A Qualified Professional (i.e. Structural Engineer) will have to be engaged to provide a suitable structural design of the new foundations with recommendations regarding foundation design to be provided by a Geotechnical Engineer. Similar to the previous recommendation for underpinning, a supplementary subsurface investigation, utilizing hand-operated equipment (i.e. WildCat Penetrometer Test Soundings) is recommended to delineate and confirm the depth to suitable bearing at the proposed new landing pad locations in order to inform the detailed design of the foundations.

It is envisaged that the advantages and disadvantages associated with this option comprise the following:

<u>Advantages</u>

- Mitigate potential for settlement-induced damages to staircase as foundations would be bearing on competent subgrade,
- Mitigate potential for undermining of staircase foundations due to ravelling/sliding of loose, surficial slope materials, as slip surfaces are unlikely to encompass very dense/hard subgrade, and
- Reduced maintenance requirements.

<u>Disadvantages</u>

- Would require demolition of the existing staircase foundations and excavation into the slope,
- Would require extensive earthworks and significant disturbance to the slope,
- Site access with typical earthworks equipment (i.e. excavators), expected to be difficult due to existing site conditions and constraints,
- Envisaged to be the most expensive reparation option for construction based on the expected equipment, materials and labour requirements,
- Possible loss of slope vegetation, including trees, during construction,
- Permitting with multiple jurisdictions envisaged to be required, and
- s.18

The construction of the new staircase foundations is expected to be feasible from a constructability perspective. However, the aforementioned challenges associated with the mobilization of earthworks equipment to the work area are also envisaged to be relevant to this remediation option. Furthermore, excavator access to the existing staircase foundation locations may be challenging and could result in significant disturbance to the North Slope and its vegetative cover. If excavator access to the foundation locations is not found to be feasible, then the demolition of the existing foundations and construction of the new foundations could be completed by hand.

9.4 Demolition of Staircase

Alternatively, the entire staircase or its upper and lower portions could be demolished in order to inhibit access from this location. Signage, as previously described, could be installed within the vicinity of the hazard assessment area to educate the public regarding the potential hazards associated with the slopes situated within this area. It is expected that the demolition of the existing beach access staircase would be practical from a constructability perspective, however, the aforementioned challenges associated with excavator access to the staircase location would also be relevant to this option. If excavator access to the staircase is not found to be practical, then it is envisaged that the demolition of the staircase could be completed with hand-operated equipment

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(i.e. jackhammers), however, this method of staircase demolition would require a comparatively longer duration to complete.

10.0 "CLASS D" COST ESTIMATES AND SCHEDULES

"Class D" cost estimates for the design and construction of the previously described slope remediation options are provided in Tables 5 to 7 below. The estimated durations of the design and construction phases for each remediation option are also summarized in these tables. It should be noted that the costs associated with permitting, engineering field reviews, environmental assessments s.18 [redacted] are excluded from the costs shown below. Furthermore, permit processing times are not accounted for in the construction schedule estimates. Tables A to E, attached in Appendix C, provide summaries of the cost breakdowns for the construction of select slope and staircase remediation options. It should be noted that equipment mobilization and site preparation costs have been included for the estimate of each option. However, it is envisaged that these costs would be halved if one remediation option is constructed concurrently with another, such that the mobilization of only one workforce/contractor is required.

s.17(1) [redacted]

The costs summarized for the design work also include the services of other disciplines (i.e. hydraulic and structural) which may be required. An additional cost contingency of 20% is recommended to be applied to the estimates to account for the uncertainties pertaining to the costs and construction timeline that are inherent. Furthermore, it should be appreciated that economic inflation could potentially further increase the costs associated with each option at the time of tender.

Table 5: Design and Construction Cost Estimates for North Slope Remediation

Slope Remediation Option	Estimated Construction Cost ($)	Construction Duration (days)	Estimated Des ign Costs ($)	Design Duration (weeks)
Partial Re-grading and Rip Rap Installation	s.17(1) [redacted]	14 to 20	s.17(1) [redacted]	3 to 4

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Partial Re-grading and MSE Buttress	s.17(1) [redacted]	17 to 23	s.17(1) [redacted]	5 to 6
Soil Nail and Mesh[3]		26		4 to 6

[1]refer to Table A of Appendix B for cost breakdown

[2]refer to Table B of Appendix B for cost breakdown, estimated based on 5 metre high Lock-Block MSE Wall

[3]cost and construction duration provided by VSS

The estimated costs summarized above include for a contingency of 20%

Table 6: Design and Construction Cost Estimates for South Slope Remediation

Slope Remediation Option	Estimated Construction Cost ($)	Construction Duration (days)	Estimated Design Costs ($)	Design Duration (weeks)
Rip Rap Installation	s.17(1) [redacted]	5 to 7	s.17(1) [redacted]	3 to 4
Soil Nail and Mesh[2]		38		5 to 6

[1]refer to Table C of Appendix B for cost breakdown

[2]cost and construction duration provided by VSS

The estimated costs summarized above include for a contingency of 20%

Table 7: Design and Construction Cost Estimates for Staircase Remediation

Staircase Remediation Option	Estimated Construction Cost ($)	Construction Duration (days)	Estimated Design Costs ($)	Design Duration (weeks)
Flex MSE Geomodular Bags (for confinement of subgrade)	s.17(1) [redacted]	2 to 3	s.17(1) [redacted]	2
Underpinning with Threadbar Anchors		5 to 7		2 to 3
New Foundations		5 to 7		2 to 3
Full Demolition of Staircase		2	N/A	N/A

[1]refer to Table D of Appendix B for cost breakdown

[2]refer to Table E of Appendix B for cost breakdown

[3]cost and construction duration provided by VSS, refere to Table F of Appendix B

[4]includes geotechnical and structural services

[5]cost provided for demolition of staircase assume that an excavator would be utilized to demolish the staircase costs for partial demolition of staircase would be less than those shown above and would depend on extent of demolition to be pursued

The estimated costs summarized above include for a contingency of 20%

It is typically considered ideal to undertake earthworks construction projects during the drier summer months of May to September. However, environmental and ecological considerations could also potentially restrict construction to specific periods of the year for the slope remediation options that entail removal of vegetation along the slopes. These considerations could include bird-nesting season, if any of the trees situated within the assessment area are found to house active nests. Thus, a suitable or preferential period of the year to construct the slope remediation options

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described above would also be governed by the findings and recommendations from the biological and environmental assessments that should be completed for the site.

11.0 RECOMMENDED REMEDIATION OPTIONS

In consideration of the estimated costs associated with each slope remediation option, presented above, and the potential slope failure mechanisms that were identified for each slope, it is recommended that rip-rap be installed to armor the lower portions of both the North and South Slopes as described in Sections 8.1.2. and 8.2.2 of this report. Re-grading of the North slope could be completed to improve the stability of this slope as it is envisaged that this slope is currently susceptible to localized, surficial failures based on our observations and slope stability analyses results. Scaling of loose, surficial slope materials could be completed for the South Slope in order to manage the risk of these materials ravelling and potentially impacting the public accessing the beach front. As previously discussed, the expansion of the two existing cavities located at the toe of the south slope could be expected to induce further instabilities of this slope. Thus, it is recommended that these cavities be backfilled with concrete in order to restore these portions of the slope and to reduce the potential for the expansion of the cavities.

As it is inferred that the flow and infiltration of surface water towards the North Slope triggered the 2021 failure of this slope, it is recommended that the interceptor trench and seepage collars, as described in Section 8.1.2, be installed within the landscaping area located at the top of the North Slope in order to direct near surface water away from the slope. The installation of rip-rap armoring at the lower portions of both the North and South Slopes would reduce the potential for tidal-induced erosion of these slopes which was identified as a potential failure mechanism for these slopes.

It is expected that the installation of rip-rap armoring and implementation of the slope stability management measures discussed above would be relatively simple from a design and constructability perspective in comparison to the other slope remediation options proposed herein. Furthermore, as previously discussed in Section 7.0 of this report, the current range of F.S. values for the North and South Slopes were estimated to be similar to those prescribed for the global stability of embankments, geotechnical systems, and natural slopes in the BC MOTI document titled "Bridge Standards and Procedures Manual – Volume 1 Supplement to CHBDC S6:19. Accordingly, it is envisaged that the construction of a buttress or soil nail and mesh systems to improve the global stability of the slopes may not be required if the F.S. criteria prescribed in the aforementioned document is to be adopted as a guideline for evaluating the adequacy of the current F.S. of the subject slopes. However, it is recommended that the risks associated with slope erosion, infiltration of surface water, localized instabilities and surficial raveling of loose materials be addressed as part of the remedial works and this could be achieved by implementing the previously described slope stability management measures.

It is inferred that the distortion of the beach access staircase is partially attributed to differential settlement of its foundations which are inferred to be bearing on loose/soft subgrade materials that overly the North Slope. Furthermore, as the North Slope is expected to be susceptible to surficial instabilities, which include the raveling of loose materials, the staircase foundations could potentially be undermined if the subgrade materials supporting these foundations were to be subjected to these instabilities. In consideration of these conditions, it is envisaged that the installation of the underpinning system, utilizing threadbar anchors as described in Section 9.2, would eliminate the aforementioned risks as the anchors would be sufficiently embedded into competent, dense to very

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dense strata. Thus, the installation of this underpinning system would suitably mitigate both settlement of the foundations and also risks of the foundations being undermined by surficial slope movement as these failures are not expected to be triggered within the dense to very dense strata underlying the slope. Battered anchors could also be installed to provide resistance to lateral movements of the staircase, if found to be structurally required.

Alternatively, if the installation of an underpinning system is not preferred by the COV, the option presented in Section 9.1, above, could be implemented. As previously indicated, this option would entail maintaining the current conditions of the staircase and undertaking survey monitoring to measure any displacements of the staircase. The staircase foundations could also be re-levelled via slab-jacking and FLEX MSE earth retention systems could be constructed to provide confinement of the pad foundation subgrades. It should be noted that this staircase remediation option is not as robust as the installation of underpinning anchors as it is possible that the foundations could potentially still be subjected to post-jacking settlements due to the presence of loose/soft subgrade and decomposable conditions below the foundations. Thus, periodic slab-jacking to re-level the foundations may be required if the long-term performance of the staircase is to be addressed.

12.0 Risk Assessment

12.1 Methodology

As the assessment area is understood to be used by the public for mainly recreational purposes, it is envisaged that the safety of the public is the main risk consideration of this project. Thus, for the purposes of this assessment, the risks associated with allowing public access to the beach front and staircase for the slope and staircase remediation options, discussed above, could be qualitatively assessed based on the following algorithm:

$$Risk = P_{Hazard} \times P_{S:H} \times P_{T:S} \times V \times E$$

Where:

P_{hazard}= probability of hazard occurrence,
$P_{S:H}$=spatial probability of impact to public
$P_{T:S}$=temporal probability of impact to public
V=occupant vulnerability (level of consequence)
E=number of occupants (or elements) at risk (taken to be 1 for this assessment)

The spatial probability of impact generally refers to the probability that a member of the public would be located within the area of impact whereas the temporal probability of impact refers to the probability that a member of the public would be situated within the area of impact at the time of the slope failure/movement.

For the purposes of this assessment and with respect to life safety, the level of consequence (i.e. V in the above equation) could be assigned based on the potential severity of the hazard to safety as follows:

- Hazard that is unlikely to result in injury of those impacted – Low Consequence Level,

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- Hazard that could potentially result in injury of those impacted – Moderate Consequence Level,
- Hazard that could potentially result in Fatality of those impacted – High Consequence Level,

In general, a qualitative assessment of the risk could entail classifying the risk level of a hazard as low, medium or high based on a series of matrices shown below.

The probability of impact ($P_{S:H}$ x $P_{T:S}$) to the public for each potential slope hazard can be qualitatively assessed based on the matrix below that relates this probability to the spatial probability of impact ($P_{S:H}$) and temporal probability of impact ($P_{T:S}$)

Table 8: Probability of Impact Matrix

Probability of Impact ($P_{S:H}$ x $P_{T:S}$)		**Spatial Probability of Impact ($P_{S:H}$)**		
		Low	**Moderate**	**High**
Temporal Probability of Impact ($P_{T:H}$)	**Low**	Low	Low	Moderate
	Moderate	Low	Moderate	High
	High	Moderate	High	High

The hazard level matrix, which relates the probability of occurrence of a hazard, P_{hazard} to the probability of impact ($P_{S:H}$ x $P_{T:S}$) as determined based on the matrix, shown in Table 8 above, could be expressed as:

Table 9: Hazard Level Matrix for Slopes

Hazard Level (P_{Hazard} x $P_{S:H}$ x $P_{T:S}$)		**Likelihood of Hazard (P_{Hazard})**		
		Low	**Moderate**	**High**
Probability of Impact ($P_{S:H}$ x $P_{T:S}$)	**Low**	Low	Low	Moderate
	Moderate	Low	Moderate	High
	High	Moderate	High	High

The risk levels could in turn be assessed based on the hazard levels, as determined from Table 9 above and the consequence level, *V*, using the matrix shown in Table 10 below:

Table 10: Risk Level Matrix for Slopes

Risk Level (P_{Hazard} x $P_{S:H}$ x $P_{T:S}$ x V)		**Hazard Level (P_{Hazard} x $P_{S:H}$)**		
		Low	**Moderate**	**High**
Consequence Level, V	**Low**	Very Low	Low	Moderate
	Moderate	Low	Moderate	High
	High	Moderate	High	Very High

The hazards associated with the staircase could also be evaluated based on the matrices provided in Tables 9 and 10 above, however, the probability of impact would generally depend on the frequency at which the staircase is expected to be used, if made accessible to the public.

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12.2 Potential Hazards

The following hazards have been identified to be relevant to the slopes and staircase based on their existing conditions and our observations from our monitoring site visits:

Slopes Hazards:

- Ravelling of loose, surficial slope materials for both slopes,
- Shallow Landslide Failures of North Slope, and
- Rockfall/spalling at South Slope.

Staircase Hazards:

- Tripping hazard due to current structural distortion of staircase, and
- Undermining of staircase foundations due to potential slope movement/failure,

It should be noted that the following antecedent events or natural processes could potentially exacerbate the above-noted hazards related to the slopes as these events could potentially trigger the above hazards or increase the likelihood that they would occur:

- Tidal erosion of the lower portions of the slopes, which could induce retrogressive failures of the slopes or potentially undermine the slopes. This would increase the hazard and probability of occurrence of shallow landslide failures of the North Slope and rockfall/spalling of the South Slope. Tidal erosion could also result in the expansion of the existing cavities at the lower portion of the South Slope, which would increase the likelihood of slope destabilization,
- Free-thaw cycles, which could increase the hazard and likelihood of ravelling of loose, surficial slope materials,
- Removal of slope vegetation due to fires, which could increase landslide hazards
- Seismic events, which could potentially trigger the above-noted slope movements
- Intense or prolonged rainfall events, which could potentially trigger the above-noted slope movements

The antecedent events summarized above would also increase the likelihood of the staircase foundations being undermined as they could potentially trigger or increase the likelihood of slope failure.

An assessment of the environmental hazards and risks associated with potential slope failures/movement is beyond the scope of this report and should be assessed by others, if required.

12.3 Risks Summary

In order to inform the CoV in the risk management decision making process for this project, the hazards, consequences and risks associated with allowing public access to the assessment area for select slope and staircase remediation options, presented above, have been based on the qualitative risk assessment algorithm discussed above. The assessment results for the hazards that are pertinent to the slopes and staircase are summarized in Tables 11 and 12, respectively, which are attached to this report in Appendix E. Specifically, and as requested by the CoV during an online

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meeting on August 23, 2024, the risks, consequences and hazards related to allowing public access to the beach area and staircase, based on the options provided in Sections 8.1.1, 8.2.1 and 9.1 as well as Sections 8.1.2, 8.2.2 and 9.3, respectively, are summarized in these tables.

As discussed above, the remediation measures discussed in Sections 8.1.1 and 8.2.1 and 9.1 generally entail actively maintaining the slopes and staircase in their conditions and carrying out monitoring of the slopes and staircase, scaling of loose, surficial materials and filling the existing cavities located at the toe of the South Slope with concrete. Flex-MSE earth retention systems would also be constructed below the staircase foundations to provide lateral confinement of the staircase foundation subgrades as part of the option presented for Section 9.1. The slope remediation options discussed in Sections 8.2.1 and 8.2.2 generally include placement of rip-rap armouring at the lower portions of both slopes for protection against tidal erosion and re-grading of the North Slope to a more gentle inclination in order to reduce the potential for surficial failures of this slope. The remediation option presented in Section 9.3 entails the demolition of the existing beach access staircase and construction of a new staircase to be founded on competent subgrade materials. As requested by the CoV, the risks associated with allowing public access for the option of maintaining the assessment area in its current condition and not implementing any of the above monitoring and remediation options (i.e. a “do nothing” option) are also presented in the aforementioned risk summary tables. As discussed in these tables, the risk levels for each potential hazard could be further reduced if the signage, monitoring and the remedial measures, summarized above, are implemented.

12.3.1 Slopes

Based on the current conditions of the staircase and slopes, as observed during our slope monitoring site visits undertaken for the periods of December to May, 2023 and March, 2024 to present, we consider the current probability of slope movement, in the form of surficial failures, spalling and rockfall to range from “moderate” to “high”. The temporal probability of impact is expected to be “low” in consideration that the beach front is inferred to be typically accessed by the public for relatively limited durations and that this area is unlikely to be accessed by the public during periods of precipitation, when there is a higher potential for slope movement. Access to the beach front is also inherently restricted to periods of low to mid-tide, which further limits the periods in which the area would be potentially occupied by the public. The spatial probability of impact for hazards such as raveling of loose, surficial slope materials and rockfall and spalling is judged to be “low” in consideration of the size of the debris that would be detached from the slopes for these types of hazards. However, the spatial probability of impact for mass wasting events such as shallow landslides, which the North Slope is expected to be potentially susceptible would be considered to range from “moderate” to “high” based on the potential area of impact of the landslide mass. Thus, based on the matrix presented in Table 9 above, the probability of impact of the hazards described above is assessed to range from “low” for hazards related to raveling of slope materials and spalling/rockfall, to “moderate” for shallow landslide hazards.

As the North Slope has previously been subjected to a shallow landslide failure, the likelihood of occurrence of this hazard is judged to be “moderate” in its existing condition. A hazard level of “moderate” would be considered to be appropriate for this type of hazard based on the hazard level matrix presented in Table 9 above. It should be noted that a consequence level of “high” would be considered appropriate for landslide failures as this hazard could potentially result in fatalities of members of the public that may be present within the impacted area at the time of the landslide.

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Accordingly, based on the risk matrix presented in Table 10, above, it is judged that a risk level of "high" would be appropriate for the hazards associated with shallow landslides at the North Slope.

