Coastal Slope Stability Assessment

Saltair - Cowichan Valley Regional District

February 14, 2022

Prepared for:

Cowichan Valley Regional District

Prepared by:

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In association with Palmer

Final

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Cowichan Valley Regional District (CVRD) manages growth and development of 350,000 ha of land on Vancouver Island and adjacent Gulf Islands. Most of that development is focused on the east coast, inland to Shawnigan and Cowichan Lakes. CVRD has a Natural Hazard Risk Tolerance Policy that requires, for new developments, that the annual risk of loss of life from natural hazards be less than 1:10,000 (CVRD, 2019). As of the date of this report, geotechnical assessments are required where slopes exceed 15%, or within limited areas (the north shore of Cowichan Lake, for example) where more detailed hazard and risk assessments have defined hazard zones.

In 2021, CVRD sought to undertake a landslide hazard assessment, including quantification of both the likelihood and potential consequences of landslides from steep slopes, for the developed portion of the region that it manages.

Separately, CVRD sought a coastal slope stability assessment to identify and characterize changes in slope stability considering changes in drainage and future sea level rise.

Both requests were part of a collective RFP R20-62, Landslide Hazard and Coastal Slope Stability Assessment.

Stantec Consulting Ltd. in association with Palmer (Stantec and Palmer), building on past experience (Palmer and Stantec, 2020a; Palmer and Stantec, 2020b; Stantec and Palmer, 2021), formed a collaborative team to bring our specific expertise to both requests. This report represents the written product for the Coastal Slope Stability Assessment. Digital files provided to the CVRD constitute the remainder of the deliverable. The Landslide Hazard Assessment is covered in a separate report, *Landslide Hazard Assessment – Cowichan Valley Regional District* (Stantec Consulting Ltd. & Palmer, 2021).

The Coastal Slope Stability Assessment addressed the Saltair coastline (CVRD Electoral Area G, excluding the Gulf Islands) and the incised lower reaches of Stocking and Porter Creeks. Request for this assessment was triggered by an increased incidence of slope failure observed in the CVRD coastal zone over recent years (CVRD, 2020). A scenario of 1.0 m sea level rise was to form the basis of this analysis as outlined in the *Risk Assessment of Floodplains and Coastal Sea Level Rise: Strategic Risk Assessment for the Cowichan Valley Regional District* (Northwest Hydraulic Consultants, 2019).

1.1 SCOPE OF WORK

Within the coastal slope stability assessment study area (**Figure 1**), Stantec and Palmer adopted a predominantly desktop-based approach using light detection and ranging (LiDAR) data, historical air photographs, and a limited, two-day field reconnaissance to:

- Identify and record evidence for slope movement or erosion
- Record observed seepages or springs
- Classify surface material type and textures and, where exposed, site stratigraphy in the foreshore and backshore environments
- Characterize observed landslides (e.g., movement style, activity state, estimated runout and size, expected velocity, evidence for cause)
- Observe and record shoreline conditions (including hardened shorelines)
- Calculate a setback distance considering a 1 m sea level rise (from Northwest Hydraulic Consultants (2019)), within which additional investigation would be reasonably expected prior to development approval

Following draft submission of the coastal slope stability assessment, the CVRD requested expansion of the study area to include the incised lower reaches of Stocking and Porter Creeks (**Figure 1**). Within the expanded study area Stantec and Palmer, used a desktop-based approach to:

- Identify potential retrogressive landslides visible within the LiDAR-generated digital elevation model (DEM)
- Calculate a setback distance within which additional investigation would be reasonably expected prior to development approval

This report should be read in conjunction with the Statement of General Conditions, which is included in **Appendix A**.

