, moist (FILL)	
			FI	Sand (SP): pitrun, gravelly, fine to medium grained, trace silt, compact, brown, moist, (FILL).	
			SP-GP	Sand & Gravel (SP-GP): medium to coarse grained, compact, brown to grey brown, moist to wet, (BEACH DEPOSIT)	Seepage; Cobbles below 2.4 m
			SM	Sand (SM): Silty, fine grained, compact, grey, moist.	
			SM	Sand (SM): Silty, fine grained, trace fine grained gravel, compact to dense, grey, moist (TILL)	Gravelly, some silt; Dense.
7.6					End of Bore Hole at 7.6 m.

Depth scale (m): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0
Depth scale (ft): 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0

Bore Hole Log Interpretation based on Lewkowich Geotechnical Engineering Ltd.'s Geotechnical Assessment - Preliminary submitted to Island Coastal Resorts LTd. on Feb 6, 2007

SOIL LOG: BH06-2

PROJECT NAME: Grand Coastals Resort & SPA	GROUND SURFACE ELEVATION AND UTM: Existing Grade
PROJECT #: G4778 / CLIENT: Island Coastal Resorts Ltd.	DATE STARTED: 11/20/2006 / DATE FINISHED: 11/20/2006
DRILLING CONTRACTOR: Lewkowich / DRILLING METHOD: Auger Drill	END OF TEST HOLE (m): 7.6 / MEASURING POINT: Top of Grade
DRILLING EQUIPMENT: Truck Mounted Auger	DEPTH TO WATER (m): 0.8
SAMPLING METHOD:	LOGGED BY: DD / PROJECT ENGINEER: TC

Moisture Content (%) ● Plasticity Limit (%) ◆ Liquidity Limit (%) ▲ (scale 20, 40, 60, 80)

Surface Elevation: Existing Grade

DEPTH (m)	DEPTH (ft)	Sample	Classification	DESCRIPTION	Notes
0.0	0.0		AS / HP / Fill	Asphalt	
			Fill	Sand & Gravel (SW): fine to medium grained, some crushed gravel to 25 mm diameter, trace silt, compact, brown, moist (FILL)	
0.5	2.0			Sand (SP): pitrun, gravelly, fine to medium grained, trace silt, compact, brown, moist, (FILL).	
1.0		G1	SM	Sand & Gravel (SM): silty, fine grained, trace fine grained gravel, compact, grey, moist (Till Like).	
1.5	4.0				
	6.0	G2	CI	Clay (CI): silty, grey, moist	
2.0				Sand (SM): Silty, some silt lenses, fine grained, compact, grey, moist	
2.5	8.0	G3			
3.0	10.0				
3.5	12.0				
4.0	14.0	G4	SM		Below 3.7m, compact to dense, trace fine grained gravel
4.5	16.0				
5.0					
5.5	18.0				Gravelly, some silt
6.0	20.0				
6.5	22.0			Sand (SM): silty, fine grained, trace fine grained gravel, compact to dense, grey, moist, (Till Like)	
7.0			SM	**Bore Hole Log Interpretation based on Lewkowich Geotechnical Engineering Ltd.'s Geotechnical Assessment - Preliminary submitted to Island Coastal Resorts LTd. on Feb 6, 2007**	
7.5	24.0				
8.0	26.0				End of Bore Hole at 7.6 m.

SOIL LOG: BH06-3

PROJECT NAME: Grand Coastals Resort & SPA	GROUND SURFACE ELEVATION AND UTM: Existing Grade
PROJECT #: G4778 CLIENT: Island Coastal Resorts Ltd.	DATE STARTED: 11/20/2006 DATE FINISHED: 11/20/2006
DRILLING CONTRACTOR: Lewkowich DRILLING METHOD: Auger Drill	END OF TEST HOLE (m): 7.6 MEASURING POINT: Top of Grade
DRILLING EQUIPMENT: Truck Mounted Auger	DEPTH TO WATER (m): 0.8
SAMPLING METHOD:	LOGGED BY: DD PROJECT ENGINEER: TC

Surface Elevation: Existing Grade

Moisture Content (%) ●   Plasticity Limit (%) ◆   Liquidity Limit (%) ▲   (scale: 20, 40, 60, 80)