In consideration of the relatively steep geometries of the slopes and the presence of loose, surficial materials overlying both slopes, the probability of raveling of slope materials would be considered to be "moderate" to "high". Based on Table 9, the hazard level would be considered to be "moderate" for this type of hazard as the probability of impact is judged to be "low". The consequence level for this hazard is judged to be "low" to "moderate" as it is expected that individuals that are impacted by this hazard would, at worst, incur injuries, in consideration of the typical size of raveled slope debris. Thus, a risk level of "low" to "moderate" would be considered to be appropriate for this hazard.

The probability of occurrence of rockfall/spalling hazards at the South Slope, is judged to be "moderate" to "high" based on our previous slope monitoring observations and the existing conditions of this slope. Thus, the hazard level would be considered to be "moderate" for this type of hazard as the probability of impact is judged to be "low". Depending on the size of the detached debris, this hazard could potentially result in injury or fatality of those impacted, thus, a consequence level of "moderate" to "high" would be considered to be appropriate for this hazard. Accordingly, based on the risk matrix above, a level of "moderate" to "high" would be considered to be appropriate for this hazard.

If the existing beach access staircase were to be demolished or partially demolished, such that access to the beach front is precluded from this location, then it is envisaged that public access to the assessment area would be limited to the properties located adjacent to the shore of Burrard Inlet as well as from the coastal areas located to the east and west (e.g. Jericho Beach and Kitsilano Beach). This would in turn, lower the temporal probabilities of impact of the above-noted hazards. However, as discussed above, the temporal probability of impact associated with these hazards are currently assessed to be low based on the existing conditions of the assessment area. Accordingly, the risk levels of each hazard would be governed by the likelihood of each hazard occurring and the consequence levels. In consideration of these governing parameters, the risk levels summarized above would generally remain unchanged, based on the risk algorithm that was adopted for this assessment, if the staircase were to be demolished and the current conditions of the slope were to be maintained (i.e. the "do nothing" approach) as the likelihood of occurrence of the hazards and the related consequence levels would remain unchanged.

It is envisaged that the demolition of the staircase could potentially be assessed to result in lower risk levels of the above-noted hazards if the reduction in public access to the assessment area, that would result from the demolition, was to be accounted for in the assessment on a more quantitative and granular level than in the risk algorithm that was implemented for this assessment. However, a quantitative risk assessment would require foot traffic data for the staircase and beach front in order to assess the impact that demolishing the staircase would have on public access to the beach front. In consideration of the absence of this data, and the limitations of the qualitative method of risk assessment that was adopted for this report, the risk levels of the aforementioned hazards were determined to remain unchanged if the staircase was to be demolished.

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12.3.2 Staircase

In its current condition, it is envisaged that the staircase presents a tripping hazard to its users as it has been subjected to settlement-induced structural distortion. However, hazards related to structural destabilization of the staircase could potentially develop if further failures of the North Slope were to result in the staircase foundations being undermined or if the slope failures were to result in further loss of lateral confinement of the subgrade supporting these foundations. These hazards and the risks to the public would generally depend on the extents to which the foundations are undermined and whether the influence zones of the pad foundations are impacted by the slope failures. Thus, the risks associated with undermined staircase foundations cannot be assessed at this time, however, it should be noted that the likelihood that the staircase foundations would become undermined based on the existing site conditions is considered to be “moderate”, as the slope that these foundations are bearing on is assessed to have a “moderate” likelihood of movement.

At this time, the probability that a pedestrian would be subjected to the aforementioned tripping hazards when accessing the staircase is expected to be “moderate” in consideration of its current distorted structural condition. We expect that the frequency of usage of the staircase, if made accessible to the public, to be “moderate”, and thus, the likelihood of a tripping hazard would be “moderate”. Accordingly, a consequence level of “moderate” would be appropriate for this hazard as an injury could potentially be incurred by pedestrians that are subjected to this hazard. Thus, a risk level designation of “moderate” would be considered appropriate for the current tripping hazards associated with the staircase. It should be understood that the tripping hazard level and the risks associated with this hazard could potentially increase if further distortion of the staircase, which could be induced by settlement of its foundations, were to occur. As discussed in Section 8.2, it is likely that the staircase foundations will undergo further settlement as they are inferred to be bearing on loose/soft and/or soil that could potentially have high organic contents and be susceptible to volumetric changes induced by the decomposition of the organic materials.

The hazards, consequences and risks summarized in Tables to 11 and 12 should be re-assessed if any further deterioration of the slopes or staircase is observed. The antecedent events and processes described above, which increase the likelihood of slope failures, would also increase the hazard levels of the staircase.

It is envisaged that the above risks associated with the staircase would be mitigated if the staircase were to be demolished such that it is no longer accessible by the public.

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13.0Closure

This report has been prepared for the sole use of the City of Vancouver and other consultants for this project, as described. Any use or reproduction of this report for other than the stated intended purpose is prohibited without the written permission of Ram.

We are pleased to be of assistance to you on this project and we trust that our comments and recommendations are both helpful and sufficient for your current purposes. If you would like further details or require clarification of the above, please do not hesitate to call.

For:
RAM GEOTECHNICAL ENGINEERING LTD.

Jason Tam, P.Eng.
Geotechnical Engineer

For:
RAM GEOTECHNICAL ENGINEERING LTD.

s.15(1), s.22(1)

Karen Savage, P.Eng., FEC
Principal Geotechnical Engineer

Reviewed by: Robert Ng P.Eng.

Engineers and Geoscientists BC Permit to Practice Number : 1001550

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Appendix A

FIGURES

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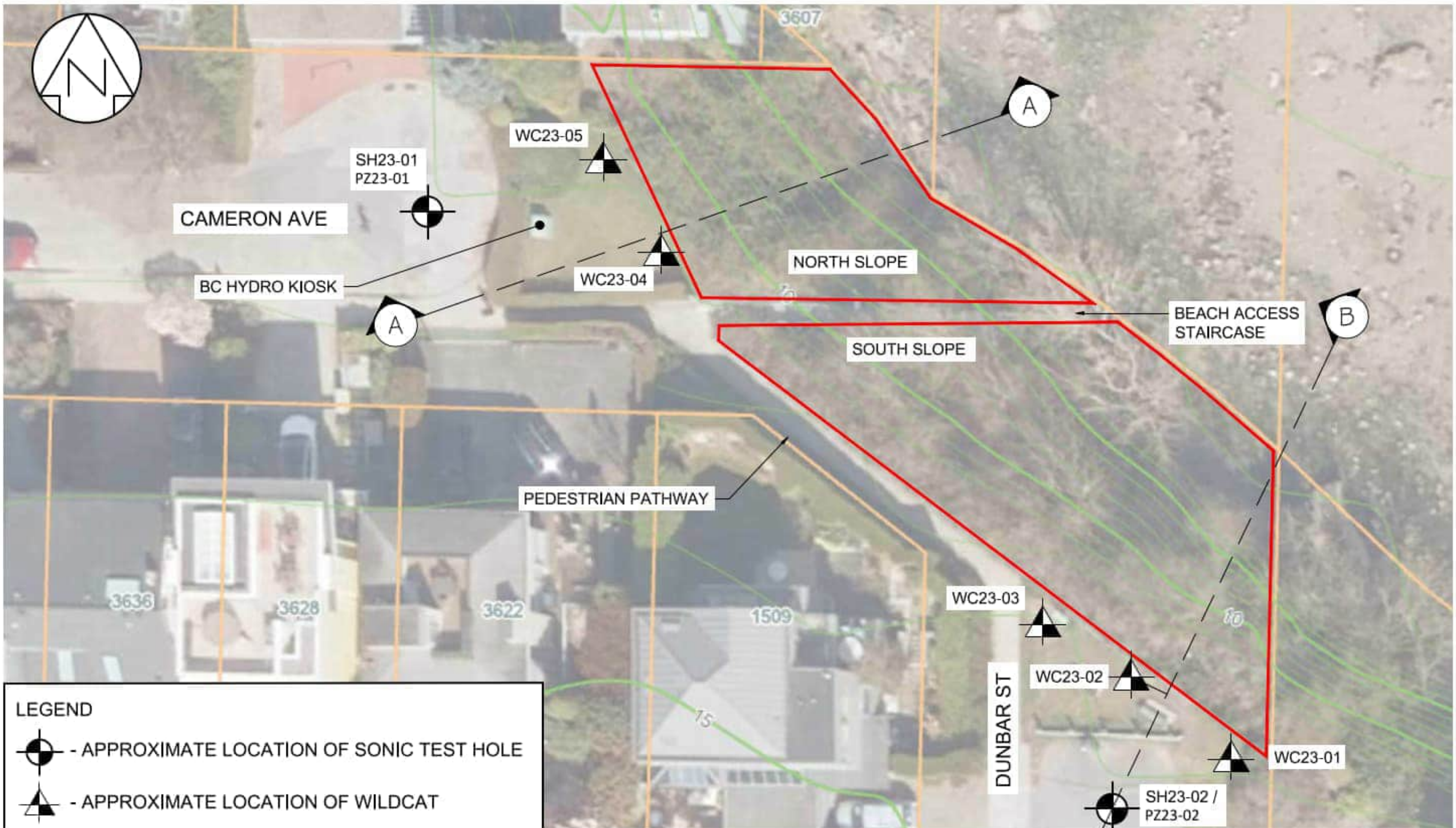
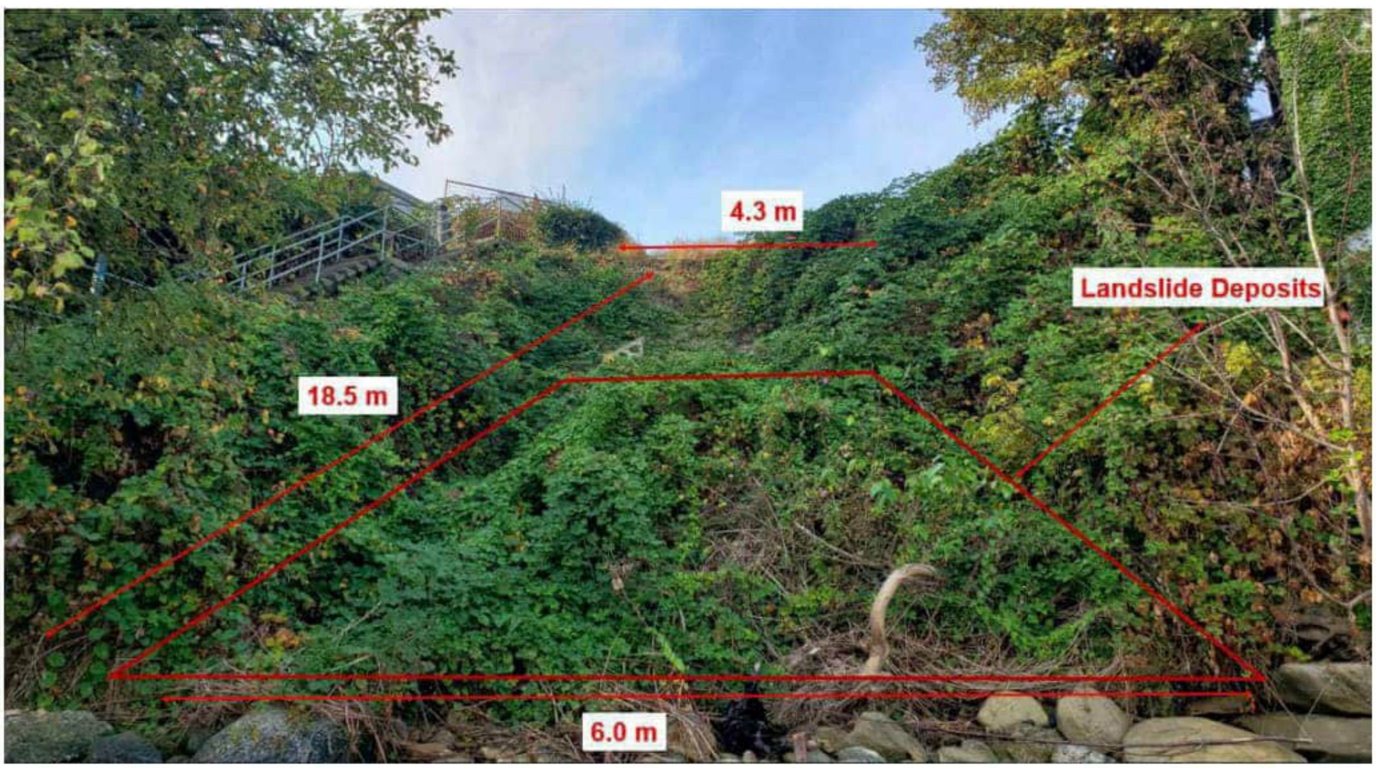


REFERENCE: CITY OF VANCOUVER GIS DATA ACCESSED 2023-06-07

SCALE: 1:500 — 0, 5m, 10m, 20m, 30m, 40m

CITY OF VANCOUVER 453 West 12th Ave, Vancouver, BC	TEST HOLE LOCATION PLAN	HORIZON ENGINEERING INC
GEOTECHNICAL ASSESSMENT Dunbar Slope, Vancouver, BC		Scale: 1:500 · File No: 122-5174 · Date: APR/2023 · FIGURE: 2 Des: JT · Dwn: JV · Chk: RS · Rev:

Photograph 1: Headscarp of North Slope (looking North from top of staircase)



Photograph 2: Landslide scarp at North Slope (looking upslope from bottom of slope)

City of Vancouver	Figure 3: Photographs 1 and 2	HORIZON ENGINEERING INC
Dunbar Slope Assessment at Cameron Ave. and Dunbar St., Vancouver, BC		Scale: NTS; File No: 122-5174; Date: March/2023; FIGURE: 3; Des: JT; Dwn: JT; Chk: KS; Rev:

Photograph 3: 900 millimetre thick deposit of colluvium/landslide debris at bottom of North Slope

Photograph 4: Existing Condition of South Slope (looking upslope from beach)

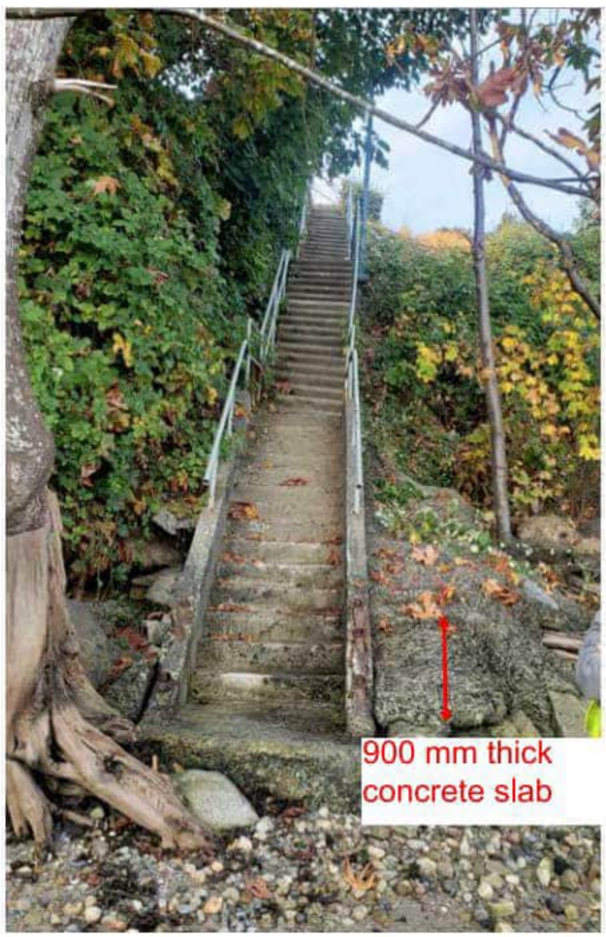
City of Vancouver	Figure 3: Photographs 3 and 4	HORIZON ENGINEERING INC
Dunbar Slope Assessment at Cameron Ave. and Dunbar St., Vancouver, BC		Scale: NTS · File No: 122-5174 · Date: March/2023 · FIGURE: 4 · Des: JT · Dwn: JT · Chk: KS · Rev:

Photograph 5: Inferred fill materials, mixed with debris overlying South Slope

Photograph 6: Existing Condition of South Slope (looking south and upslope from beach)

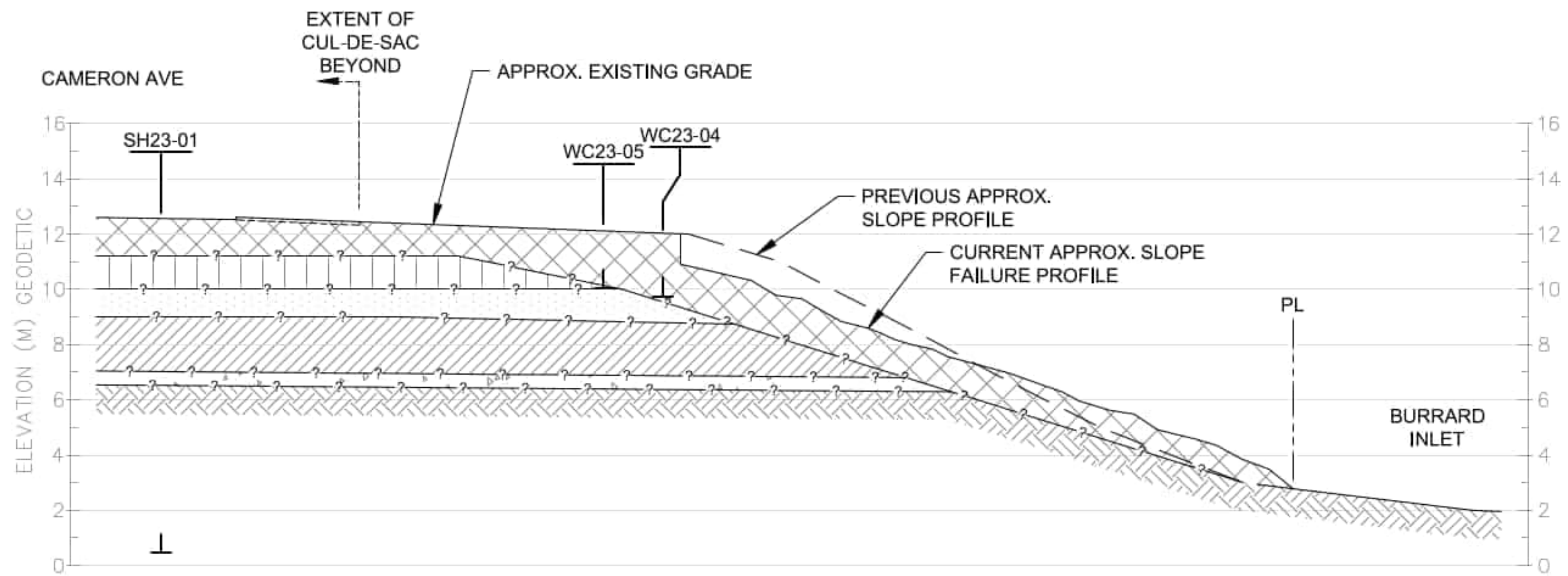
City of Vancouver	Figure 4: Photographs 5 and 6	HORIZON ENGINEERING INC
Dunbar Slope Assessment at Cameron Ave. and Dunbar St., Vancouver, BC		Scale: NTS; File No: 122-5174; Date: March/2023; FIGURE: 5; Des: JT; Dwn: JT; Chk: KS; Rev:

Photograph 7: Bedrock exposure at bottom of South Slope



Photograph 8: Existing condition of beach access staircase, looking up from bottom

City of Vancouver	Figure 4: Photographs 7 and 8	HORIZON ENGINEERING INC
Dunbar Slope Assessment at Cameron Ave. and Dunbar St., Vancouver, BC		Scale: NTS · File No: 122-5174 · Date: March/2023 · FIGURE: 6 Des: JT · Dwn: JT · Chk: KS · Rev:



LEGEND:

FILL LOOSE SOIL	SANDY SILT
SAND	SILT
SILT AND SAND	SILTSTONE (BEDROCK)

SCALE: 1:250 — 0, 5m, 10m, 15m, 20m

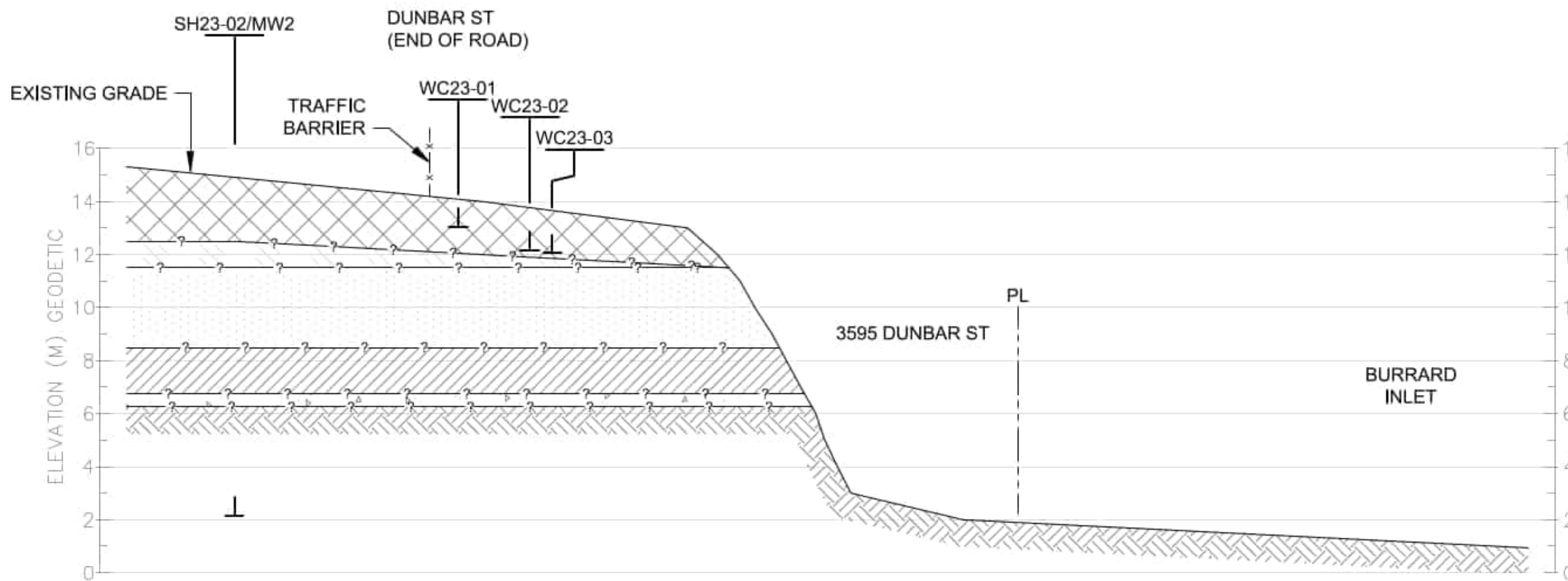
CITY OF VANCOUVER
453 West 12th Ave, Vancouver, BC

GEOTECHNICAL ASSESSMENT
Dunbar Slope, Vancouver, BC

STRATIGRAPHIC SECTION A

HORIZON ENGINEERING INC

Scale: 1:250	File No: 122-5174	Date: APR/2023	FIGURE: 7
Des: JT	Dwn: JV	Chk: RS	Rev:



LEGEND:

FILL LOOSE SOIL	SANDY SILT
SANDY SILT	SILT
SILT AND SAND	SILTSTONE (BEDROCK)

SCALE: 1:250 — 0, 5m, 10m, 15m, 20m

CITY OF VANCOUVER
453 West 12th Ave, Vancouver, BC

GEOTECHNICAL ASSESSMENT
Dunbar Slope, Vancouver, BC

STRATIGRAPHIC SECTION B

HORIZON ENGINEERING INC

Scale:	File No:	Date:	FIGURE:
1:250	122-5174	APR/2023	8

Des:	Dwn:	Chk:	Rev:
JT	JV	RS	

Figure 9: South Slope F.O.S. <1

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
	Fill Materials	Mohr-Coulomb	18	0	33	1
	Sandy Silt (Slightly Lithified)	Mohr-Coulomb	20	27	34	1
	Sandy Silt to Silt	Mohr-Coulomb	18	0	33	1
	Silt (Possible Petrified Topsoil Layer)	Mohr-Coulomb	18	0	35	1
	Silt and Sand	Mohr-Coulomb	19	17	34	1
	Siltstone (Bedrock)	Mohr-Coulomb	23	200	0	1

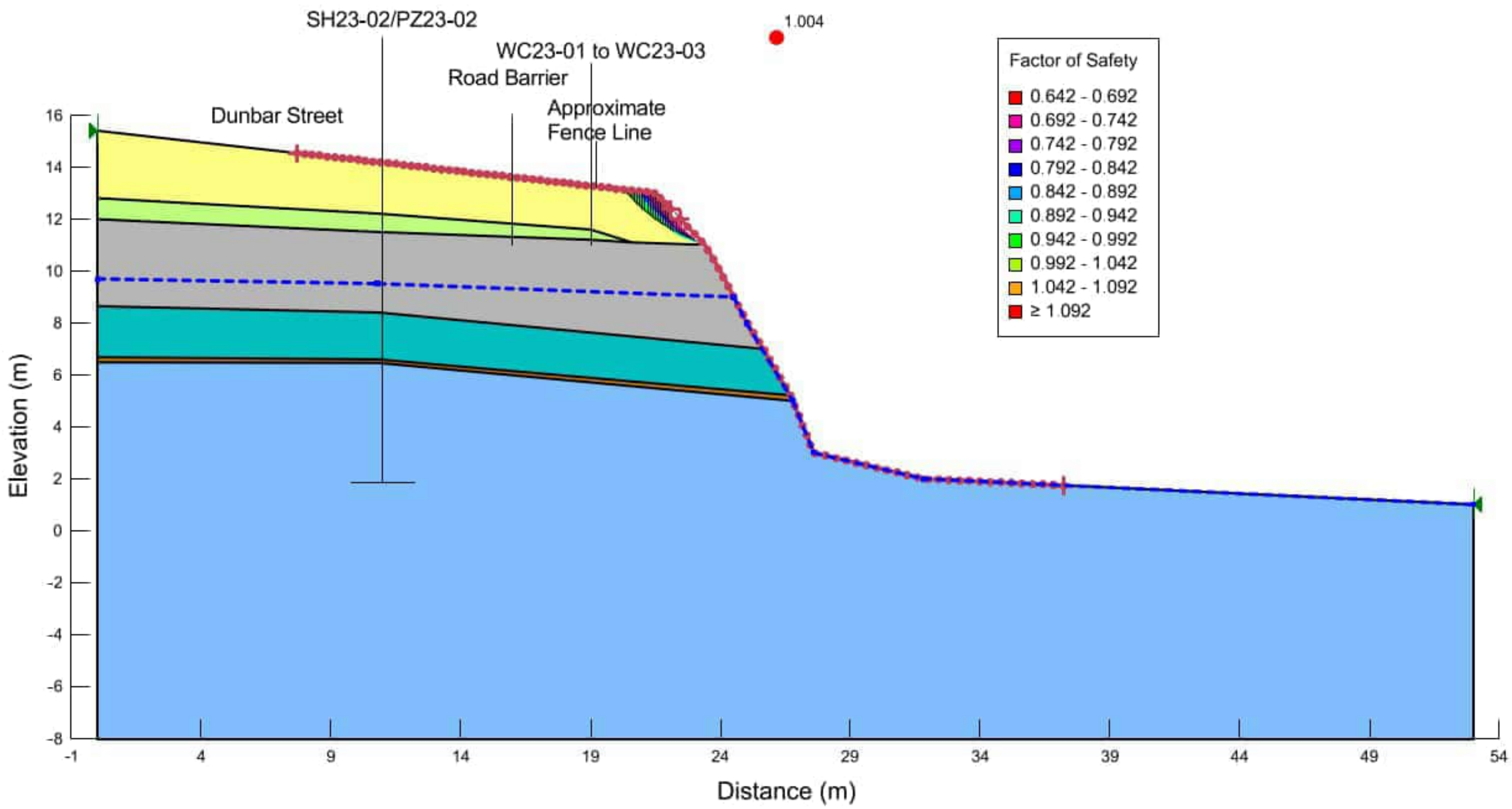


Figure 10: South Slope Critical Slip Surface

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
	Fill Materials	Mohr-Coulomb	18	0	33	1
	Sandy Silt (Slightly Lithified)	Mohr-Coulomb	20	27	34	1
	Sandy Silt to Silt	Mohr-Coulomb	18	0	33	1
	Silt (Possible Petrified Topsoil Layer)	Mohr-Coulomb	18	0	35	1
	Silt and Sand	Mohr-Coulomb	19	17	34	1
	Siltstone (Bedrock)	Mohr-Coulomb	23	200	0	1

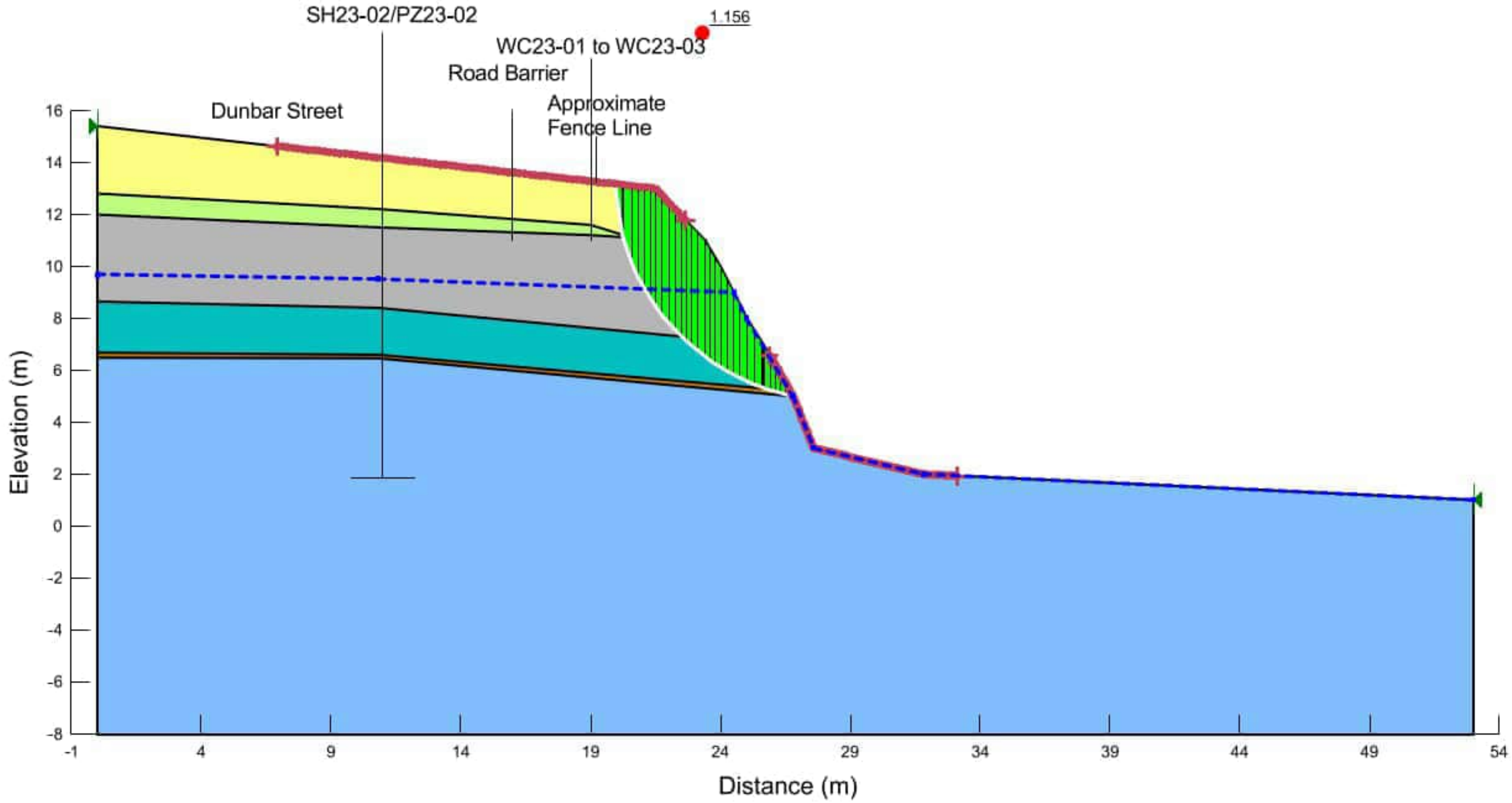


Figure 11: South Slope Global Slip Surface Encompassing Roadway

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Phi (°)	Piezometric Line
	Fill Materials	Mohr-Coulomb	18	0	33	1
	Sandy Silt (Slightly Lithified)	Mohr-Coulomb	20	27	34	1
	Sandy Silt to Silt	Mohr-Coulomb	18	0	33	1
	Silt (Possible Petrified Topsoil Layer)	Mohr-Coulomb	18	0	35	1
	Silt and Sand	Mohr-Coulomb	19	17	34	1
	Siltstone (Bedrock)	Mohr-Coulomb	23	200	0	1

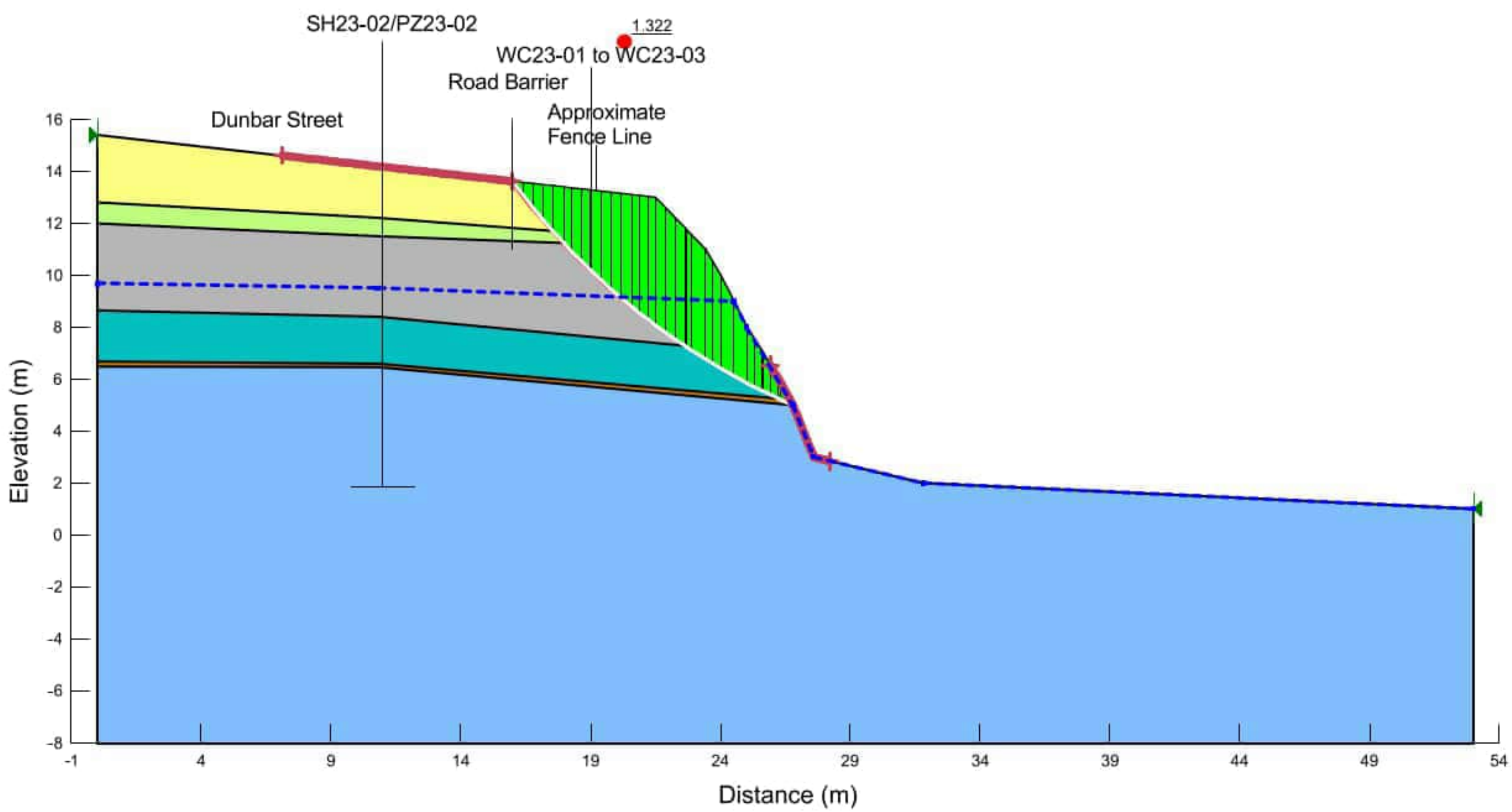


Figure 12: North Slope Pre-failure Geometry F.O.S. ≤1.0

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
	Sandy Silt (slightly lithified)	Mohr-Coulomb	20	27	34	1
	Silt (Possible Petrified Topsoil Layer)	Mohr-Coulomb	18	0	35	1
	Silt and Sand	Mohr-Coulomb	19	17	34	1
	Siltstone(Bedrock)	Mohr-Coulomb	23	200	0	1
	Surficial Loose Deposits/Fill	Mohr-Coulomb	18	0	34	1