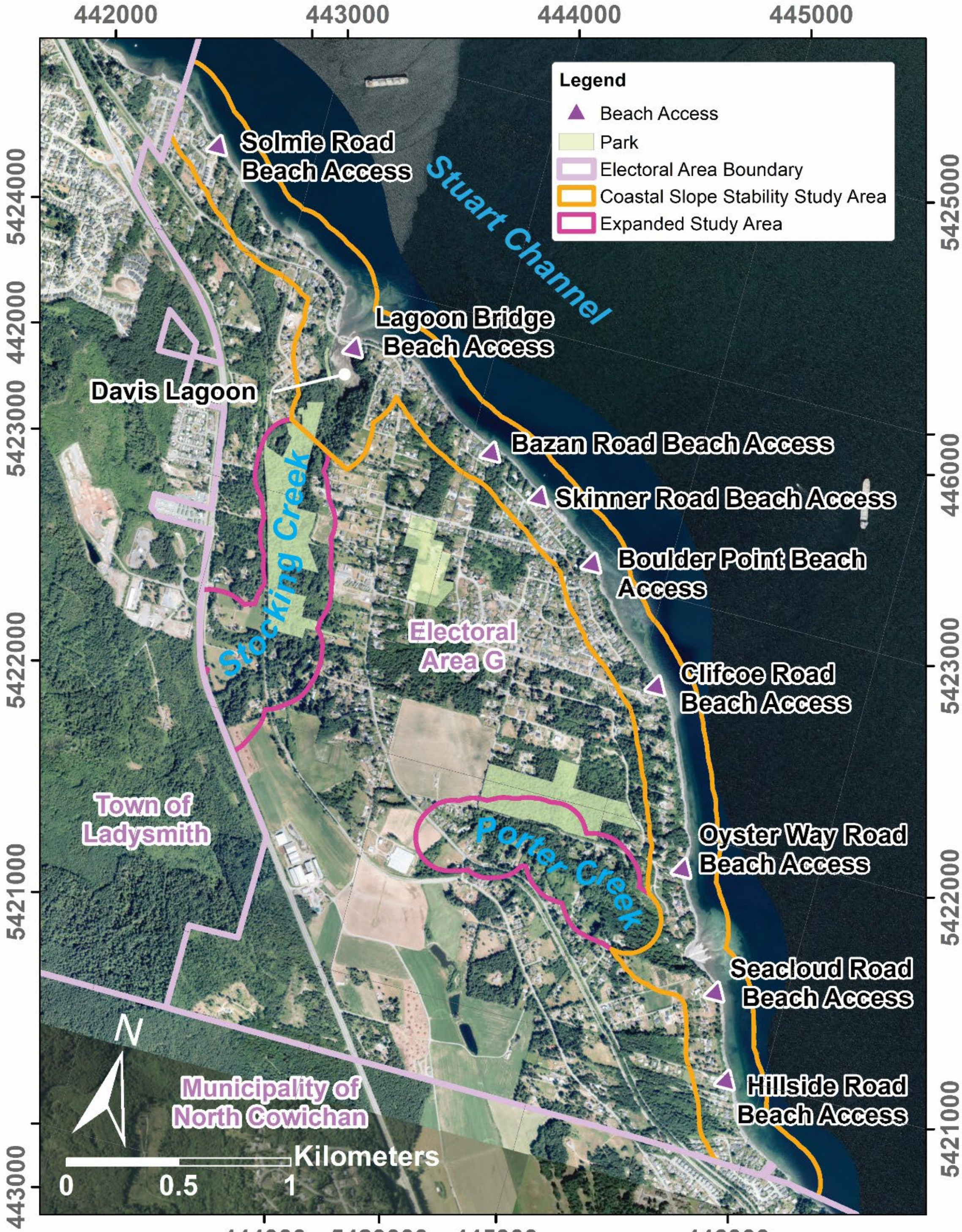

Figure 1. Study area map.

2.0 BACKGROUND

2.1 PHYSICAL SETTING

The approximately seven-kilometre long Saltair coastline is characterized by sand and gravel intertidal beach platforms of variable width, backed by coastal bluffs and interrupted by the mouths of Stocking and Porter Creeks and their associated estuarine environments (**Figure 1**). Davis Lagoon, at the mouth of Stocking Creek, is one of the few remaining lagoons on southeastern Vancouver Island (CVRD, 2017b). Relief within the coastal slope stability study area varies from sea level to 50 m and includes steep (> 35°) and moderately steep (27° to 35°) (Howes & Kenk, 1997) coastal bluffs and generally flat terrain inland from the crest of the slopes (classically known as flat-over-steep). Relief within the expanded study area (Stocking and Porter Creek valleys) increases in a seaward direction as the creeks becomes more incised.