DEPTH (m)	DEPTH (ft)	Sample	Classification	DESCRIPTION	Notes
0.0	0.0		AS HP	Asphalt	
			Fill	Sand & Gravel (SW): fine to medium grained, some crushed gravel to 25 mm diameter, trace silt, compact, brown, moist (FILL)	
			Fill	Sand (SP): pitrun, gravelly, fine to medium grained, trace silt, compact, brown, moist, (FILL).	
			SM	Sand (SM): silty, fine grained, trace fine grained gravel, compact, grey, moist.	
2.4		G1 (at 3.4 m)	CL	Clay (Cl): silty, stiff, grey, moist	From 3.8 m to 4.1 m, sandier, soft
4.6			SM	Sand (SM): Silty, some silt lenses, fine grained, compact, grey, moist	Below 4.7m, compact to dense, trace fine grained gravel; From 5.2 m to 5.8 m, gravelly
5.6			SM	Sand (SM): silty, fine grained, trace fine grained gravel, dense to very dense, grey, moist, (Till Like)	
7.6					End of Bore Hole at 7.6 m.

Depth scale (m): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0
Depth scale (ft): 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0

Bore Hole Log Interpretation based on Lewkowich Geotechnical Engineering Ltd.'s Geotechnical Assessment - Preliminary submitted to Island Coastal Resorts LTd. on Feb 6, 2007

SOIL LOG: BH06-4

PROJECT NAME: Grand Coastals Resort & SPA	GROUND SURFACE ELEVATION AND UTM: Existing Grade
PROJECT #: G4778 CLIENT: Island Coastal Resorts Ltd.	DATE STARTED: 11/20/2006 DATE FINISHED: 11/20/2006
DRILLING CONTRACTOR: Lewkowich DRILLING METHOD: Auger Drill	END OF TEST HOLE (m): 7.6 MEASURING POINT: Top of Grade
DRILLING EQUIPMENT: Truck Mounted Auger	DEPTH TO WATER (m): 0.8
SAMPLING METHOD:	LOGGED BY: DD PROJECT ENGINEER: TC

Surface Elevation: Existing Grade

Moisture Content (%) ● Plasticity Limit (%) ◆ Liquidity Limit (%) ▲ (20, 40, 60, 80)

DEPTH (m)	DEPTH (ft)	Sample	Classification	DESCRIPTION	Notes
0.0	0.0		AS	Asphalt	
			HP Fill	Sand & Gravel (SW): fine to medium grained, some crushed gravel to 25 mm diameter, trace silt, compact, brown, moist (FILL)	
			Fill	Sand (SP): pitrun, gravelly, fine to medium grained, trace silt, compact, brown, moist, (FILL).	
			ML	Silt (ML): some clay, stiff, grey, moist	
1.0			SM	Sand (SM): Silty, fine grained, trace fine grained gravel, compact, grey, moist	
3.5			CL	Clay (Cl): silty, stiff, grey, moist	
4.5			SM	Sand (SM): Silty, some silt lenses, fine grained, compact, grey, moist	
6.5			SM	Sand (SM): Silty, fine grained, trace fine grained gravel, dense to very dense, grey, moist (Till-like)	
7.6					End of Bore Hole at 7.6 m.

Depth scale (m): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0

Depth scale (ft): 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0

Bore Hole Log Interpretation based on Lewkowich Geotechnical Engineering Ltd.'s Geotechnical Assessment - Preliminary submitted to Island Coastal Resorts LTd. on Feb 6, 2007

SOIL LOG: BH06-5

PROJECT NAME: Grand Coastals Resort & SPA	GROUND SURFACE ELEVATION AND UTM: Existing Grade
PROJECT #: G4778 — CLIENT: Island Coastal Resorts Ltd.	DATE STARTED: 11/20/2006 — DATE FINISHED: 11/20/2006
DRILLING CONTRACTOR: Lewkowich — DRILLING METHOD: Auger Drill	END OF TEST HOLE (m): 7.6 — MEASURING POINT: Top of Grade
DRILLING EQUIPMENT: Truck Mounted Auger	DEPTH TO WATER (m): 0.9
SAMPLING METHOD:	LOGGED BY: DD — PROJECT ENGINEER: TC

Surface Elevation: Existing Grade

Moisture Content (%) ●; Plasticity Limit (%) ◆; Liquidity Limit (%) ▲ — scale 20, 40, 60, 80