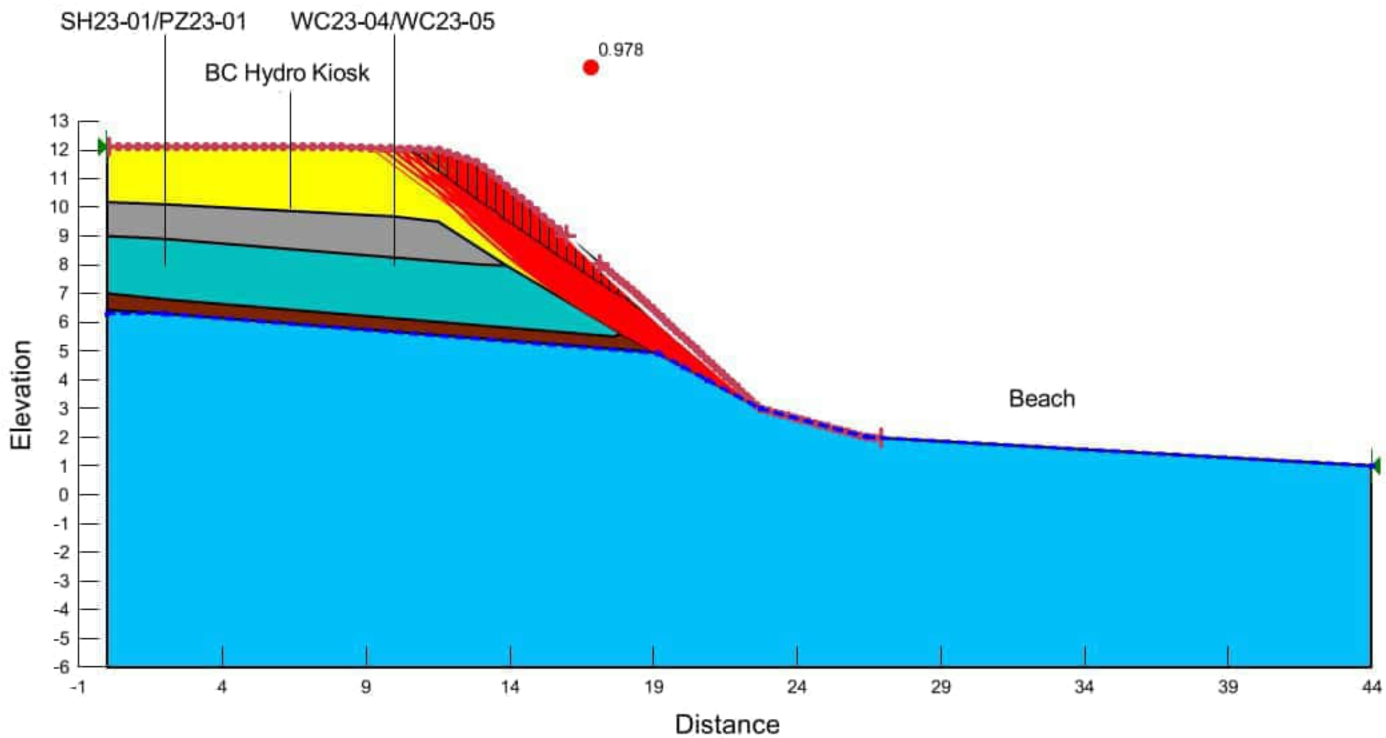


Figure 13: North Slope Pre-failure Geometry - Slip Surface Encompassing BC Hydro Kiosk

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
	Sandy Silt (slightly lithified)	Mohr-Coulomb	20	27	34	1
	Silt (Possible Petrified Topsoil Layer)	Mohr-Coulomb	18	0	35	1
	Silt and Sand	Mohr-Coulomb	19	17	34	1
	Siltstone(Bedrock)	Mohr-Coulomb	23	200	0	1
	Surficial Loose Deposits/Fill	Mohr-Coulomb	18	0	34	1

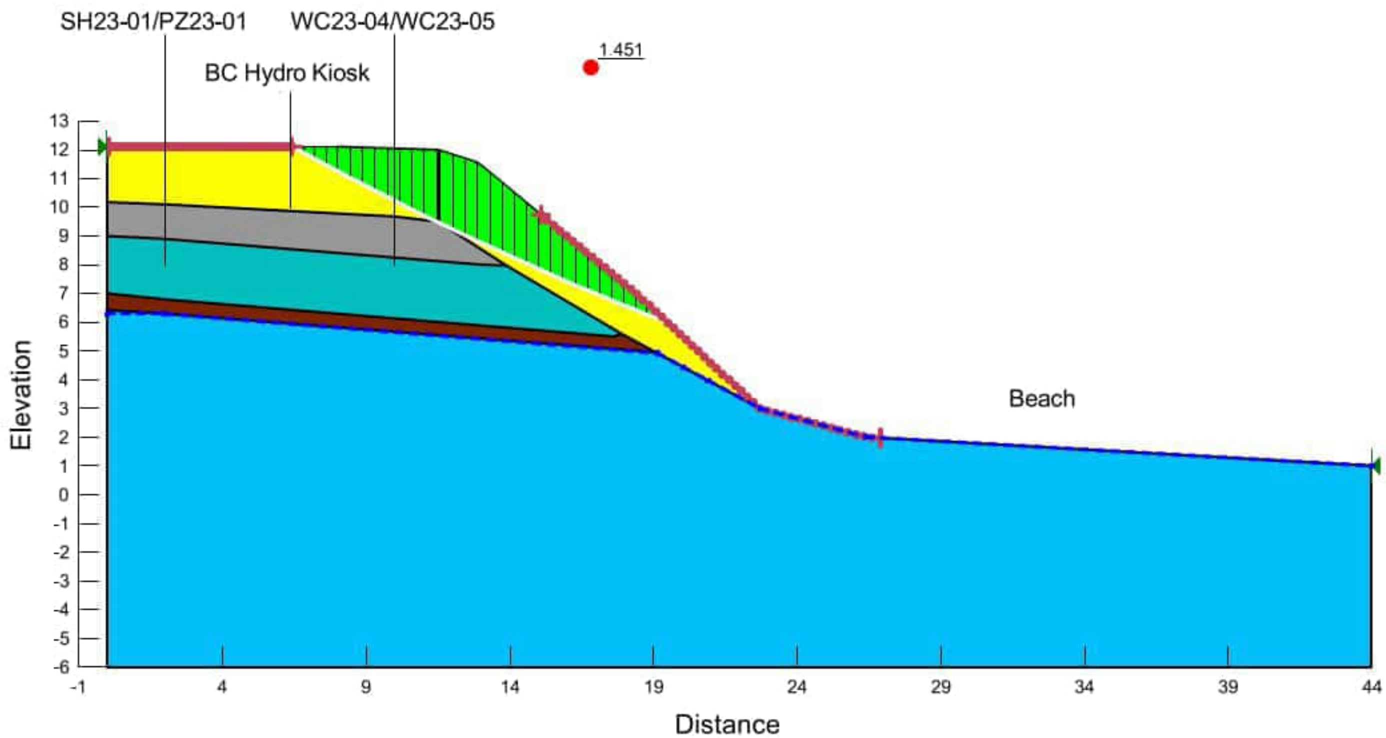


Figure 14: North Slope Post Failure Geometry-Slip Surfaces
F.S. $\leq$ 1.0 Encompassing Headscarp Area

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
	Landslide Debris	Mohr-Coulomb	11	0	30	1
	Sandy Silt (slightly lithified)	Mohr-Coulomb	20	27	34	1
	Silt (Possible Petrified Topsoil Layer)	Mohr-Coulomb	18	0	35	1
	Silt and Sand	Mohr-Coulomb	19	17	34	1
	Siltstone(Bedrock)	Mohr-Coulomb	23	200	0	1
	Surficial Loose Deposits/Fill	Mohr-Coulomb	18	0	34	1

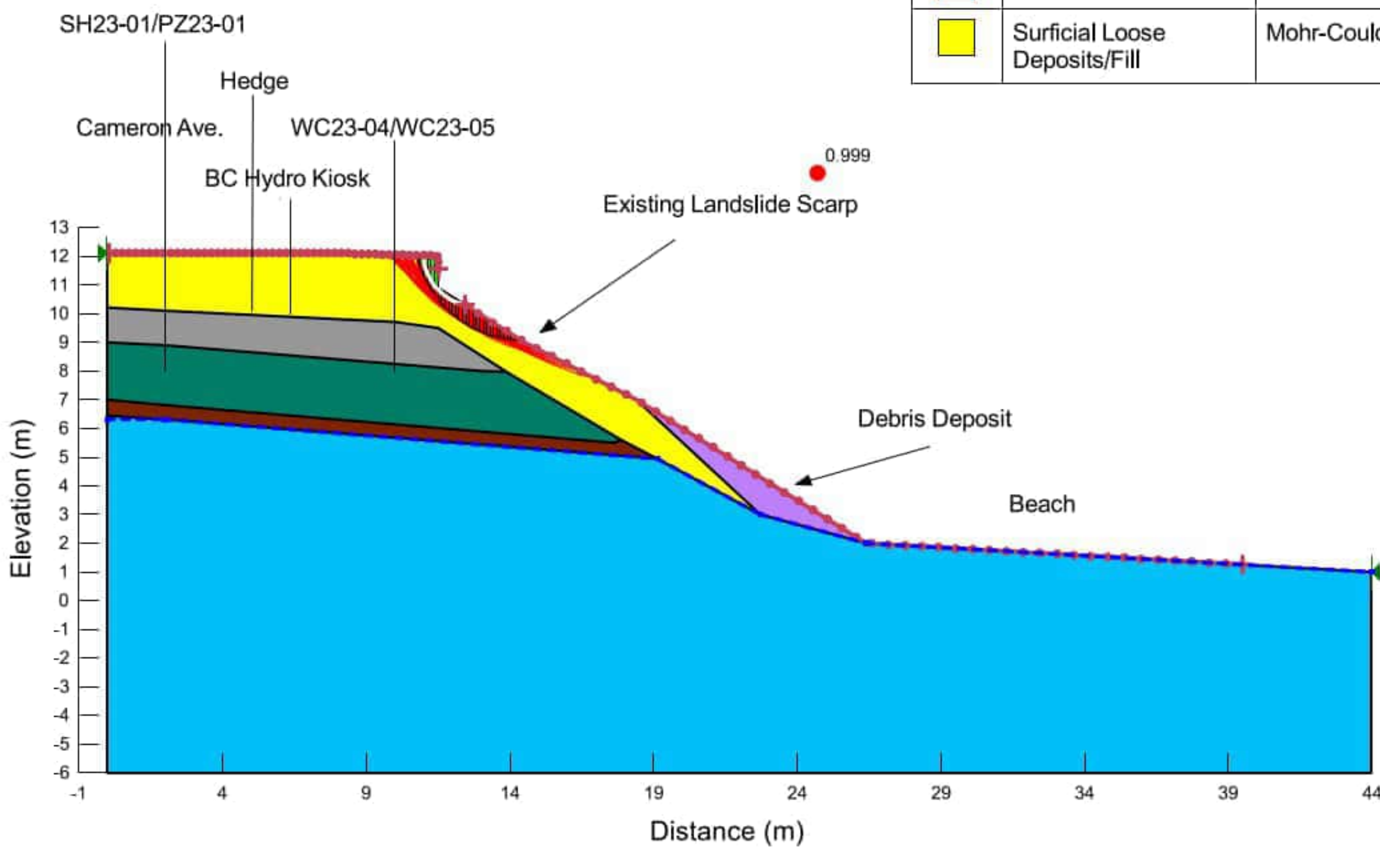


Figure 15: North Slope Post Failure Geometry Slip Surfaces
F.S. ≤ 1.0 Encompassing Landslide Deposit

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
	Landslide Debris	Mohr-Coulomb	11	0	30	1
	Sandy Silt (slightly lithified)	Mohr-Coulomb	20	27	34	1
	Silt (Possible Petrified Topsoil Layer)	Mohr-Coulomb	18	0	35	1
	Silt and Sand	Mohr-Coulomb	19	17	34	1
	Siltstone(Bedrock)	Mohr-Coulomb	23	200	0	1
	Surficial Loose Deposits/Fill	Mohr-Coulomb	17	0	34	1

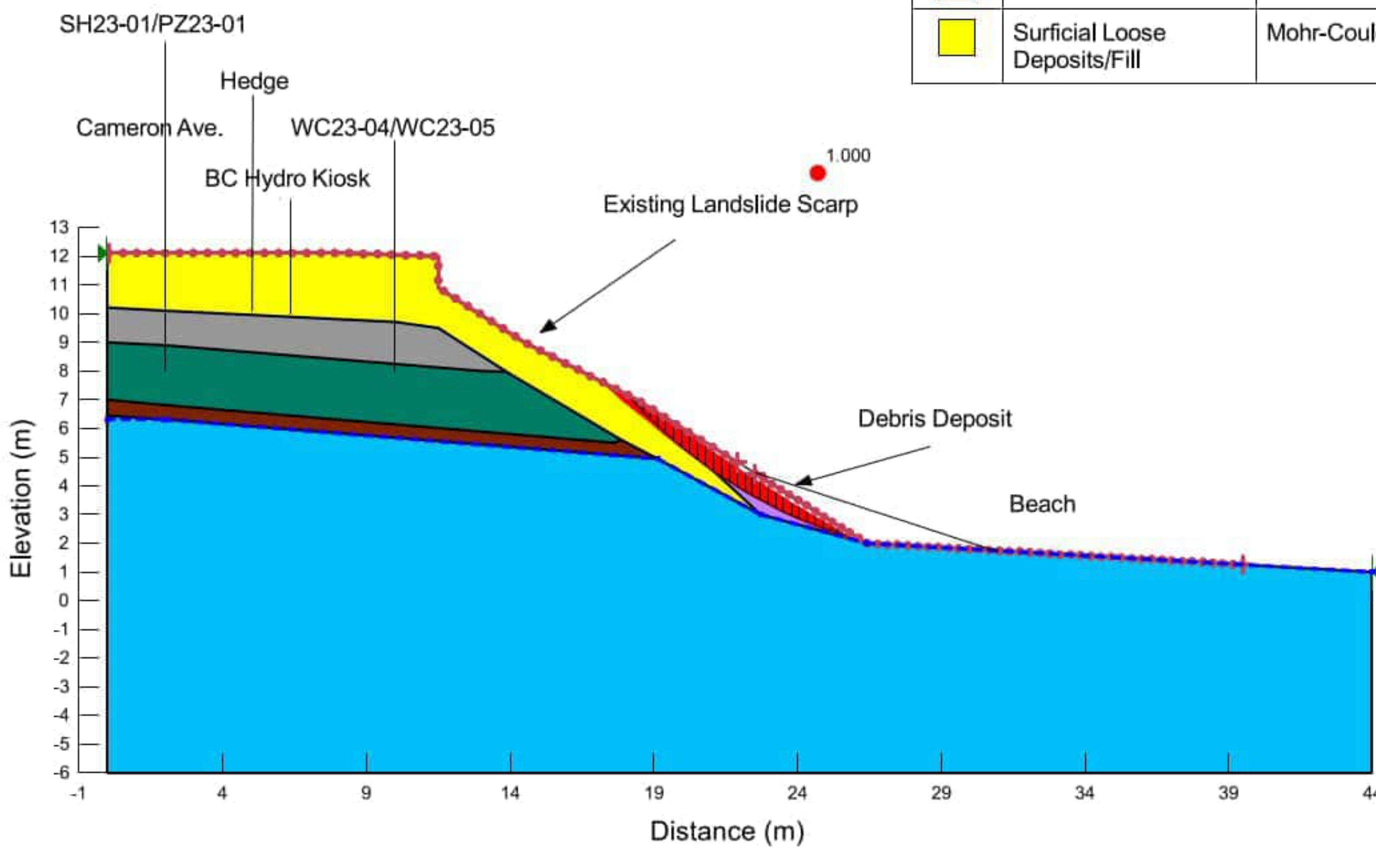
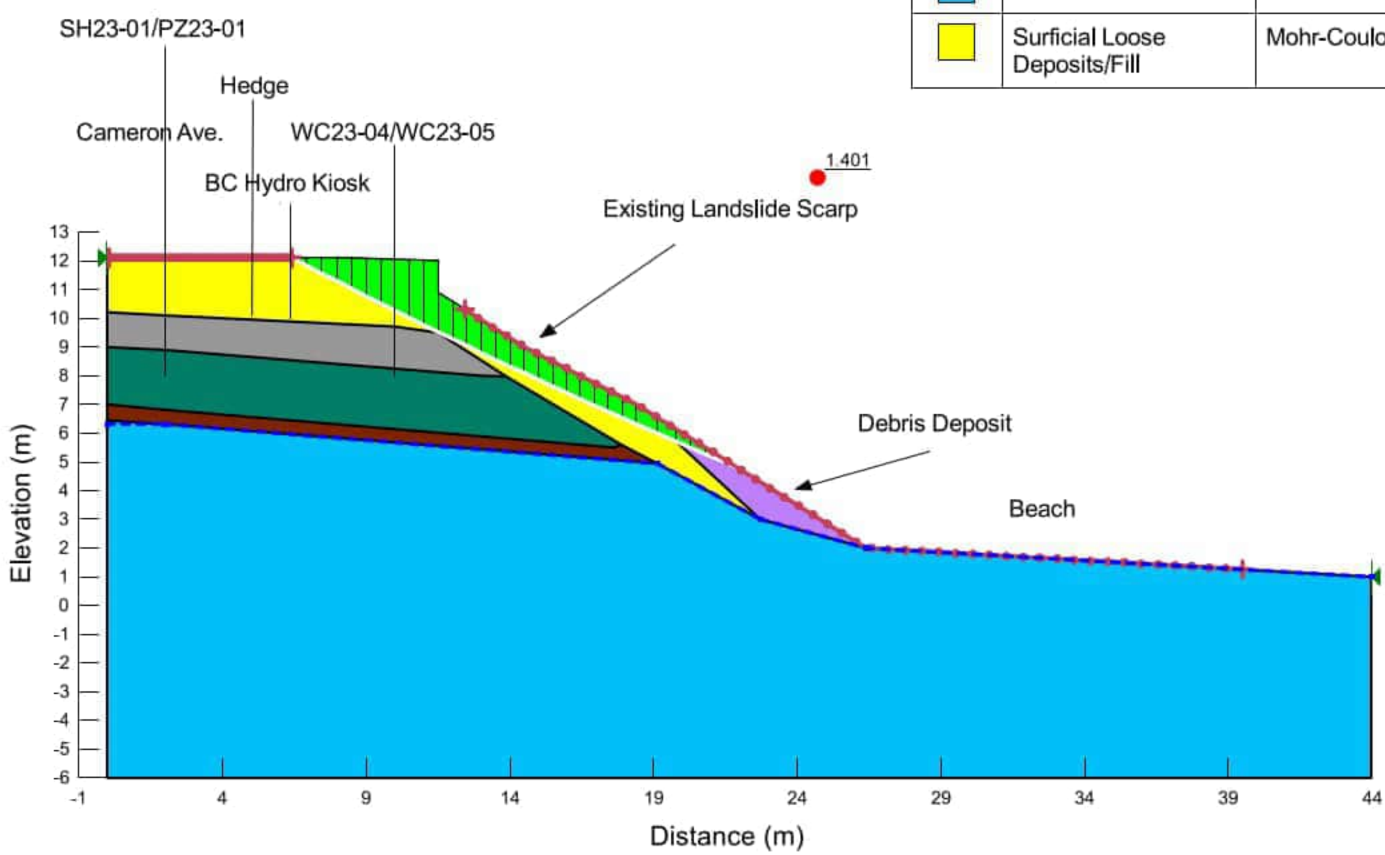