The northwest-southeast trending coastline is on the relatively sheltered Stuart Channel within the larger Strait of Georgia. Fetch lengths (the distance over which wave-generating winds blow) vary from 10 to 20 km (Northwest Hydraulic Consultants, 2019). Tides are classified as mixed and semi-diurnal (i.e., two highs and lows of unequal height are experienced daily). The reported tidal range from nearby Chemainus Canadian Hydrographic Service Station 07455 is approximately 2.7 m (mesotidal regime; Canadian Hydrographic Service, 2021).

2.2 ADMINISTRATIVE SETTING

Saltair is part of the CVRD Electoral Area G and is a predominantly rural community (CVRD, 2017b). The coastline primarily comprises private land excepting existing rights-of-way, portions of Stocking Creek Park in Davis Lagoon, and public beach access points. Properties in the coastal slope stability study area are part of the Ocean Shoreline Development Permit Area, within which guidance is provided to landowners on various topics including vegetation management, drainage, beach access, and erosion control methods. Stormwater management requirements include: limiting runoff and impervious surfaces; assessment by a Qualified Professional in areas subject to erosion or ground instability; construction of runoff detention ponds or swales, sediment traps and basins to manage surface water; avoidance of discharge that could negatively impact groundwater; and avoidance of vegetation removal. No stormwater infrastructure exists in Saltair, and Stantec and Palmer understand the majority of runoff is routed through ditches and culverts prior to discharge into a receiving water body. Most residences have a septic tank and on-site disposal field rather than connection to a community-wide sewage collection and treatment system (CVRD, 2017a).

2.3 GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

Southern Vancouver Island is positioned along the Juan de Fuca and North America tectonic subduction zone, which trends northwest to southeast along the coast of British Columbia (BC) and is actively driven by crustal spreading along the Pacific Plate and Juan de Fuca spreading ridge. Much of the regional bedrock geology in the CVRD is derived from the tectonic process associated with the accretion and uplift of island terrains to the North American plate during the Mesozoic era during formation of coastal BC (Cui, Miller, Schiarizza, & Diakow, 2017). The Nanaimo Group spans the eastern coast of the CVRD, underlying the Saltair study area and extending inland up the Cowichan Valley to Lake Cowichan (Massey, Friday, Tercier, & Potter, 1991). This stratigraphic group includes a mix of undivided sedimentary rocks (boulder, cobble, and pebble conglomerates, coarse to fine sandstones, siltstone, shale, and coal) from the later Mesozoic era (Cui, Miller, Schiarizza, & Diakow, 2017) and was formed in the back basin of Vancouver Island during accretionary episodes. Outcrops of the volcanic Sicker Group (Nitinat Formation) are also mapped within the study area (Massey, Friday, Tercier, & Potter, 1991).

The study area is part of the Nanaimo Lowlands (Yorath, 2005). Thick unconsolidated sediments underlie much of the lowlands, providing a detailed record of late Quaternary environments (Clague, 1981). The study area has undergone multiple episodes of ice advance and retreat, and sea level has shifted in response to both tectonism and the timing and magnitude of isostatic response to glaciation. Most exposed sediments in the Strait of Georgia are assigned to the following lithostratigraphic units, from youngest to oldest: Salish sediments (postglacial), Fraser Glaciation Drift (till, complex outwash diamicton), and Cowichan Head Formation (fluvial, estuarine and marine sediments from the Olympia nonglacial interval) (Clague, 1976). Surficial materials for the Saltair study area have been mapped as:

- predominantly thick and continuous till deposits (Manson, Couture, & James, 2019) with high percentages of clay and silt (Blyth & Rutter, 1993 A; Blyth & Rutter, 1993 B) and smaller areas of glaciolacustrine and fluvial deposits (Blyth & Rutter, 1993 A);
- predominantly marine deposits, including glaciomarine materials, comprised of silt, clay, stony clay and a till-like mixture overlying. Smaller areas of ground moraine (till deposits of gravel, sand, and silt) are mapped and, in some locations, shown to be underlying marine deposits (Halstead, 1966); or
- predominantly deep (greater than one metre) moraine deposits with smaller areas of glaciofluvial, marine, and glaciomarine materials (Guthrie, 2005).