DEPTH (m)	DEPTH (ft)	Sample	Classification	DESCRIPTION	Notes
0.0	0.0		AS	Asphalt	
			HP Fill	Sand & Gravel (SW): fine to medium grained, some crushed gravel to 25 mm diameter, trace silt, compact, brown, moist (FILL)	
			Fill	Sand (SP): pitrun, gravelly, fine to medium grained, trace silt, compact, brown, moist, (FILL).	
			SP	Sand & Gravel (SP-GP): medium to coarse grained, compact, brown to grey brown, moist to wet, (BEACH DEPOSIT)	
			SM	Sand (SM): Silty, trace silt lenses, fine grained, compact, grey, moist.	
			SM	Sand (SM): Silty, fine grained, trace fine grained gravel, dense to very dense, grey, moist (TILL Like)	
8.0	26.0				End of Bore Hole at 7.6 m.

Depth scale (m): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0
Depth scale (ft): 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0

Bore Hole Log Interpretation based on Lewkowich Geotechnical Engineering Ltd.'s Geotechnical Assessment - Preliminary submitted to Island Coastal Resorts LTd. on Feb 6, 2007

SOIL LOG: BH17-01

PROJECT NAME: Proposed Apartment		GROUND SURFACE ELEVATION AND UTM: Existing Grade	
PROJECT #: 5077	CLIENT: Campbell Shore Holdings Ltd.	DATE STARTED: 2/9/2017	DATE FINISHED: 2/9/2017
DRILLING CONTRACTOR: Terran Geo	DRILLING METHOD: Hand Auger	END OF TEST HOLE (m): 1.3	MEASURING POINT: Top of Grade
DRILLING EQUIPMENT: Hand Auger		DEPTH TO WATER (m): 0.3	
SAMPLING METHOD: Grab		LOGGED BY: DL	PROJECT ENGINEER: TL

DEPTH (m)	DEPTH (ft)	Sample	Classification	Lithology	DESCRIPTION Surface Elevation: Existing Grade	Moisture Content (%) ● Plasticity Limit (%) ◆ Liquidity Limit (%) ▲ 20 40 60 80	Notes
0.0–1.3	0.0	G1	TS		TOPSOIL, silty, black, rootlets and organic debris, saturated [Possible Landslide Debris]		Auger hole located down slope of previous landslide
1.3							End of Hole @ 1.3 m :Poor soil recovery due to water table.

DEPTH (m) scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0

DEPTH (ft) scale: 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0

SOIL LOG: BH17-02

PROJECT NAME: Proposed Apartment		GROUND SURFACE ELEVATION AND UTM: Existing Grade	
PROJECT #: 5077	CLIENT: Campbell Shore Holdings Ltd.	DATE STARTED: 2/9/2017	DATE FINISHED: 2/9/2017
DRILLING CONTRACTOR: Terran Geo	DRILLING METHOD: Hand Auger	END OF TEST HOLE (m): 1.2	MEASURING POINT: Top of Grade
DRILLING EQUIPMENT: Hand Auger		DEPTH TO WATER (m): N/A	
SAMPLING METHOD: Grab		LOGGED BY: DL	PROJECT ENGINEER: TL

Moisture Content (%) ●
Plasticity Limit (%) ◆
Liquidity Limit (%) ▲
(scale: 20, 40, 60, 80)

Surface Elevation: Existing Grade

DEPTH (m)	DEPTH (ft)	Sample	Classification	Lithology	DESCRIPTION	Notes
0.0	0.0		TS		TOPSOIL, silty, black, rootlet, moist	Auger hole located at bottom of scarp (Post landslide)
0.2–1.2		G2	SM		Silty SAND, trace gravels and cobbles, loose, poorly graded, light brown, trace organics and rootlets, saturated (Glacio-marine) [Landslide Interface]	
1.2						End of Hole @ 1.2 m

Depth scale (m): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0
Depth scale (ft): 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0

SOIL LOG: BH17-03

PROJECT NAME: Proposed Apartment		GROUND SURFACE ELEVATION AND UTM: Existing Grade	
PROJECT #: 5077	CLIENT: Campbell Shore Holdings Ltd.	DATE STARTED: 2/9/2017	DATE FINISHED: 2/9/2017
DRILLING CONTRACTOR: Terran Geo	DRILLING METHOD: Hand Auger	END OF TEST HOLE (m): 1.3	MEASURING POINT: Top of Grade
DRILLING EQUIPMENT: Hand Auger		DEPTH TO WATER (m): 0.2	
SAMPLING METHOD: Grab		LOGGED BY: DL	PROJECT ENGINEER: TL