Figure 16: North Slope Post Failure Geometry Critical Slip Surface Encompassing BC Hydro Kiosk

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
	Landslide Debris	Mohr-Coulomb	11	0	30	1
	Sandy Silt (slightly lithified)	Mohr-Coulomb	20	27	34	1
	Silt (Possible Petrified Topsoil Layer)	Mohr-Coulomb	18	0	35	1
	Silt and Sand	Mohr-Coulomb	19	17	34	1
	Siltstone(Bedrock)	Mohr-Coulomb	23	200	0	1
	Surficial Loose Deposits/Fill	Mohr-Coulomb	17	0	34	1



Appendix B

COST ESTIMATES AND SCHEDULES

220-18 GOSTICK PLACE
NORTH VANCOUVER, BC V7M 3G3

P: 604.990.0546
RAMCONSULTING.COM/GEO

Table A: Construction Cost Estimate - North Slope Rip-Rap and Partial Re-grading of Slope

Cost Category	Item	Typical Unit Cost ($)	Unit	Estimated Quantities	Estimated Costs ($)
Equipment	Excavator	s.17(1) [redacted]	hr	112	s.17(1) [redacted]
	Excavator Mobilization	[redacted]	per mob	1	[redacted]
	Barge (For mobilization of equipment and materials)*	[redacted]	*	1	[redacted]
	Barge (For demobilization of excavator)	[redacted]	*	1	[redacted]
Labour	Foreman	[redacted]	hr	112	[redacted]
	Supervisor	[redacted]	hr	112	[redacted]
	Laborer x 2	[redacted]	hr	112	[redacted]
	Operator	[redacted]	hr	112	[redacted]
	Surveyor (2 person crew)	[redacted]	hr	15	[redacted]
	Flagger	[redacted]	hr	112	[redacted]
Materials	Rip-rap	[redacted]	m^3	188	[redacted]
	CDF for Seepage Collar	[redacted]	m^3	1.5	[redacted]
	Filter Cloth	[redacted]	for 1.5 m x 110 m roll	1	[redacted]
	Clear Crushed Gravel	[redacted]	m^3	33	[redacted]
	Rip-Rap Erosion Control Fabric	[redacted]	For 3.8 m x 110 m roll	1	[redacted]
Misc.	Site Preparation	[redacted]		1	[redacted]
				Estimated Construction Costs:	[redacted]
				(+20% Contingency)	[redacted]
				Estimated Duration of Construction (days)	10- 14 days

220-18 GOSTICK PLACE
NORTH VANCOUVER, BC V7M 3G3

P: 604.990.0546
RAMCONSULTING.COM/GEO

Table B: Construction Cost Estimate - North Slope MSE Buttress and Partial Re-grading of Slope

Cost Category	Item	Typical Unit Cost ($)	Unit	Estimated Quantities	Estimated Cost ($)
Equipment	Excavator	s.17(1) [redacted]	hr	184	s.17(1) [redacted]
	Excavator Mobilization			1	
	Barge (For mobilization of equipment and materials)*			1	
	Barge (For demobilization of excavator)			1	
	Stone Slinger		hr	5	
Labour	Foreman		hr	184	
	Supervisor		hr	184	
	Surveyor (2 person crew)		hr	20	
	Labourer (x3)		hr	184	
	Operator		hr	184	
	Flagger		hr	184	
Materials	Geogrid (UX1600MSE)		1.3 m x 61 m roll	8	
	CDF for Seepage Collar		m^3	1.5	
	Engineered Fill (Sand)		m^3	950	
	Clear Crushed Gravel (trench)		m^3	33	
	Clear Crushed Gravel (Drainage Blankets)		m^3	130	
	Filter Cloth		1.5 m x 110 m roll	2	
	Lock Blocks		per block	105	
Misc.	Site Preparation			1	
				Estimated Construction Costs:	
				(+20% Contingency)	
				Estimated Duration of Construction (days)	17 to 23 days

220-18 GOSTICK PLACE
NORTH VANCOUVER, BC V7M 3G3

P: 604.990.0546
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Table C: Construction Cost Estimate – South Slope Rip Rap Armoring

Cost Category	Item	Typical Unit Cost ($)	Unit	Estimated Quantities	Estimated Cost ($)
Equipment	Excavator	s.17(1)	hr	56	s.17(1)
	Excavator Mobilization			1	
	Barge in (Transportation of Equipment and Materials)			1	
	Barge Out (Excavator)			1	
Labour	Foreman		hr	56	
	Supervisor		hr	56	
	Surveyor (2 person crew)		hr	15	
	Labourer (x2)		hr	56	
	Operator		hr	56	
	Flagger		hr	20	
Materials	Rip-rap		m^3	122	
	Rip-Rap Erosion Control Fabric		For 3.8 m x 110 m roll	1	
Site Preparation				1	
Estimated Construction Costs:					
(+20% Contingency)					
Estimated Duration of Construction (days)					5-7 days

Table D: Construction Cost Estimate – FLEX MSE system for confinement of staircase subgrade

Cost Category	Item	Typical Unit Cost ($)	Unit	Estimated Quantities	Estimated Cost ($)
Material	FLEX MSE Geomodular Bag	s.17(1) [redacted]	Per Filled bag+plate	130	s.17(1) [redacted]
	19 mm Clear Crushed Gravel		m^3	2	
Labour	Foreman		hr	24	
	Laborer x 2		hr	24	
				Total Construction Costs:	
				(+20% Contingency)	
				Estimated Duration of Construction (days):	2 to 3

220-18 GOSTICK PLACE
NORTH VANCOUVER, BC V7M 3G3

P: 604.990.0546
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Table E: Construction Cost Estimate – New Staircase Foundations

Cost Category	Item	Typical Unit Cost ($)	Unit	Estimated Quantities	Estimated Cost ($)
Labour	Excavator	s.17(1) [redacted]	hrs	25	s.17(1) [redacted]
	Foreman		hrs	38	
	Supervisor		hrs	38	
	Labourer x 3		hrs	38	
	Operator		hrs	16	
	Flagger		hrs	24	
Materials	Reinforcing Steel		per 3 metres	100	
	Structural Concrete (25 MPa)		m^3	60	
				Total Construction Costs:	
				(+20% Contingency)	
				Estimated Duration of Construction (days):	5 to 7

Table F: Construction Cost Estimate – Soil Nails and Staircase Underpinning (provided by VSS)

Remediation Option	Area	UOM	Slope	Slope Factor	Factored Area (m^2)	Anchor Spacing Width (m)	Anchor Spacing Height (m)	Anchor Factor	Total Anchors Required	Average Anchor Length (m)	Total Drill (m)	Estimated Cost
North Slope Soil Nails	223	m^2	1:1	1.42	317	2	2	43.1	80	4.6	366	s.17(1) [redacted]
South Slope Soil Nails	309	m^2	1:1	1.42	439	2	2	43.1	110	7.6	838	
Staircase Underpinning	0	0		0	0	0.0	0.0	0.0	16	3	49	
											Total Construction Costs (from 2023):	
											Total Construction Costs (for 2024):	
											(+20% Contingency)	

220-18 GOSTICK PLACE
NORTH VANCOUVER, BC V7M 3G3
P: 604.990.0546
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Appendix C

TEST HOLE LOGS

220-18 GOSTICK PLACE
NORTH VANCOUVER, BC V7M 3G3
P: 604.990.0546
RAMCONSULTING.COM/GEO

Test Hole Log No. SH23-01

LOGGED BY: **JT** DATE: **January 27, 2023** ADDRESS: **North and East Termini of Dunbar Street and Cameron Avenue**
REVIEWER: **KS** METHOD: **Track-mounted Sonic Drill Rig**

COORDINATES: UTM	TYPE OF SAMPLE:	NOTES:
LAT / EASTING (X): **0** LON / NORTHING (Y): **0** ELEVATION: **12.1 m**	SPT - Split spoon S - Shelby tube G - Grab O - Other (Specify)	Test Hole advanced at east terminus of Cameron Avenue

DEPTH (FT)	DEPTH (M)	DESCRIPTION	SYMBOL	SPT	SAMPLE NO.	STANDARD PENETRATION TEST (SPT) 14 28 42 56 70 84 98 112 126	COMMENTS/ADDITIONAL NOTES	PIEZOMETER
		Ground Surface — EL 12.1 m						J Plug
0–1	0–0.3	**ASPHALT** 300 millimetre thick layer of asphalt — 0.3 m, EL 11.8 m					0-0.45 m: Filter Sand Backfill	Standpipe
1–2	0.3–0.6	**NO RECOVERY** no sample recovery — 0.6 m, EL 11.5 m					0.45-1.5 m: Bentonite Seal	
2–3	0.6–0.9	**FILL-SILTY SAND (brown)** fine grained, moist - inferred to be compact — 0.9 m, EL 11.2 m			G1			
3–4	0.9–1.2	**SAND (reddish brown)** fine to medium grained, trace gravel, moist - inferred to be compact — 1.2 m, EL 10.9 m			G2			
5–6	1.2–2	**SAND (light brown)** well graded sand, moist - inferred to be compact to dense — 2 m, EL 10.1 m		45		45	1.5-3.3 m: Sand Backfill	
7–10	2–3.2	**SILT AND SAND (light brown)** fine grained sand, moist - slightly lithified - inferred to be hard/very dense — 3.2 m, EL 8.9 m		90	G3, G4	90	Inferred perched groundwater level measured at depth of 2.1 metres on March 9, 2023 SPT effective refusal: 90 blows/150 mm	
11–16	3.2–5	**SANDY SILT (grey)** fine grained sand, moist - slightly cemented - inferred to be hard		90	G5, G6, G7	90, 132	3-5.2 m: Bentonite Seal SPT effective refusal 90 blows/50 mm	

(continued)

HORIZON ENGINEERING INC

PROJECT: VAN COV DUNBAR SLOPE	PROJECT NO.: 122-5174
CLIENT: City of Vancouver	SHEET: 1 of 6

Test Hole Log No. SH23-01

LOGGED BY: **JT**
REVIEWER: **KS**
DATE: **January 27, 2023**
METHOD: **Track-mounted Sonic Drill Rig**
ADDRESS: **North and East Termini of Dunbar Street and Cameron Avenue**

COORDINATES: **UTM**
LAT / EASTING (X): **0**
LON / NORTHING (Y): **0**
ELEVATION: **12.1 m**

TYPE OF SAMPLE:
SPT - Split spoon
S - Shelby tube
G - Grab
O - Other (Specify)

NOTES:
Test Hole advanced at east terminus of Cameron Avenue

DEPTH FT	DEPTH M	DESCRIPTION	SPT	SAMPLE NO.	STANDARD PENETRATION TEST (SPT) 14 28 42 56 70 84 98 112 126	COMMENTS/ADDITIONAL NOTES
17	5	*(continued)* **SANDY SILT (grey)** fine grained sand, moist				
18		- slightly cemented - inferred to be hard 5.3 m EL 6.8 m		G8 G9		5.2-8.8 metres: Filter Sand Backfill
19		**SILT(dark brown)** trace to some fine grained sand, moist				
20	6	- possible inclusions of quartz and feldspar - inferred to be very stiff - inferred to be possible decomposed, organic-rich stratum 5.8 m EL 6.3 m		G10		Ambient/static groundwater level measured at depth of 6.2 metres on March 9/2023
21		**SILTSTONE (grey)** some fine grained sand, moist		G11		
22		- inferred to be very weak to weak				
23	7					
24				G12		
25			132		132	SPT effective refusal: 132 blows/225 mm
26	8					
27						
28						
29	9					8.8-12.2 m: Bentonite Seal
30						
31						
32	10				100	

27 Jan 2023

RSLog / ** SPT Drill Hole Log 11m / horizon / Engineer / April 11, 2023 03:45 PM

HORIZON ENGINEERING INC

PROJECT: **VAN COV DUNBAR SLOPE**
PROJECT NO.: **122-5174**
CLIENT: **City of Vancouver**
SHEET: **2 of 6**

Test Hole Log No. SH23-01

LOGGED BY: **JT**
REVIEWER: **KS**
DATE: **January 27, 2023**
METHOD: **Track-mounted Sonic Drill Rig**
ADDRESS: **North and East Termini of Dunbar Street and Cameron Avenue**

COORDINATES: **UTM**
LAT / EASTING (X): **0**
LON / NORTHING (Y): **0**
ELEVATION: **12.1 m**

TYPE OF SAMPLE:
SPT - Split spoon
S - Shelby tube
G - Grab
O - Other (Specify)

NOTES:
Test Hole advanced at east terminus of Cameron Avenue

DEPTH FT	DEPTH M	DESCRIPTION	SYMBOL	SPT	SAMPLE NO.	STANDARD PENETRATION TEST (SPT) 14 28 42 56 70 84 98 112 126	COMMENTS/ADDITIONAL NOTES	PIEZOMETER
33–35	10	*(continued)* **SILTSTONE (grey)** some fine grained sand, moist - inferred to be very weak to weak			G13			
35	10.7 m EL 1.4 m	**SILTSTONE (grey)** silt and sand, moist - inferred to be very weak		100		● 100	SPT effective refusal: 100 blows/150mm	
36–40	11–12				G14			
40	12.2 m EL -0.1 m	End of Test Hole at 12.1 (m)						
41–49	13–15							

HORIZON ENGINEERING INC

PROJECT: **VAN COV DUNBAR SLOPE**
PROJECT NO.: **122-5174**
CLIENT: **City of Vancouver**
SHEET: **3 of 6**

Test Hole Log No. SH23-02

LOGGED BY: **JT**
REVIEWER: **KS**
DATE: **January 27, 2023**
METHOD: **Track-mounted Sonic Drill Rig**
ADDRESS: **North and East Termini of Dunbar Street and Cameron Avenue**

COORDINATES: **UTM**
LAT / EASTING (X): **0**
LON / NORTHING (Y): **0**
ELEVATION: **14.2 m**

TYPE OF SAMPLE:
SPT - Split spoon
S - Shelby tube
G - Grab
O - Other (Specify)

NOTES:
North terminus of Dunbar Street

DEPTH (FT / M)	DESCRIPTION	SYMBOL	SPT	SAMPLE NO.	STANDARD PENETRATION TEST (SPT) 20 40 60 80 100 120 140 160 180	COMMENTS/ADDITIONAL NOTES	PIEZOMETER
	Ground Surface EL 14.2 m						J Plug
0 ft / 0 m	**ASPHALT** 75 millimetre thick layer of asphalt 0.075 m EL 14.12 m						Standpipe
1–2 ft	**FILL-SAND (grey)** well graded, some gravel, dry - inferred to be compact 0.6 m EL 13.6 m			G1		0-0.45 m: Sand Backfill 0.45-1.2 m: Bentonite Seal	
3 ft / 1 m	**FILL-SAND (brown)** fine to medium grained, dry to moist - inferred to be compact 0.75 m EL 13.45 m						
4–5 ft	**FILL-SAND (dark brown)** fine to medium grained sand, moist - inferred to be moist 0.9 m EL 13.3 m		28	G2	28	SPT inferred to have encountered effective refusal on a cobble	
6 ft / 2 m	**FILL-SAND (grey)** well graded, trace to some gravel, dry to moist - inferred to be compact 2 m EL 12.2 m			G3		1.2 - 3 m: Filter Sand	
7–8 ft	**SANDY SILT (light grey)** fine grained sand, trace gravel, occasional cobbles, moist - brown mottling within the upper 150 millimetres - inferred to be stiff 2.3 m EL 11.9 m			G4 G5 G6			
9–11 ft / 3 m	**SILT (light brown)** some sand, trace clay, trace to no organics (rootlets), moist - inferred to be low to medium plastic - inferred to be firm to stiff 2.7 m EL 11.5 m		100	G7 G8	100	SPT effective refusal: 100 blows/200 mm	
12–14 ft / 4 m	**SAND AND SILT (grey)** fine grained, moist - inferred to be very dense/hard 4.4 m EL 9.8 m			G9		3-5.8 m: Bentonite Seal	
15–16 ft / 5 m	**SILT AND SAND TO SAND AND SILT (light brown)** fine grained sand, moist - inferred to be very dense/hard *(continued)*		100	G10 G11	100 49	SPT effective refusal: 100 blows/75 mm Groundwater level measured at depth of 4.7 metres on Mar. 9/2023	

27 Jan 2023

HORIZON ENGINEERING INC

PROJECT: **VAN COV DUNBAR SLOPE**
PROJECT NO.: **122-5174**
CLIENT: **City of Vancouver**
SHEET: **1 of 8**

Test Hole Log No. SH23-02

LOGGED BY: **JT**
REVIEWER: **KS**
DATE: **January 27, 2023**
METHOD: **Track-mounted Sonic Drill Rig**
ADDRESS: **North and East Termini of Dunbar Street and Cameron Avenue**

COORDINATES: **UTM**
LAT / EASTING (X): **0**
LON / NORTHING (Y): **0**
ELEVATION: **14.2 m**

TYPE OF SAMPLE:
SPT - Split spoon
S - Shelby tube
G - Grab
O - Other (Specify)

NOTES:
North terminus of Dunbar Street

DEPTH (M)	DESCRIPTION	SPT	SAMPLE NO.	COMMENTS/ADDITIONAL NOTES
5	*(continued)* **SILT AND SAND TO SAND AND SILT (light brown)** fine grained sand, moist; - inferred to be very dense/hard		G11, G12, G13	
5.8 m (EL 8.4 m)	**SANDY SILT (grey)** fine grained, occasional cobbles, moist; - slightly cemented; - inferred to be hard		G14, G15, G16	5.8 - 9.4 m: Filter sand backfill
7.6 m (EL 6.6 m)	**SILT (dark brown)** some fine grained sand, moist; - inferred to be a decomposed, organic-rich stratum; - inferred to be very stiff to hard; - inferred to be slightly petrified	49	G17	
7.75 m (EL 6.45 m)	**SILTSTONE (light grey)** some sand to sandy, moist; - 100 millimetre lens of darker brown sand at 8.2 metres; - inferred to be very weak to weak		G18	
9.1 m (EL 5.1 m)	**SILTSTONE (dark grey)** trace fine grained sand, trace clay, moist; - inferred to be slightly plastic; - inferred to be extremely weak	188		SPT effective refusal: 188/250 mm
9.7 m (EL 4.5 m)	*(continued)*			

Depth scale: FT 17–32; M 5–10. SPT scale: 20 40 60 80 100 120 140 160 180. Plotted SPT: 49; 188.