The coastal bluffs are predominantly unconsolidated sedimentary deposits and are subject to ongoing erosion. As the bluffs have receded in response to predominantly wave-action driven erosion at the toe of the slope, a beach platform has formed. Sub-aerial processes acting on the slopes include mass movement processes (e.g., creep, slides, flows) and transport processes resulting from open slope and channelized water-based erosion (e.g., wave splash, rain splash, overland flow). The relative importance of subaerial processes depends on the surficial geology, precipitation, vegetation, temperature, groundwater, and slope angle (Davidson-Arnott, Bauer, & Houser, 2019). The beach platform within the study area appears to be predominantly derived from bluff materials. Accretionary features associated with longshore transport and other littoral processes are largely absent with the exception of reworked depositional features at the mouth of Stocking and Porter Creeks. Both deltaic deposits and limited longshore transport deposits identified up to approximately 850 m south of the mouth of Porter Creek and 550 m north of the mouth of Stocking Creek, are visible in air photos. The beach platform is notably wider at Boulder Point south to the Clifcoe Road beach access.

The lower reaches of Stocking and Porter Creeks are incised into the thick surrounding unconsolidated sedimentary deposits in Saltair. Relief is approximately 2 m in the upper extent of the expanded study area and increases to 40 m in the lower extent of the expanded study area. The valleys are largely confined, v-shaped valleys, dominated by gullying processes. Porter Creek is a first order stream and Stocking Creek is a second order stream, where stream order is a topological ordering of streams and reflects a stream's distance from the source.

2.4 CLIMATE

The CVRD has a warm temperate climate with dry, warm summers (Köppen-Geiger Climate classification Csb; Kottek, Grieser, Beck, Rudolf, & Rubel, 2006). Annual daily average temperature recorded from 1981-2010 from nearby Environment Canada Station Nanaimo A is 10.1°C and average annual precipitation is 1165 mm (Government of Canada, 2021). A monthly summary of climate normal data is shown in **Figure 2**.