Surface Elevation: Existing Grade

Legend: Moisture Content (%) ●; Plasticity Limit (%) ◆; Liquidity Limit (%) ▲; scale 20, 40, 60, 80

DEPTH (m)	DEPTH (ft)	Sample	Classification	Lithology	DESCRIPTION	Notes
0.0	0.0				TOPSOIL, silty, black, rootlet, moist	Auger hole located at bottom of scarp (Post landslide)
		G3			Silty SAND, trace gravels and cobbles, loose, poorly graded, light brown, trace organics and rootlets, saturated (Glacio-marine) [Landslide Interface]	
0.5	2.0					
1.0	4.0					End of Hole @ 1.3 m
1.5						
2.0	6.0					
2.5	8.0					
3.0	10.0					
3.5	12.0					
4.0	14.0					
4.5	16.0					
5.0						
5.5	18.0					
6.0						

SOIL LOG: Clay Outcrop

PROJECT NAME: Proposed Apartment	GROUND SURFACE ELEVATION AND UTM: Existing Grade
PROJECT #: 5077 CLIENT: Campbell Shore Holdings Ltd.	DATE STARTED: 4/11/2017 DATE FINISHED: 4/11/2017
DRILLING CONTRACTOR: Terran Geo DRILLING METHOD: Mapping	END OF TEST HOLE (m): 4.5 MEASURING POINT: Top of Grade
DRILLING EQUIPMENT: None	DEPTH TO WATER (m): N/A
SAMPLING METHOD:	LOGGED BY: DL PROJECT ENGINEER: TL

DEPTH (m)	DEPTH (ft)	Sample	Classification	Lithology	DESCRIPTION (Surface Elevation: Existing Grade)	Moisture Content (%) ● Plasticity Limit (%) ◆ Liquidity Limit (%) ▲ (20 40 60 80)	Notes
0.0 – 4.5	0.0 – 14.8		CL		Clay (Cl): dark grey, very stiff to hard, massive, blocky, laminated, low plasticity, dry to moist		Impermeable layer, groundwater flows overtop, laminated at 155/6; Pocket Pen reading >420 kPa
4.5							See Photo 3 and 4

Depth scale (m): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0

Depth scale (ft): 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0

SOIL LOG: Till Outcrop

PROJECT NAME: Proposed Apartment		GROUND SURFACE ELEVATION AND UTM: Existing Grade	
PROJECT #: 5077	CLIENT: Campbell Shore Holdings Ltd.	DATE STARTED: 4/11/2017	DATE FINISHED: 4/11/2017
DRILLING CONTRACTOR: Terran Geo	DRILLING METHOD: Mapping	END OF TEST HOLE (m): 1.3	MEASURING POINT: Top of Grade
DRILLING EQUIPMENT: None		DEPTH TO WATER (m): N/A	
SAMPLING METHOD:		LOGGED BY: DL	PROJECT ENGINEER: TL

Moisture Content (%) ●
Plasticity Limit (%) ◆
Liquidity Limit (%) ▲

Surface Elevation: Existing Grade

DEPTH (m)	DEPTH (ft)	Sample	Classification	Lithology	DESCRIPTION	20 40 60 80	Notes
0.0 – 0.5	0.0		TS	■	Top Soil, silty, tree roots, organics, wet		
0.5 – 1.3	2.0, 4.0		SP	▨	SANDS, trace gravel and trave cobbles, dense to very dense, coarse, subangular, light brown to grey, dry (TILL)		See Photo 1 and 2

Depth scale (m): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0

Depth scale (ft): 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0

WILDCAT DYNAMIC CONE LOG

Terran Geotechnical Consultants Ltd.
109-3011 Underhill Avenue
Burnaby, BC

PROJECT NUMBER: 5077
DATE STARTED: 02-09-2017
DATE COMPLETED: 02-09-2017

HOLE #: DCPT17-01
CREW: Dylan Lee
PROJECT: Proposed Apartment
ADDRESS: 1430 South Island Hwy
LOCATION: Campbell River, BC