HORIZON
ENGINEERING INC

PROJECT: **VAN COV DUNBAR SLOPE**
PROJECT NO.: **122-5174**
CLIENT: **City of Vancouver**
SHEET: **2 of 8**

Test Hole Log No. SH23-02

LOGGED BY: **JT** DATE: **January 27, 2023** ADDRESS: **North and East Termini of Dunbar Street and Cameron Avenue**
REVIEWER: **KS** METHOD: **Track-mounted Sonic Drill Rig**

COORDINATES: **UTM**
LAT / EASTING (X): **0**
LON / NORTHING (Y): **0**
ELEVATION: **14.2 m**

TYPE OF SAMPLE:
SPT - Split spoon
S - Shelby tube
G - Grab
O - Other (Specify)

NOTES:
North terminus of Dunbar Street

DEPTH (M)	DESCRIPTION	SPT	SAMPLE NO.	STANDARD PENETRATION TEST (SPT)	COMMENTS/ADDITIONAL NOTES
10	*(continued)* **SILTSTONE (light grey)** sandy, moist - inferred to be weak		G20, G21		9.4 - 12.1 m: Bentonite Seal
10.7 m (EL 3.5 m)	**SILTSTONE (grey)** trace fine grained sand, trace clay, moist - inferred to be slightly plastic - inferred to be extremely weak		G22		
11.3 m (EL 2.9 m)	**SILTSTONE (grey)** sandy, moist - slightly cemented - inferred to be weak		G23		
12.1 m (EL 2.1 m)	End of Test Hole at 12.1 (m)	100	G24	100	SPT effective refusal: 100 blows/75 mm

Depth scale: FT 33–49; M 10–15. SPT scale: 20 40 60 80 100 120 140 160 180

PIEZOMETER

HORIZON ENGINEERING INC

PROJECT: **VAN COV DUNBAR SLOPE** PROJECT NO.: **122-5174**
CLIENT: **City of Vancouver** SHEET: **3 of 8**

RSLog / ** SPT Drill Hole Log 11m / horizon / Engineer / April 11, 2023 03:45 PM

Appendix D

UTILITY LOCATE REPORT

220-18 GOSTICK PLACE
NORTH VANCOUVER, BC V7M 3G3

P: 604.990.0546
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FJM Utility Locating Ltd
fjmcontracting.com
604-704-3375 11744 203 St, Maple Ridge, BC V2X 4T9

Time: 7:45 pm	**Date of Survey:** Jan 24, 2023

Oil Tank & Utility Locate Report

Customer Name	:	Horizon Engineering Inc	**BC One Call**	:	20225302664
Contacts	:	Jason Tam	**Date**	:	Dec 29, 2022
Site Address:	:	1509 Dunbar St, Vancouver, BC	**Job Order**	:	na
			Locator	:	Abbas Hamadah

Remarks, specific job requirement: Clear 8 test holes in area as specified by the customer.

Legend:
Red: Hydro **Yellow:** Gas **Orange:** Telecom **Blue:** Water **Green:** Sanitary or Storm **White:** Temporary Marking **Purple:** Unknown utility or dead/decommissioned utility **Black:** Property line or street marking

Marking Used: ☒ Paint ☐ Flags ☐ Nails ☐ Robins

Sketch and/or Report

Scope:

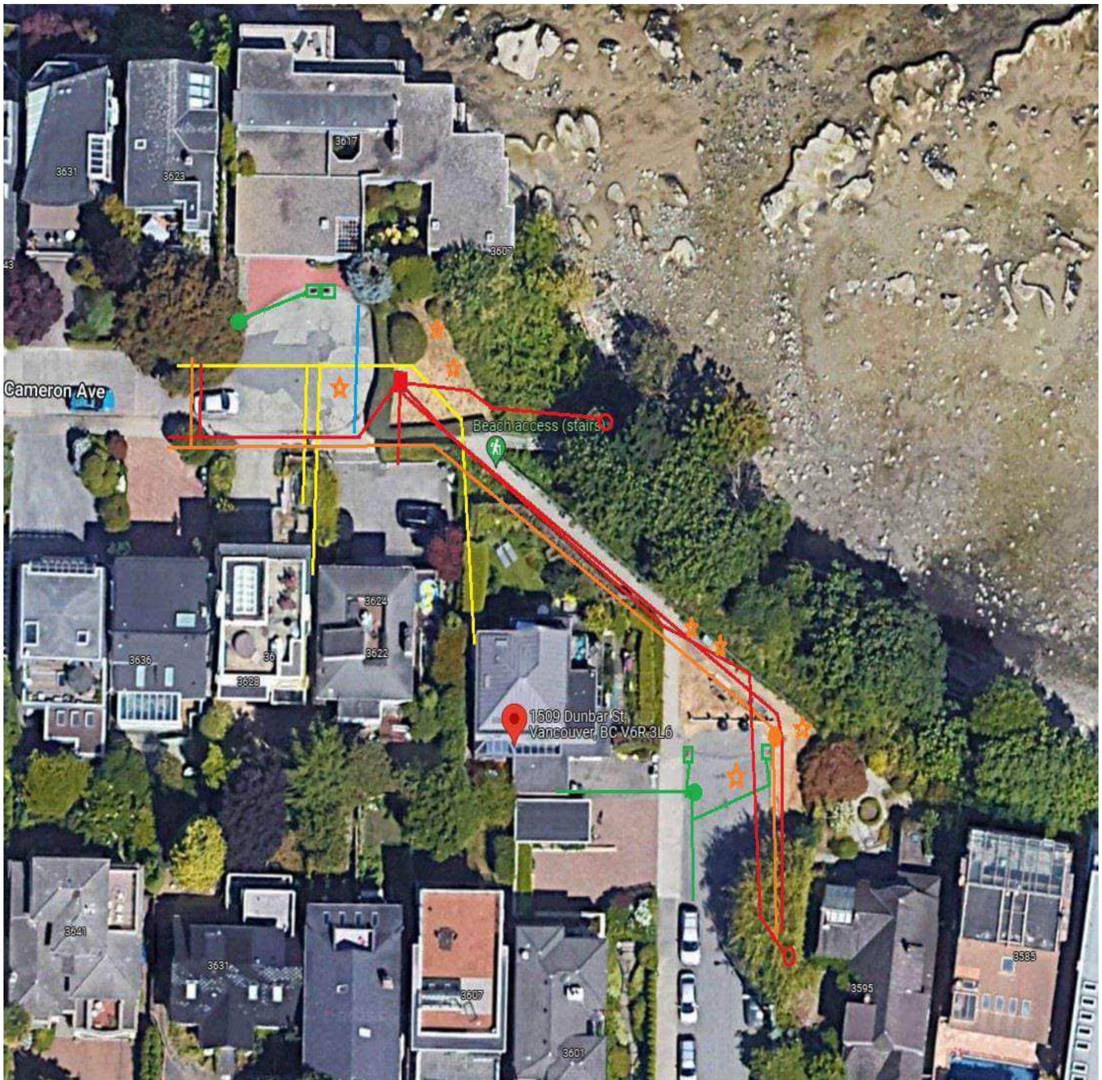
FJM Utility Locating Ltd carried a non-destructive underground utility locating scan in the subject property of this report.

We typically conduct our scan using Ground Penetrating Radar (GPR) and Electromagnetic Locator (EM).

- EM Locator is used to detect buried conductive utilities.
- GPR is used to detect any none conductive utilities and to confirm EM locates.

Results:

- Please see enclosed sketch and pictures


Cameron Ave
Beach access (stairs)
1509 Dunbar St,
Vancouver, BC V6R 3L6


s.22(1)

Conditions Before Use

By using this report and the outcome of this locate the client agrees to the following:

1.The Client (named in this report) understands that the entity FJM Utility Locating Ltd ("FJM") means and includes FJM Utility Locating Ltd, including FJM management, shareholders, employees, individual locators, whether an employee or independent contractor and/or that independent contractors company and acknowledges and agrees that the covenants list hereunder legally binding between the Client and FJM as defined.

2- The Client hereby requests that FJM performs Utility Locating and/or oil tank scan and/or CCTV Camera Inspection (the Locate) of the Subject Property and prepare a written report (the "Report"), to be provided to the Client no later than 48 hours of the date of the Locate. The locating Report is subject to the following limitations and conditions, each of which are acknowledged, understood and accepted by the Client:

a) The Locate and the Report shall be performed and prepared in accordance with the generally accepted practices at the time and using the equipment available in the market at the time of locating;

b) The Locating is non-invasive and non-destructive and the Report constitutes an opinion of the Subject Property based on a visual examination and machine scanning of the readily accessible areas of the Subject Property;

c) The Report does not constitute a guarantee, warranty or an insurance policy;

d) The Client is encouraged, at their own risk, to expose any suspected anomalies and locates following the rules and regulations set forth by the relevant agencies and regulators

e) The Locate does not include inaccessible areas around the property such as locked shed, under stair case, overgrown bushes, water body or a storage area where the items remain in place and hinder any machine scanning;

f) Weather conditions may limit the extent of the Locating; the Client understands that the scope and accuracy of the locate can be affected by weather conditions existing at the time of the Locate;

g) The Client shall protect and indemnify FJM from any claim against any third party arising from disclosure of the Report.

3- The Report is for the exclusive use of the Client and it is not reasonable for any other party to rely on the Report. Liability for errors, omissions, breaches of contract and/or negligence in any part of the Locate or the Report to any person other than the client is expressly denied and, accordingly, no responsibility is accepted for any damages suffered by any such person as a result of decisions made or actions based on the Report.

4- Markings and drawings are approximate only. Exposing is the only accurate method of locating buried utilities. Therefore, we do not offer guarantees or warranties that all utilities are found or that our markings are accurate. We do not offer refunds. We are not liable for damages incurred as a result of any locates. You are responsible for any damages or injuries incurred by your operations. It is your responsibility to expose utilities with methods appropriate to the prevention of injury and damage.

All activities near buried utilities are required to conform to WCB regulation 20.79 Excavations Underground Utilities and any other relevant WCB regulations. Leave flags and markings in place for contractors' reference. Contractors are to remove all markings and flags after work have been completed.

Appendix E

RISK SUMMARY TABLES

220-18 GOSTICK PLACE
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Table 11: Summary of Hazards, Consequences and Risks Associated with Slope Remediation Options

Slope Remediation Option	Hazard (Likelihood of Hazard vs Spatial and Temporal Probability of Impact) (P_{Hazard} x $P_{S:H}$ x $P_{T:S}$)	Potential Consequences, V Low=No injury Moderate=Potential for Injury High=Potential for Fatality	Risks (Hazard Rating x Consequence) (P_{Hazard} x $P_{S:H}$ x $P_{T:S}$ x V)
Maintain slopes in current conditions (i.e. no monitoring, installation of signage and implementation of any remediation measures) – "Do nothing option"	Raveling of surficial, loose materials overlying both slopes. The hazard rating for raveling of the slope materials is expected to be "moderate" as the likelihood of raveling is judged to be "moderate to high" based on the observed slope conditions and the low probability of impact. Specifically, the temporal probability of impact is considered to be "low" as the beach area is typically accessed for limited durations as discussed in Section 12.0 and access is also inherently restricted to periods of low-tide. The spatial probability of impact is considered low as the raveled debris is typically small in size and the likelihood that an individual would be situated within its area of impact would be low. The likelihood of slope raveling would increase during periods of precipitation; however, the probability of impact would be considered to be low as it is less likely that the public would access the beach during these periods.	Raveling of surficial, loose slope materials and rockfall could potentially impact members of the public and their pets accessing the beach. The severity of injury incurred by impacted users of the beach would largely depend on the size of the debris detached from the slopes. The consequence of impact would generally be considered "low to moderate" as raveling of debris of the observed/expected size is typically expected to result in injury, at worse.	Risks of slope raveling to public safety are expected to be "low" to "moderate" based on the hazard rating and consequence of impact.

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Slope Remediation Option	Hazard (Likelihood of Hazard vs Spatial and Temporal Probability of Impact) (P_{Hazard} x $P_{S:H}$ x $P_{T:S}$)	Potential Consequences, V Low=No injury Moderate=Potential for Injury High=Potential for Fatality	Risks (Hazard Rating x Consequence) (P_{Hazard} x $P_{S:H}$ x $P_{T:S}$ x V)
Continued from above ("Do nothing option")	<u>Shallow landslide failures triggered within the surficial loose materials overlying the North Slope.</u> The hazard rating associated with this failure mode is considered to be "moderate" as the likelihood of shallow landslides is judged to be "moderate to high" based on the observed slope conditions and slope stability analyses results. Furthermore, the probability of impact is judged to be "moderate" as the spatial probability of impact is judged to be high in consideration of the area of impact of a typical mass-wasting event and the temporal probability of impact is considered to be "low" as the beach area is typically accessed for limited durations as discussed above.	Shallow landslide failures could potentially result in injury or fatality of beach users depending on the extent of the landslide/slip surface and impact. Thus, the consequence of impact could be considered to be "moderate" to "high".	Risk of shallow landslide to public safety is expected to be "high".
	<u>Rockfall hazards and spalling at the South Slope, posed by the existing overhanging and steepened geometries at the lower portion of this slope</u>. Rating for this hazard is expected to be "moderate" as the likelihood of this hazard occurring is expected to be "moderate to high" and the probability of impact is expected to be "low".	Rockfall hazard could potentially result in injury or fatality of beach users depending on the size of debris and the force of impact. Thus, the consequence of impact could be considered to be "moderate" to "high".	Risk of rockfall hazard to public safety is expected to be "moderate" to "high".

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Slope Remediation Option	Hazard (Likelihood of Hazard vs Spatial and Temporal Probability of Impact) (P_{Hazard} x $P_{S:H}$ x $P_{T:S}$)	Potential Consequences, V Low=No injury Moderate=Potential for Injury High=Potential for Fatality	Risks (Hazard Rating x Consequence) (P_{Hazard} x $P_{S:H}$ x $P_{T:S}$ x V)
Maintain slopes in current conditions with the implementation of remedial and monitoring measures recommended in Sections 8.1.1. and 8.2.1. These measures include the following: -Filling of existing cavities at the toe of the South Slope, -Scaling of loose surficial slope materials, -Installation of signage to inform public of slope hazards and to deter access to the portion of the beach situated within a 3 metre setback from the toe of the South Slope, where there is a higher likelihood of impact from rockfall and spalling hazards, and -Monitoring of slopes at a frequency to be determined.	<u>Raveling of surficial, loose materials overlying both slopes.</u> Scaling of loose, surficial slope materials would reduce the hazard level for raveling to "low" as the likelihood of this hazard occuring would be reduced to "low to moderate". Probability of impact would also be reduced if signage was installed to inform public of potential hazards and to maintain the specified setback from slopes. <u>Shallow landslide failures triggered within the surficial loose materials overlying the North Slope.</u> The hazard rating provided above for this hazard would generally remain unaffected, however, the probability of impact could be lowered if monitoring was completed, such that indicator signs of slope instability are identified prior to failure and suitable measures could be implemented to deter access to the beach area and staircase. Furthermore, signage advising beachgoers of risks should prevail upon them to watch for changes in slope conditions *and listen* for movement of the slope, and advise CoV accordingly;	"Low" to "moderate", as discussed above "Moderate" to "high", as discussed above	Risks of slope raveling impacting the public could be reduced to "low" if the slope remediation measures summarized in Sections 8.1.1 and 8.2.1 are implemented. Risk level would be the same as described above, however, the likelihood that the landslide would impact public safety could be reduced if monitoring was undertaken.

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Slope Remediation Option	Hazard (Likelihood of Hazard vs Spatial and Temporal Probability of Impact) (P_{Hazard} x $P_{S:H}$ x $P_{T:S}$)	Potential Consequences, V Low=No injury Moderate=Potential for Injury High=Potential for Fatality	Risks (Hazard Rating x Consequence) (P_{Hazard} x $P_{S:H}$ x $P_{T:S}$ x V)
Continued from above (Maintain slopes in current conditions with the implementation of remedial and monitoring measures recommended in Sections 8.1.1. and 8.2.1.)	Rockfall hazards and spalling at the South Slope, posed by the existing overhanging and steepened geometries at the lower portion of this slope. Rating for this hazard could be reduced to "low" if loose debris is scaled from the South Slope and a pedestrian setback zone from the toe of this slope is established. It is envisaged that signage could be used for this purpose.	"Moderate to high" as discussed above.	Risk level of rockfall/spalling hazards could be reduced to "moderate" if scaling of loose materials and monitoring were undertaken.
Placement of Rip-rap to armor both slopes and re-grading of North Slope (per Sections 8.1.2 and 8.2.2):	Raveling of surficial, loose materials overlying both slopes. Hazard rating could be reduced to low if North Slope was to be re-graded to a more gentle geometry and scaling of the South Slope was carried out	"Low to moderate", as discussed above	Risk classification for slope raveling would be reduced to "very low to low" if options presented in Sections 8.1.2 and 8.2.2 were to be implemented
Placement of rip-rap armoring, re-grading of North Slope, installation of interceptor trenches and seepage collars near the crest of the North Slope, backfilling of cavities located at the toe of the South Slope, scaling of surficial materials at south slope	Shallow landslide failures triggered within the surficial loose materials overlying the North Slope. Hazard level would be reduced to "low" if North Slope was to be re-graded to a more gentle/stable geometry such that the slope would not be susceptible to shallow failures. Rockfall hazards and spalling at the South Slope, posed by the existing overhanging and steepened geometries at the lower portion of this slope. Rating for this hazard could be reduced to "low" if loose debris is scaled from the South Slope and if the rip-	"Moderate to high" as discussed above. "Moderate to high" as discussed above.	Risk classification of shallow landslide would be reduced to "low to moderate" if options presented in Sections 8.1.2 and 8.2.2 were to be implemented Risks of rockfall hazards impacting public safety could be reduced to "low" to "moderate"

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Slope Remediation Option	Hazard (Likelihood of Hazard vs Spatial and Temporal Probability of Impact) (P_{Hazard} x $P_{S:H}$ x $P_{T:S}$)	Potential Consequences, V Low=No injury Moderate=Potential for Injury High=Potential for Fatality	Risks (Hazard Rating x Consequence) (P_{Hazard} x $P_{S:H}$ x $P_{T:S}$ x V)
Placement of Rip-rap to armor both slopes and re-grading of North Slope (per Sections 8.1.2 and 8.2.2)	rap armoring to be placed against this slope was to extend to a sufficient height.		