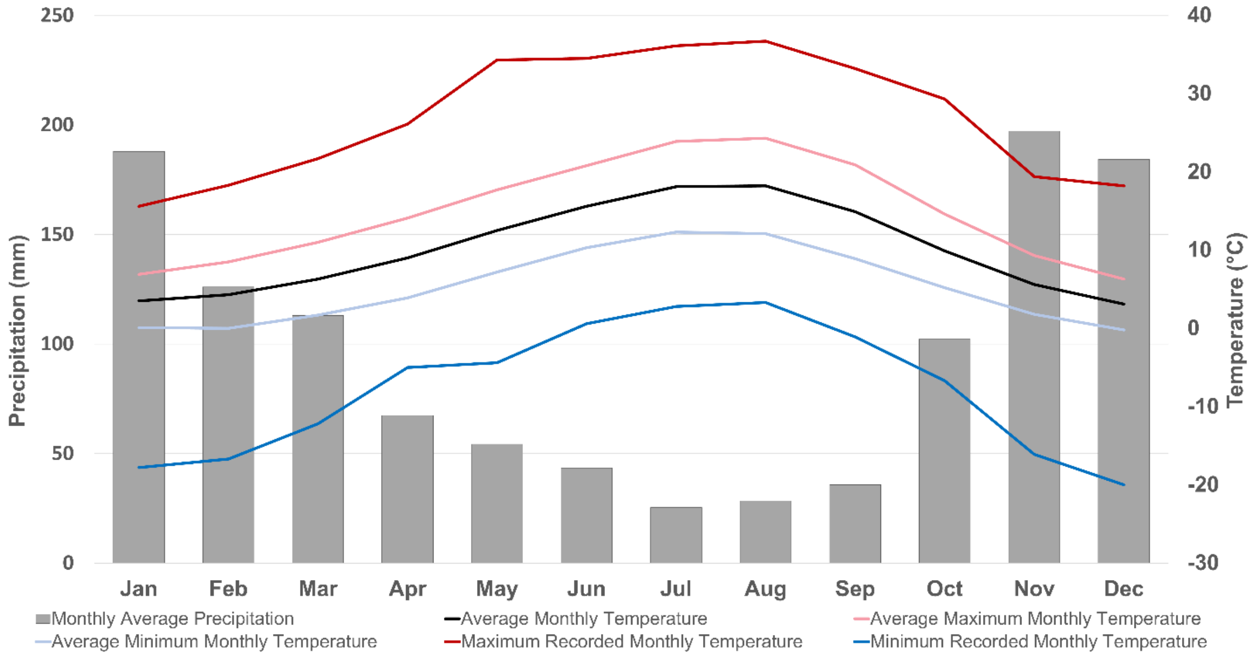

Figure 2. Climate normal data (1981-2010) for Environment Canada Station Nanaimo A (Government of Canada, 2021).

Local winds are modified by the topography and the region experiences primarily northwest through southwest summer winds and southeast winter winds (Northwest Hydraulic Consultants, 2019).

Recently in the northeastern Pacific and, more specifically, coastal BC, there has been a demonstrated increase in the frequency and intensity of extreme events linked to climate variability phenomena (e.g., El Nino, Aleutian Low-Pressure System, and the Pacific Decadal Oscillation) and climate change trends (Storlazzi, Willis, & Griggs, 2000; Ruggerio, Komar, McDougal, Marra, & Beach, 2001; Allan & Komar, 2006; Walker & Barrie, 2006; Cummings, 2007; Abeysirigunawardena & Walker, 2008; Walker & Sydneysmith, 2008). This increase may translate to higher winds, temporarily elevated sea levels, and higher significant wave heights and peak periods contributing to higher runup levels. Combined with global sea level rise predictions, total water levels[1] along the Saltair coastline are expected to continue trending upward. Higher total water levels may contribute to increased coastal erosion, shoreline retreat, flooding, saltwater intrusion into coastal wells and aquifers, ecosystem shifts, and impacts to infrastructure. In addition, an increase in the frequency and intensity of extreme events may lead to accelerated fluvial erosion along Stocking and Porter Creeks, and increased surface water runoff and altered groundwater levels and pathways, potentially exacerbating slope failures in the study area.

[1] A function of the interaction between tidal elevation, surge, and wave runup.

Due to the predictive nature of climate change modeling, there is considerable uncertainty in the projected rate and magnitude of sea level rise. Ausenco Sandwell (2011) reviewed a range of both planning and date-specific global sea level rise estimates and recommended BC sea level rise policy and adaptation planning adopt the sea level rise curve shown below in **Figure 3**, predicting 1 m sea level rise between the year 2000 and 2100. At the time of publication, a 1 m sea level rise projection between 2000 and 2100 was considered within the higher range of projections (Ausenco Sandwell, 2011). However, research on sea level rise is ongoing and sea level rise projections have been revised since the planning guideline was released. More recent peer-reviewed publications present a 2.5 m ‘extreme’ upper-bound scenario of global sea level rise by the year 2100 and an intermediate scenario of 1 m by the year 2100 (Sweet, et al., 2017). These same scenarios (including an additional 1.5 m ‘intermediate-high’ scenario) were used by Northwest Hydraulic Consultants (2019) in their sea level rise risk assessment.