SURFACE ELEVATION: At grade
WATER ON COMPLETION: 0.3
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	TESTED CONSISTENCY COHESIVE
-	0	0.0		0	VERY LOOSE	VERY SOFT
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
- 1 ft	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
- 2 ft	10	44.4	••••••••••••	12	MEDIUM DENSE	STIFF
-	5	22.2	••••••	6	LOOSE	MEDIUM STIFF
-	3	13.3	•••	3	VERY LOOSE	SOFT
- 3 ft	3	13.3	•••	3	VERY LOOSE	SOFT
- 1 m	2	8.9	••	2	VERY LOOSE	SOFT
-	2	7.7	••	2	VERY LOOSE	SOFT
- 4 ft	3	11.6	•••	3	VERY LOOSE	SOFT
-	2	7.7	••	2	VERY LOOSE	SOFT
-	2	7.7	••	2	VERY LOOSE	SOFT
- 5 ft	7	27.0	•••••••	7	LOOSE	MEDIUM STIFF
-	30	115.8	•••••••••••••••••••••••••••••••••	25+	DENSE	HARD
-						
- 6 ft						
-						
- 2 m						
- 7 ft						
-						
-						
- 8 ft						
-						
-						
- 9 ft						
-						
-						
- 3 m 10 ft						
-						
-						
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

WILDCAT DYNAMIC CONE LOG

Terran Geotechnical Consultants Ltd.
109-3011 Underhill Avenue
Burnaby, BC

PROJECT NUMBER: 5077
DATE STARTED: 02-09-2017
DATE COMPLETED: 02-09-2017

HOLE #: DCPT17-03
CREW: Dylan Lee
PROJECT: Proposed Apartment
ADDRESS: 1430 South Island Hwy
LOCATION: Campbell River, BC

SURFACE ELEVATION: At grade
WATER ON COMPLETION: 0.2
HAMMER WEIGHT: 35 lbs.
CONE AREA: 10 sq. cm

DEPTH	BLOWS PER 10 cm	RESISTANCE Kg/cm²	GRAPH OF CONE RESISTANCE 0 50 100 150	N'	TESTED CONSISTENCY NON-COHESIVE	COHESIVE
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
- 1 ft	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
- 2 ft	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	2	8.9	••	2	VERY LOOSE	SOFT
- 3 ft	1	4.4	•	1	VERY LOOSE	VERY SOFT
- 1 m	1	4.4	•	1	VERY LOOSE	VERY SOFT
-	3	11.6	•••	3	VERY LOOSE	SOFT
- 4 ft	9	34.7	••••••••••	9	LOOSE	STIFF
-	11	42.5	••••••••••••	12	MEDIUM DENSE	STIFF
-	10	38.6	•••••••••••	11	MEDIUM DENSE	STIFF
- 5 ft	10	38.6	•••••••••••	11	MEDIUM DENSE	STIFF
-	7	27.0	•••••••	7	LOOSE	MEDIUM STIFF
-	10	38.6	•••••••••••	11	MEDIUM DENSE	STIFF
- 6 ft						
-						
- 2 m						
- 7 ft						
-						
-						
- 8 ft						
-						
-						
- 9 ft						
-						
-						
- 3 m 10 ft						
-						
-						
-						
- 11 ft						
-						
-						
- 12 ft						
-						
-						
- 4 m 13 ft						

APPENDIX C

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

February 17, 2017

Site: 49.987 N, 125.227 W   User File Reference:

Requested by: ,

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	**Sa(0.2)**	Sa(0.3)	**Sa(0.5)**	**Sa(1.0)**	**Sa(2.0)**	**Sa(5.0)**	**Sa(10.0)**	**PGA (g)**	**PGV (m/s)**
0.313	0.489	**0.603**	0.620	**0.585**	**0.411**	**0.266**	**0.095**	**0.034**	**0.285**	**0.490**

Notes. Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. ***These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.051	0.139	0.204
Sa(0.1)	0.078	0.217	0.322
Sa(0.2)	0.107	0.277	0.404
Sa(0.3)	0.111	0.282	0.415
Sa(0.5)	0.096	0.252	0.382
Sa(1.0)	0.059	0.164	0.259
Sa(2.0)	0.032	0.098	0.163
Sa(5.0)	0.0094	0.032	0.056
Sa(10.0)	0.0038	0.011	0.020
PGA	0.045	0.126	0.188
PGV	0.064	0.198	0.314

References

National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français