Additional Notes:

- Risks summarized above are assessed based on staircase being accessible by the public for the above-noted options
- Filling of existing cavities at South Slope could reduce the rate at which tidal erosion impacts this slope and would be beneficial for the management of this hazard
- Placement of rip-rap would provide erosion protection for slopes and in turn, reduce likelihood of the above-noted hazards induced by tidal-erosion

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Table 12: Summary of Hazards, Consequences and Risks Associated with Staircase Remediation Options

Staircase Remediation Option	Hazards (Likelihood of Hazard vs Spatial Probability of Impact)	Potential Consequences Low=No impact to public Moderate=Potential injury to public High=Potential Fatality	Risks (Hazard x Consequence)
Maintain staircase in current conditions (i.e. "Do Nothing" option)	Current condition of the staircase presents a tripping hazard to users due to distortion of its structure. Current rating of this hazard is estimated to be "moderate". Additional movement/failures of the North Slope could potentially result in the staircase foundations being undermined if the subgrade materials supporting these foundations were to be mobilized. The likelihood of foundation undermining is expected to be "moderate" based on the likelihood of slope failure of the North Slope as described above	Consequence of tripping hazard could be classified as "moderate" as hazards could result in potential injury to users of the staircase. Undermining of staircase foundations could potentially compromise stability of the staircase depending on the extent to which the foundations are undermined. Consequence level would depend on extent of foundation undermining.	Risk to public safety based on current conditions of the staircase is expected to be "moderate". Risk level associated with foundation undermining would vary depending on the extent of undermining.
Actively maintain and re-level staircase conditions and undertake monitoring as well as installation of Flex-MSE system to laterally confine subgrade materials of staircase foundations	Tripping hazards associated with the current condition of the staircase would be reduced to "low" if the staircase was to be re-levelled via slab-jacking	Consequence could be classified as "low" to "moderate" as hazards could result in potential injury to users of the staircase.	Risks to public safety would be reduced to "low" provided the staircase was re-levelled. Periodic slab-jacking may be required if the staircase structure is subjected to further settlement.

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Staircase Remediation Option	Hazards (Likelihood of Hazard vs Spatial Probability of Impact)	Potential Consequences Low=No impact to public Moderate=Potential injury to public High=Potential Fatality	Risks (Hazard x Consequence)
Continued from above (Maintain and re-level staircase conditions and undertake monitoring as well as installation of Flex-MSE system to laterally confine subgrade materials of staircase foundations)	Hazards related to undermined foundations could be reduced to "low" if the FLEX-MSE earth retention system was to be founded on the natural, very dense/hard materials that are expected to underlie the slope such that the earth retention system would not be impacted by potential shallow landslide failures. Thus, the likelihood of occurrence of this hazard would be reduced to "low". Monitoring would also reduce hazard rating if indicator signs of slope instability that could impact the staircase are identified prior to failure and measures are undertaken to restrict public access to the staircase.	Undermining of staircase foundations could potentially compromise stability of the staircase depending on the extent to which the foundations are undermined. Consequence level would depend on extent of foundation undermining.	Risk of any potential instability of the staircase impacting the public would be reduced if monitoring of the slopes and staircase was undertaken as indicator signs of movement or instability of the slopes or staircase could be identified and access to the staircase could be restricted, if assessed to pose a significant hazard to public safety. It is expected that the installation of FLEX MSE earth retention system would further limit risk levels associated with the undermining of the staircase foundations to "low" to "moderate"
Demolition of Existing Staircase and Construction of New Staircase	The hazards described above would be significantly reduced or mitigated if the new staircase were to be founded on very dense/hard subgrade such that the staircase would not be subjected to settlement that could compromise the performance of the staircase. Hazards associated with potential slope instabilities impacting the staircase would be reduced or mitigated if the new staircase is founded on competent	N/A	Risk to the public would be reduced to "very low" provided that the performance of the staircase foundations and stability of the North Slope are considered in the design and construction of the new staircase

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Staircase Remediation Option	Hazards (Likelihood of Hazard vs Spatial Probability of Impact)	Potential Consequences Low=No impact to public Moderate=Potential injury to public High=Potential Fatality	Risks (Hazard x Consequence)
Continued from above (Demolition of Existing Staircase and Construction of New Staircase)	subgrade and at sufficient depths such that any critical, shallow slip surfaces would not intersect the footing locations		

Additional Notes:

The risks associated with the existing beach access staircase, as summarized above, would be mitigated if the staircase was to be demolished such that it will not be accessible by the public

Tree Risk and Windthrow Assessment
Point Grey Slope Remediation
Vancouver, BC

Submitted by:
Judith Cowan, RPF, ISA Cert Arb
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Submitted to:
Karen Savage P.Eng
Horizon Engineering Inc.,
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North Vancouver, BC
604-990-0546
Karen@horizoneng.ca

May 29, 2024

B.A. Blackwell
& Associates Ltd.

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EXECUTIVE SUMMARY

BA Blackwell was subcontracted by Horizon Engineering Inc. to conduct an arborist and tree risk assessment on the steep, forested slopes at the foot of Dunbar St. on English Bay in Vancouver, BC. The assessment is part of a larger study reviewing the impact from a recent slope failure with the aim to develop mitigation options for the City of Vancouver.

A summary of the recommendations outlined in this report is provided below:

1. Based on the tree risk assessment, all of the trees in the study area represent a low or medium risk of failure;
2. Tree# 14 was assessed with medium risk and recommended for re-assessment after any treatments for the staircase are complete;
3. Tree protection plans are to be determined once project plans are finalized; and
4. Engage an ISA certified arborist supervise the staircase underpinning and construction, if pursued by the City of Vancouver (see Section 5.0).

1.0 INTRODUCTION

B.A. Blackwell and Associates Ltd. (the Consultant) were under subcontractor agreement with Horizon Engineering (the Client) to prepare an arboriculture report for trees within a forested area located on steep terrain above the natural beaches and foreshore of English Bay in the Point Grey neighbourhood (referred to throughout this report as 'Subject Area' or 'AOI [Area of Interest]) (Map 1). This report provides treatment recommendations for all the trees with respect to slope remediation options proposed by Horizon. The objectives of this report are:

1- Inventory of all trees within the subject area;

2- Tree risk assessment of the trees based on Level 2 – Basic Assessment following the ISA's Tree Risk Assessment methodology;

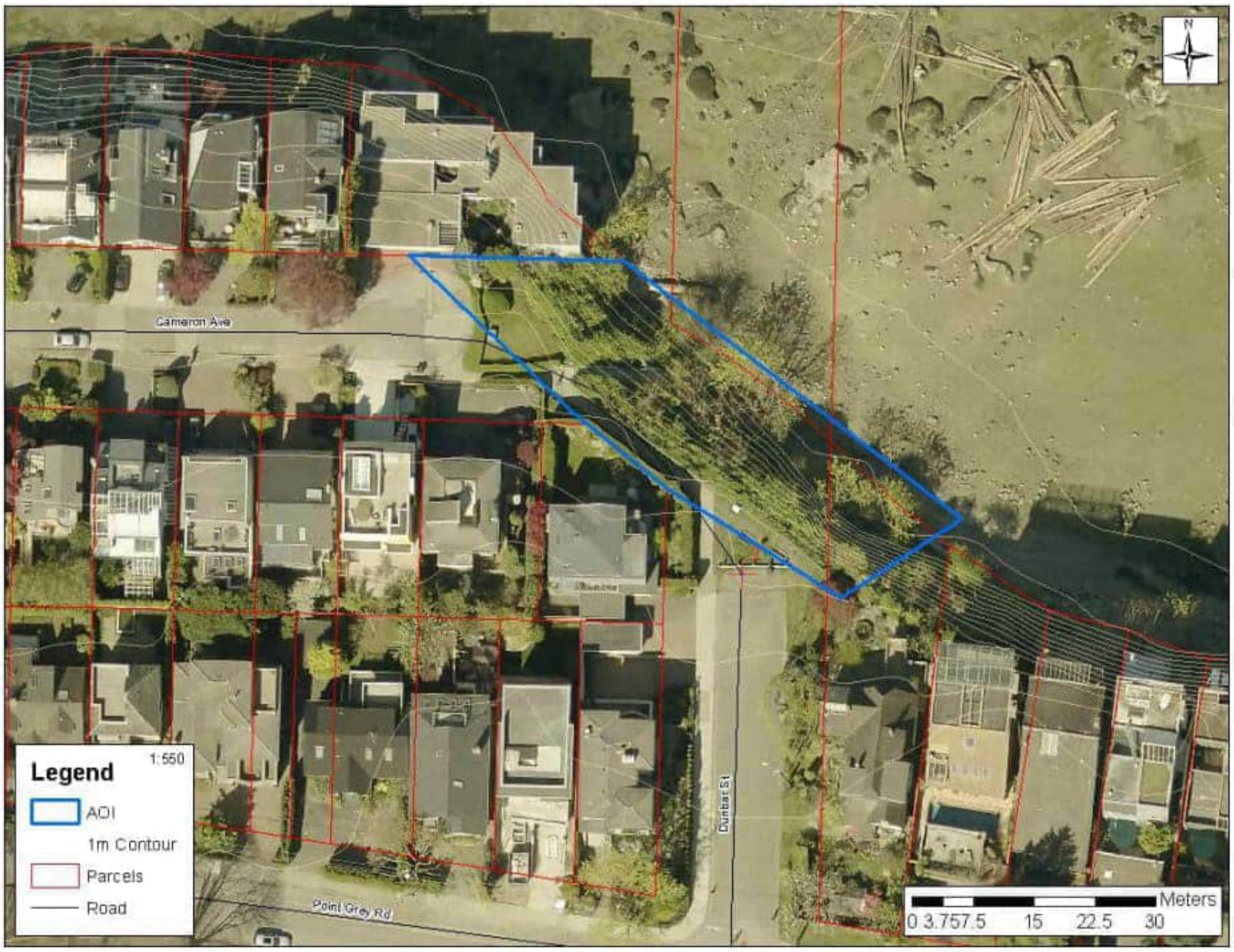
3- Windthrow risk assessment for the site and recommendations for any post-clearing windfirming of the edge that may occur; and

4- Treatment recommendation for each tree in conjunction with Geotechnical assessment by Horizon.

This Report should be shared with contractors, developers, and landscapers, as relevant, to ensure that requirements are noted and recommendations are followed as part of compliance with the Arborist's Report.

1.1 Property Description

The Subject Area is located at the foot of Dunbar St. and north of Cameron Ave. The southeastern section of the Subject Area overlaps a portion of the property at 3595 Point Grey Road, PID #010-240-951.



Map 1. The Point Grey Slope Remediation project area.

1.2 Qualifications

The City of Vancouver requires that an Arborist Report completed by a Certified Arborist be submitted as part of the slope remediation project, as per the request for proposals. Judith Cowan, ISA Certified Arborist and Tree Risk Assessor #PN-7314A meets this requirement. An arboricultural assessment of the trees and site was conducted on February 7, 2023 by Judith Cowan and Ali Rahi. The weather that day was cloudy and 8°C.

2.0 METHODOLOGY

2.1 Tree Inventory

All vegetation defined as "tree" according to Bylaw 9958[1] Section 1 and Section 2.2 were assigned a number between 1-21, located on a digital map using Avenza software, and assessed/measured for the following attributes:

- Species;
- Diameter at breast height (DBH);
- Total height; and
- General condition (Poor, Fair, Good).

For trees with multiple stems, DBH was measured as combined diameters of the three largest stems (trunks) at breast height (1.4m). Each tree was photographed but not tagged. Due to the unacceptable hazard, qualitative visual assessments (i.e., remote assessment) was conducted from a safe distance for the trees on the steep sections of the slope.

2.2 Windthrow Risk

The loading and resistance of trees to wind reflect the short- and long-term interaction of trees and their immediate site, as well as regional terrain and weather patterns. To comprehensively assess these varying spatial scales, windthrow risk assessment involves three hazard subcomponents: 1) Site hazard; 2) Stand hazard; and 3) Topographic hazard. Even-aged, second-growth stands generally have a higher hazard windthrow class due to stand homogeneity. Opening forests up or clearing portions of them, leaves new exposed edges and often results in windthrow of some remaining trees; which are not windfirm in isolation (Stathers, et. al. 1994).

For this project, the windthrow risk assessment was conducted using Card #712-2 that has been developed by the Ministry of Forests, Forest Practices Branch, Province of BC. Diagnostic considerations framed as a series of questions (Mitchell, 2012) were generated in order to understand the inter-relationship between trees, weather, and site conditions (Table 3). One soil pit was also dug to assess soil texture and coarse fragment, depth of tree rooting systems and soil drainage. Photographs from the soil pit were also taken.

2.3 Tree Risk

The risk assessment was conducted on all trees within the Subject Area that can pose any risk to targets (Map 2). The targets are Cameron Ave to the north, beach area to the south, and the staircase. The assessment was completed according to the International Society of Arboriculture's (ISA) Basic Assessment[2] - Level 2 hazard tree assessment methodology and documentation requirements, and was performed by arborists with Tree Risk Assessment Qualification (TRAQ) training and experience.

The risk that a tree could impose was assessed based on the type of target, occupancy rate, likelihood of impact, and consequence of tree failure (Table 1). Trees in the 'Significant' or 'Severe' categories (Matrix 2: Risk Rating) and

[1] https://bylaws.vancouver.ca/9958c.PDF

[2] https://www.isa-arbor.com/education/onlineresources/basictreeriskassessmentform

assessed with an overall risk rating of Moderate to Extreme (outlined in red below) were recommended for removal or treatment.

Table 1: Matrices used to assess the risk rating of each tree.

Matrix 1: Likelihood				
Likelihood of Failure	**Likelihood of Impacting Target**			
	Very Low	**Low**	**Medium**	**High**
Imminent	Unlikely	Somewhat likely	Likely	Very likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely
Improbable	Unlikely	Unlikely	Unlikely	Unlikely

Matrix 2: Risk Rating				
Likelihood of Failure & Impact	**Consequences of Failure**			
	Negligible	**Minor**	**Significant**	**Severe**
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	High
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

A complete inventory of all assessed trees with their risk ratings can be found in the accompanied Excel spreadsheet "Point Grey Slopes Vegetation Inventory Table" to be submitted as a separate document. All the recommended treatments are solely based on the resulted "risk rating" and the conditions of the trees at the time of the field assessment without taking the impacts from recommended slope-remediation options into consideration. Impacts to vegetation based on Horizon's slope remediation options can be found in Table 4.

3.0 SITE DESCRIPTION

The Subject Area is facing northeast and located on a steep slope that leads down from Cameron Ave. to the beach area and is divided by a staircase into north and south sections (Figure 1). Adjacent private properties are 3595 Point Grey Road to the east, 3607 and 3617 Cameron Ave to the north, and 1509 Dunbar St to the southwest. It is located between 0-20m above sea level with a northeast aspect and located within the Coastal Western Hemlock (CWH) Zone of the Biogeoclimatic Ecosystem Classification system of British Columbia (BEC)3. The site falls within the Dry Maritime (CWHdm) subzone which is defined by wet winters, relatively dry and mild summers. The site was dominated by red alder (Alnus rubra), and bigleaf maple (Acer macrophyllum) with some Sycamore maple (Acer pseudoplatanus) and beech (Fagus sp.). English ivy (Hedera helix) and Himalayan blackberry (Rubus armeniacus) were the main invasive plant species found throughout the site. Some of the trees are heavily covered by English ivy which would add extra load to the trees on the steep slope.

3 Field Guide for Site Identification and Interpretation for the Vancouver Forest Region
https://www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh28.pdf

On the south section, a thin layer of soil covers the rock formation and its thickness is subject to the gravitational movement of the particles and the position of the trees (Figure 2). On the north section, the soil profile appears to be thicker, however, sectional soil erosion is evident.

Trees are mostly on the south section where the slope ranges between 20 (on the crest) to 80%. The soil consists of a thin layer of loamy sand mineral soil mixed with organic matter at different stage of composition over the rock formation (Figure 2, Left). On the north section, adjacent to Cameron Ave, soil profile is thicker (up to 20cm) due to less steep slope which allows the accumulation and development of organic and mineral soil (Figure 2, right). Trees are mostly adapted to the steep slope, low soil content and exposure to wind by growing multiple branches with shorter and well tapered main stem that grows along the slope, as opposed to grow upright (Figure 3, left). A few trees with upright main stem grow on less-steep sites (Figure 3, right). On the north section, there are fewer trees and the ground is covered by invasive plants (Figure 1, right). This section has slightly lower slope (10-65%) compared to the east section.

Figure 1. South section (left) and north section (right) of the Subject Area.

Figure 2. Soil formation on the south section (Left) and north section with exposed profile due to the erosion (right).