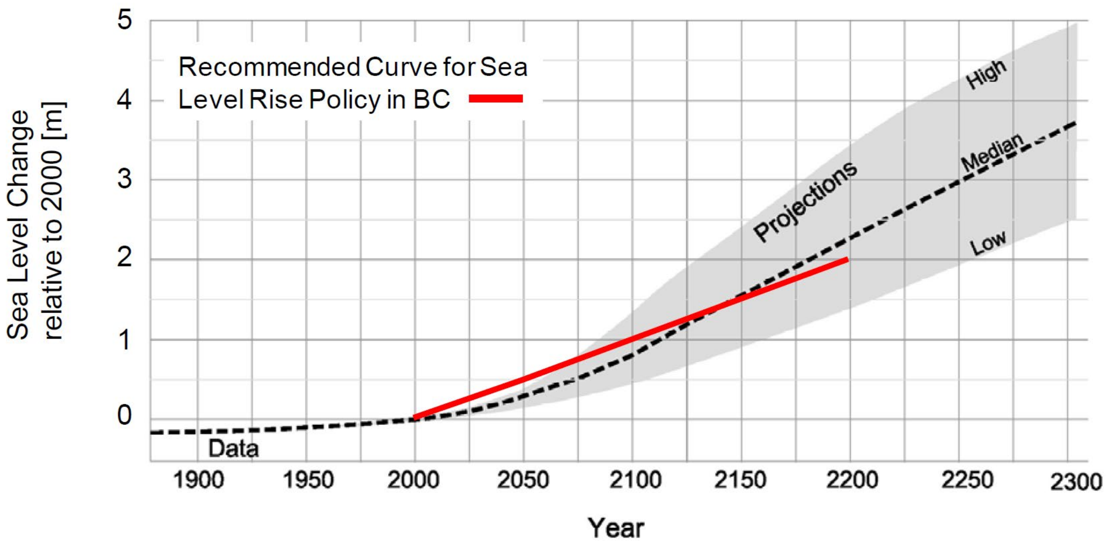

Figure 3. Recommended global sea level rise curve for planning and design in BC (Ausenco Sandwell, 2011).

Climate change projections for the CVRD predict: warmer temperatures; longer dry periods in summer months; more fall, winter and spring precipitation; a decrease in snowpack; and more intense extreme events (CVRD, 2017a).

3.0 METHODS

Stantec and Palmer conducted a primarily desktop-based assessment with the support of a two-day field program. The field program was restricted to the coastal slope stability study area. Setback recommendations were developed according to the Fahrböschung angle or angle of reach method (Heim, 1932) and adapted to consider future predicted sea level (i.e., shifting position of the toe of the slope), where applicable. Probability of occurrence of retrogressive landslides within the coastal slope stability study area was calculated. Recommendations for management of land use, drainage, and vegetation were sourced from local guidelines (e.g., Stewardship Centre for British Columbia, 2016).

3.1 REFERENCE REPORTS

Thirty geotechnical reports[2] provided by the CVRD were reviewed and contribute to our understanding of the coastal slope stability study area:

- Lewkowich Geotechnical Engineering Ltd. (2007). *4221 Solmie Road, Ladysmith, BC. Geotechnical Sites Observations – Redi-Rock Retaining Wall.* Memorandum, 31 July 2007.
- Levelton Consultants Ltd. (2009). *Geotechnical Assessment. Lots 25 and 26 – Clifcoe Road, Seaside Woods Estates. Saltair, BC.* Memorandum, 12 March 2009.
- C.N. Ryzuk & Associates Ltd. (2009). *Assessment of Foreshore Slope. Strata Lot 5, Clifcoe Road – Saltair, BC.* Letter Report, December 18, 2009.
- Lewkowich Engineering Associates Ltd. (2010). *Proposed Addition, 3729 Gardner Road, Ladysmith, BC. Geotechnical Review of D&L Ahola Residence Renovations & Additions Landscape Plan and Additional Construction Considerations.* Memorandum, 7 January 2010.
- Simpson Geotechnical Ltd. (2010). *Shoreline Erosion Protection Assessment, 11193 Old Chemainus Road, Chemainus, BC (Part of Lot 12, District Lot 34, Oyster District).* Memorandum, 12 April 2010.
- Lewkowich Engineering Associates Ltd. (2010). *3755 Gardner Road, Saltair, BC. Geotechnical Evaluation.* Memorandum, 26 April 2010.
- Ground Control Geotechnical Engineering (2010). *Geotechnical Engineering Assessment. Retaining Walls (Under Construction). 11101 Chemainus Road, Saltair, BC.* Memorandum, 26 June 2010.
- C.N. Ryzuk & Associates Ltd. (2010). *Assessment of Existing Retaining Structure. 3901 Linton Circle – Ladysmith, BC.* Memorandum, 23 July 2010.
- Lewkowich Engineering Associates Ltd. (2011). *Residential Development, 3857 Rumble Road, Chemainus (CVRD), BC. Geotechnical Slope Assessment.* Memorandum, 9 December 2011.
- Levelton Consultants Ltd. (2012). *Preliminary Geotechnical Assessment, Proposed Single-Family Residence, 3741 Gardner Road, Saltair.* Memorandum, 21 March 2012.
- Levelton Consultants Ltd. (2013). *Preliminary Geotechnical Assessment, Single Family Residence, 3695 Gardner Road (Ladysmith), BC.* Memorandum, 20 June 2013.
- Lewkowich Engineering Associates Ltd. (2013). *Residential Development, 3857 Rumble Road, Chemainus, BC. Field Reviews During Development.* Memorandum, 30 September 2013.