Figure 3. Branchy, short, well-tapered trees on less steep side (left - Tree #11), and steeper side (right – Tree # 12)

Figure 4. Trees at the toe of slope (left - #15); and infested with English ivy into the crown (right - Tree #4)

4.0 ASSESSMENTS

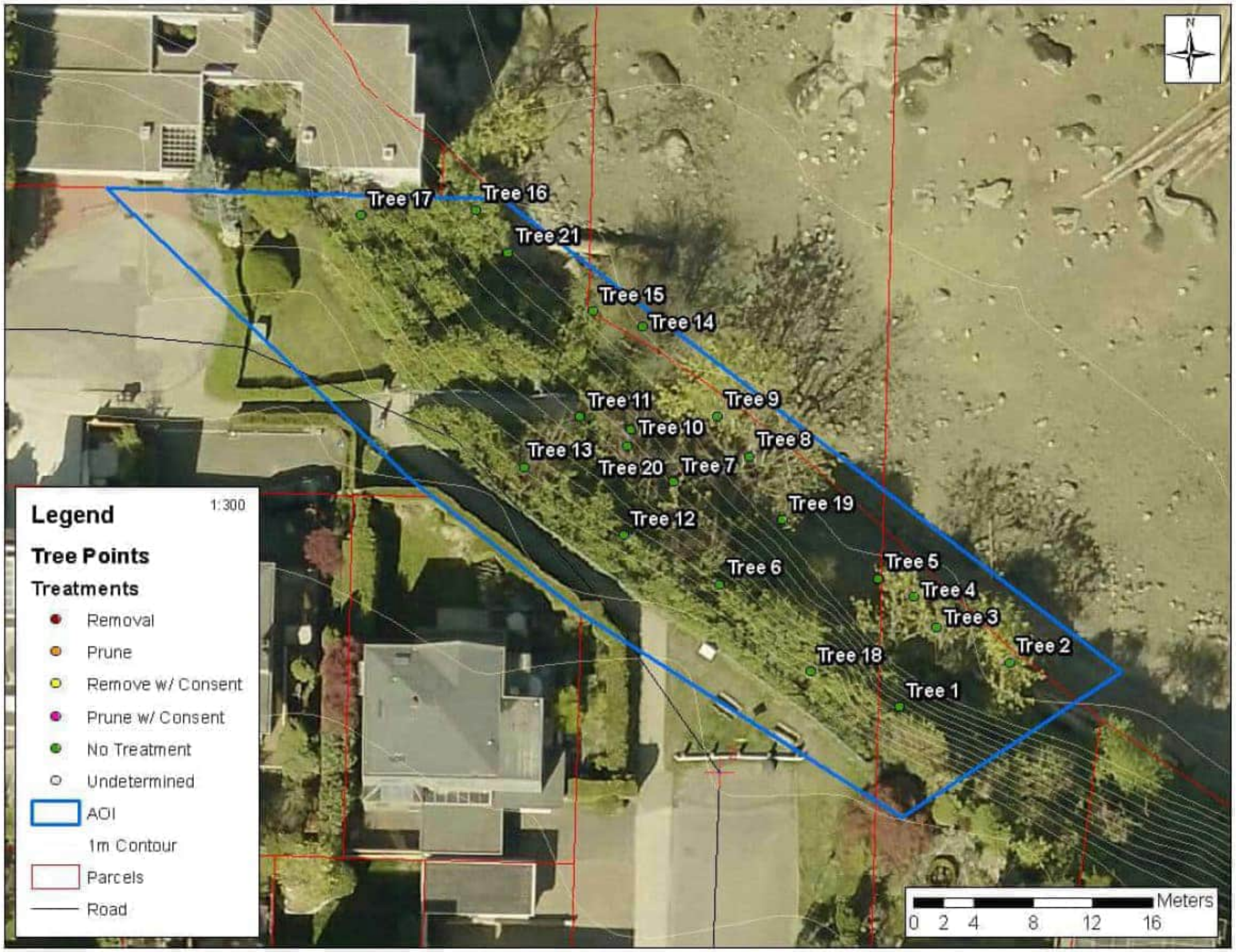
4.1 Tree Inventory

A total of twenty-one trees were assessed in relation to the proposed slope remediation project. Table 2 provides details for each tree assessed. Table 4 summarizes the tree management recommendations for each recommended option.

Table 2. Vegetation inventory table.

Tree #	Species (common name)	DBH (cm)	Height (m)	Condition	Comment	Tree Risk Rating	Treatment
1	Red alder	28	7	Poor	Repeatedly topped, multiple stems (5), 80-90% Slope, dense ivy and blackberry	Low	Retain – Offload ivy from stem
2	Red alder	35	13	Good	Vigorous young tree perched on edge of cliff precipice, healthy	Low	No Treatment
3	Red alder	32	7	Fair	Topped, vigorous regrow this, covered in ivy, stem connects to Tree 3	Low	Retain – Offload ivy from stem
4	Red alder	25	4	Fair	Topped, vigorous regrow this, covered in ivy, stem connects to Tree 4, 8 stems	Low	Retain – Offload ivy from stem
5	Big-leaf maple	35	9	Fair	Codominant stem, covered in ivy, vigorous, edge of precipice	Low	Retain – Offload ivy from stem
6	Red alder	30	4	Fair	Topped, adjacent to top walkway, many stems	Low	No Treatment
7	Big-leaf maple	50	12	Fair	Mid slope, exposed sloughing soil, topped, multiple stems, vigorous re-growth	Low	No Treatment
8	Big-leaf maple	40	10	Poor	Multistem (6), only 1 alive, exposed roots from tide and wave action	Low	Remove dead stems
9	Big-leaf maple	42	13	Fair	Multistem (38 12), mechanical injury lower Bole, exposed roots from tides	Low	No Treatment

Tree #	Species (common name)	DBH (cm)	Height (m)	Condition	Comment	Tree Risk Rating	Treatment
10	Big-leaf maple	30	6	Good	Multi-stem, vigorous, mid-slope, 90% Slope, previously topped	Low	Retain – Offload ivy from stem
11	Sycamore maple	33	13	Good	Vigorous, beside stairs, codominant stem at 2 metres	Low	No Treatment
12	Red alder	25	5	Fair	10 stems, vigorous regrowth, topped repeatedly, top of bank	Low	No Treatment
13	Big-leaf maple	99.8	9	Fair	5 large stems, 32 30 30 28 25, topped multiple times, old tree, vigorous new growth, top of slope	Low	Retain – Offload ivy from stem
14	Big-leaf maple	52	6	Poor	4 stems (28 25 9 8), 1 dead 14cm, exposed roots, bottom of slope	Moderate	Remove one dead stem, re-assess after staircase repair
15	Red alder	40.6	5	Fair	6 stems, 22 7 4 6 6 8, exposed roots, draped over driftwood, copious new buds	Low	Retain – Offload ivy from stem
16	Big-leaf maple	26.2	8	Fair	2 stems 19 + 12, bottom of slope by home, pistol butt, heavy lean towards water	Low	Retain – Offload ivy from stem
17	Red alder	35	10	Good	Edge of AOI, pollarded, top of bank, 90% Slope, open crown, good form	Low	Retain – Offload ivy from stem
18	Red alder	25	7	Fair	Repeatedly topped, multiple stems (5), 80-90% Slope, dense ivy and blackberry, beside top walkway	Low	No Treatment
19	Red alder	33	5	Fair	Covered in ivy, 12 stems	Low	Retain – Offload ivy from stem
20	Sycamore maple	26	6	Fair	Young codominant with 2 stems and heavily included bark, mid slope	Low	No Treatment
21	Beech sp.	13	3	Poor	Gnarled, misshapen but vigorous top growth, 75% of root mass missing	Low	No Treatment



Map 2. Tree Inventory and recommendations

4.2 Windthrow Risk

***Endemic windthrow*[4]** *– damage to stand edges caused by routine peak winds which normally occur every 1-3 years where trees have been exposed by disturbance, including land clearing for development.*
Windthrow *– tree uprooting or stem breakage that results when wind loads exceed stem or root anchorage strength.*

The site is exposed to prevailing winds from northwest to southeast throughout the year, and endemic winds that are more frequent during late fall to early spring. Gusts with 40km/hr or higher cause significant movement of the trees which would compromise their stability; especially those that are located on the slope with shallow and/or exposed root systems. The resistance of the root/soil system to uprooting and overturning depends in part on root/soil strength which is a combination of good rooting arrangement, a large root/soil mass, and a cohesive bond between the root system and soil (Zielke et al. 2010).

Windthrow risk rating is comprised of two subcomponents that in combination, give the overall windthrow risk for the site:

Biophysical hazard - describes biotic and abiotic attributes (topographic exposure, soil properties, and forest stand structure) influencing the likelihood of windthrow occurring (Figure 5). The topographic hazard of Subject Area, based on its exposure to wind, is ranked "**Moderate**" to "**High**" since it is near a large water body and at a side slope. The soil hazard is ranked "**High**" due to the layers of fill soil with shallow rooting depth, hard silt and sand layers, all underlain by very weak siltstone parent material. It is worth noting that the root systems are likely anchored in cracks within the rocks and compacted silt/sand layers. The trees are well adapted to high wind (i.e., low height and large stem diameters) and no windthrown tree was observed during the site visits. The stand is, therefore, "**Low**" hazard. The overall biophysical hazard is "**Medium**".

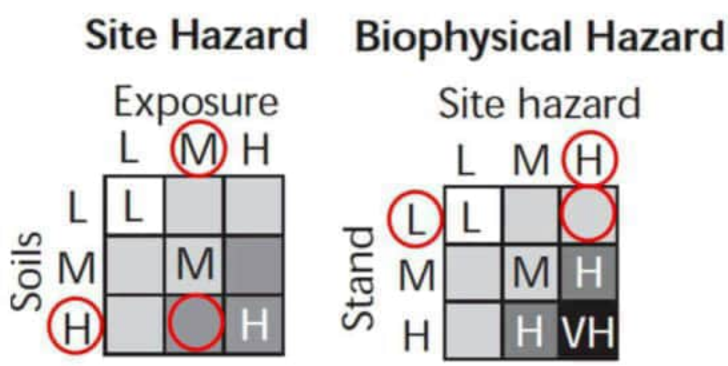


Figure 5. The biophysical hazard rating for subject area is moderate

Treatment risk - describes the type of opening created by a particular treatment (tree removal), and if it increases or decreases the windloading or wind resistance of trees. For example, tree removal can expose

4 https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/bc-timber-sales/business-plans-performance-reports/bcts-coastal-windthrow-manual.pdf

new edges comprised of trees that have been sheltered from wind forces. The impact of the treatment on the windthrow risk rating should be determined after the slope remediation option is selected.

The following answers to diagnostic questions relating to windthrow hazard for the Point Grey Slope Remediation Subject Area are found in Table 3.

Table 3. Diagnostic considerations for windthrow risk assessment procedures (Mitchell et al. 2012).

Wind Patterns	**From what direction do prevailing winds originate?** *Prevailing southeast winds (based on Vancouver Airport weather data).*
Topographic Exposure	**Is terrain exposed or sheltered from routine winds? What is the slope angle?** *The site is exposed to prevailing winds from southeast. The slope is on the right angle.*
Soil	**Is the soil fertile enough to support a closed-canopied stand? Does the soil restrict root anchorage or become easily saturated?** *On the steep slope, the soil is sloughing and cannot support a closed-canopy stand. The soil restricts the anchorage of trees.*
Stand Conditions	**Are individual trees acclimated to above canopy winds? Are trees at stand edges windfirm? What is the stand's disturbance history?** *Individual trees are well adapted to the winds. No windthrow was observed during site visit.*
Species Profile	**Are trees shallow rooted or do they develop tap roots? What is their pattern of failure – overturning at the root plate, trunk failure, or stem breakage?** *Although the soil profile is mostly undeveloped and thin, root systems are mostly anchored into the rock fractures.*

4.3 Tree Risk

Tree# 14 had a rating of "Moderate" as a result of having dead limbs which was recommended for re-assessment after the treatment for the staircase is complete. The risk rating for all inventoried trees within the subject are can be found in the accompanied Tree Risk Assessment Table.

5.0 VEGETATION RECOMMENDATIONS BASED ON GEOTECHNICAL CONSIDERATIONS

The geotechnical report prepared by Horizon Engineering proposed three remedial options for North Section, three options for South Section, and three options for Staircase (Table 4). Each tree is assigned to a set of treatment options pertinent to the recommended slope-remediation option and the impact of the remediation to the tree. Installation of groundwater interceptor trench is proposed as part of remediation options. It should be noted that the installation within the dripline of a tree can have impacts on the long-term stability and health of the tree. Blackwell recommends consultations with an arborist during the design of the trenches and consideration of tunneling instead to reduce the impact on the trees.

Table 4. Slope remediation options for the Subject Area.

Section	Options ID No.	Slope Remediation Option*	Anticipated Impacts to Vegetation	Vegetation Treatment Recommendations
North	NS1	Placement of rip-rap to armour and buttress the lower portion of the slope and re-grading of the upper portion.	Rip-rap will smother tree roots at the toe of slope	Remove Tree #'s 14, 15, 16, 21 Retain Tree #17
	NS2	Construction of a buttress at the lower portion of slope and re-grading of the upper potion	MSE buttress wall will smother tree roots at the toe of slope	Remove Tree #'s 14, 15, 16, 21 Retain Tree #17
	NS3	Soil Anchors and Mesh	Significant impact to trees. Vegetation (trees) growing through the mesh could become problematic (girdled) over time because openings would not be large enough to accommodate secondary growth. Tree growth through mesh will need to be managed (weeded) as regeneration occurs.	Remove all vegetation
Staircase	SC1	Maintain staircase in its current condition and construction of an earth retention system below the north edge of the staircase	Tree# 11 is in proximity staircase	All vegetation to remain since disturbance is on north side only – Tree #11 won't be affected
	SC2	Underpinning of the existing staircase foundations	Depending on installation requirements of threadbare dowels, extent of impacts to the root systems of all trees immediately adjacent to the staircase will need to be determined to decide upon tree retention or removal	Exact locations of dowel placement may need to be adjusted to avoid any structural root. Status of Tree #11 to be determined on-site
	SC3	Construction of new foundations bearing on suitable/competent subgrade	Higher level of disturbance in comparison with SC1 and SC2, during both demolition and construction. This means a greater number of trees adjacent to the staircase and within an access path require removal.	Tree #11 will need to be removed to accommodate construction Tree protection fencing needed for other trees
South	SS1	Maintain current condition of slope with scaling of loose surficial slope materials and backfilling of existing cavities	Vegetation will not be impacted	Retain all vegetation
	SS2	Placement of rip-rap to armour and buttress the lower portion of the slope	Rip-rap will smother tree roots at the toe of slope	Remove Tree #'s 2, 3, 4, 5, 8, 9, 19
	SS3	Soil Nails and Mesh	Significant impact to vegetation	Remove all vegetation

*Description, advantages and disadvantages of each option can be found in the geotechnical report.

The recommended fill areas during the slope remediation process cannot pass through the dripline (tree protection zone) of a tree. In addition, the root system of the retained tree should not be buried with more than 5cm (2 inches) of soil material or rip-rap. Table 5 provides approximate number of the trees to be removed based on the sketches and proximal locations of each tree and its associated dripline. Field verification is required to determine the exact number of trees to be removed and to define specific tree protection zones for retained trees, depending upon which option is chosen.

Table 5. Summary of tree treatments based on geotechnical options.

Option ID No.	Removal	Pruning	Invasive Plant Removal*
NS 1	4 (#'s 14, 15, 16, 21)	0	9 (#1-5, 10, 13, 18, 19)
NS 2	4 (#'s 14, 15, 16, 21)	0	9 (#1-5, 10, 13, 18, 19)
NS 3	5 (#'s 14, 15, 16, 17, 21)	0	9 (#1-5, 10, 13, 18, 19)
SC 1	0	2 (#13, 14)	9 (#1-5, 10, 13, 18, 19)
SC 2	1 (Possibly # 11)	2 (#13, 14)	9 (#1-5, 10, 13, 18, 19)
SC 3	1 (Possibly # 11)	2 (#13, 14)	9 (#1-5, 10, 13, 18, 19)
SS 1	0	1 (#8)	9 (#1-5, 10, 13, 18, 19)
SS 2	7 (#2-5, 8, 9, 19)	0	4 (#1, 10, 13, 18)
SS 3	14 (#1-7, 9-13, 19, 20)	1 (#8)	0

*Removal of English ivy or Himalayan blackberry from the trunk and around the base of the tree.

6.0 LIMITATIONS

This windthrow and tree risk assessment report is based on site observations noted on the date(s) specified only. The project foresters have endeavored to use their skill, education, and knowledge to provide accurate representation. Every effort has been made to ensure that the opinions expressed are an accurate assessment of the tree information and site conditions.

Tree assessments represent the condition of the tree and site at the time of inspection. Tree inspections are limited to visual examination only without employing methods of coring, climbing, or excavating. The inherent characteristics of trees are that they are unpredictable and can fail due to environmental or internal problems. It is not possible for the Consultant to detect every condition or defect that could result in failure of a tree, shrub, or part thereof. Trees, as living organisms, are prone to attack by insects, disease, and other abiotic factors such as wind, snow, and frost. Given these factors, the Consultant cannot guarantee that the tree will be safe and healthy under all situations or for a given amount of time. Any prescribed mitigation measures for tree health or safety cannot be assured.

Adjustments, assumptions, and the conclusions drawn in this report are based on the professional experience of Ali Rahi RPF, ISA Certified Arborist and Tree Risk Assessor and Judith Cowan - RPF, ISA Certified Arborist and Tree Risk Assessor of B.A. Blackwell and Associates Ltd. (the 'Consultant'). The opinions expressed below are also based on written and verbal information supplied in part by other parties.
The Consultant cannot accept responsibility for any issues or events that have arisen since the date of the inspection and the date the report was written. The Consultant accepts that the report represents professional judgment and that the Consultant's responsibilities are limited to the content of this report.

7.0 REFERENCES

Stathers et al. (2001) Windthrow Assessment and Management in British Columbia - Proceedings of the Windthrow Researchers Workshop, 2001. UBC Department of Forest Sciences, Vancouver BC.

Mitchell, S.J. (2012) Wind as a natural disturbance agent in forests: a synthesis. Forestry Chronicle Volume 86, Issue 2, pp. 147 – 157. doi: 10.1093/forestry/cps058.

Zielke et al. (2010). BCTS Windthrow Manual: A Compendium of Information and Tools for Understanding, Predicting and Managing Windthrow on the BC Coast.

APPENDIX A – TREATMENT SCHEDULE

Section	Tree*	Species	DBH	Height	First year treatment	Every 2 Year Treatment
North Section	14	Mb	52	6	Remove one dead stem, reassess after stairway construction	Re-assess
	15	Dr	37	5	Retain and monitor	Re-assess
	16	Mb	31	8	Offload invasive plants from tree	Re-assess and remove any new growth of invasive plant
	17	Dr	35	10	Offload invasive plants from tree	Re-assess and remove any new growth of invasive plant
	21	Beech sp.	13	3	No treatment	Re-assess
South Section	1	Dr	28	7	Offload invasive plants from tree	Re-assess and remove any new growth of invasive plant
	2	Dr	35	13	No treatment	Re-assess
	3	Dr	32	7	Offload invasive plants from tree	Re-assess and remove any new growth of invasive plant
	4	Dr	25	4	Offload invasive plants from tree	Re-assess and remove any new growth of invasive plant
	5	Mb	35	9	Offload invasive plants from tree	Re-assess and remove any new growth of invasive plant
	6	Dr	30	4	No treatment	Re-assess
	7	Mb	50	12	No treatment	Re-assess
	8	Mb	40	10	Remove dead stems	Re-assess
	9	Mb	50	13	No treatment	Re-assess
	10	Mb	30	6	Offload invasive plants from tree	Re-assess and remove any new growth of invasive plant
	11	Sycamore maple	33	13	No treatment	Re-assess
	12	Dr	25	5	No treatment	Re-assess
	13	Mb	92	9	Offload invasive plants from tree	Re-assess and remove any new growth of invasive plant
	18	Dr	25	7	No treatment	Re-assess
	19	Dr	33	5	Offload invasive plants from tree	Re-assess and remove any new growth of invasive plant
	20	Sycamore maple	26	6	No treatment	Re-assess

*Mb: bigleaf maple, Dr: red alder.

8.0 SIGNATURES

Project Forester

s.15(1), s.22(1)

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May 29, 2024

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s.15(1), s.22(1)

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