[2] Two reports were duplicates.

- Lewkowich Engineering Associates Ltd. (2014). *Residential Strata Development 11255 Chemainus Road, Saltair, BC. Legal: Lot 2 & 3, Plan 7540 and Lot A Plan 8823 All Within District, Lot 41, Oyster District. Geotechnical Assessment – Post Development.* Memorandum, 21 August 2014.
- Lewkowich Engineering Associates Ltd. (2014). *Foresore (sic) Protection, 10597 Whitecap Place, Ladysmith, B.C. Geotechnical Site Observations – Foreshore Assessment – Post Construction.* Report, 21 November 2014.
- Ryzuk Geotechnical Engineering & Materials Testing (2015). *Foreshore Slope Assessment, 3258 Dogwood Road – Saltair, BC.* Letter Report, 7 May 2015.
- Lewkowich Engineering Associates Ltd. (2015). *10735 Roacky Beach Road, Ladysmith, BC. Preliminary Geotechnical Assessment; Slope Stability and Tree Removal.* Memorandum, 16 October 2015
- Lewkowich Engineering Associates Ltd. (2015). *Existing Residence & Foreshore Improvements. 11149 Chemainus Road, Ladysmith, BC. Summary Discussions & Geotechnical Assurance Re: Cowichan Valley Regional District Development Permit Application.* Letter Report, 4 March 2015.
- Lewkowich Engineering Associates Ltd. (2016). *Foreshore Protection, 3755 Gardner Road, Saltair, B.C. Geotechnical Site Observations – Foreshore Assessment.* Report, 1 February 2016.
- Lewkowich Engineering Associates Ltd. (2016). *11195 Chemainus Road, Saltair, BC. Comment on Erosion Protection.* Memorandum, 18 March 2016.
- Saturna Studios Planning + Design (2016). *Footing Coverage on Slope.* Plan Drawings, 10 May 2021.
- Lewkowich Engineering Associates Ltd. (2016). *Residential Development, 11199 Chemainus Road, Saltair (CVRD), BC. Geotechnical Slope Assessment.* Letter Report, 3 May 2016.
- Lewkowich Engineering Associates Ltd. (2018). *Lot 4 Stuart Avenue, Saltair, BC. Preliminary Geotechnical Assessment; Tree Management Plan.* Memorandum, 23 April 2018.
- Lewkowich Engineering Associates Ltd. (2019). *Staircase Installation, 4221 Solmie Road, Saltair, B.C. Geotechnical Site Observations – Coastal Slope Assessment.* Report, 18 March 2019.
- Lewkowich Engineering Associates Ltd. (2019). *1101 Chemainus Road, Ladysmith, BC. Geotechnical Hazard Assessment – Steep Slope & Lock-Block Wall Construction.* Letter Report, 16 May 2019.
- Lewkowich Engineering Associates Ltd. (2019). *Two (2) Lot Residential Subdivision. 3549 Clifcoe Road, Ladysmith, BC. Geotechnical Assessment Report.* Report, 5 July 2019.
- Lewkowich Engineering Associates Ltd. (2019). *1101 Chemainus Road, Ladysmith, BC. Geotechnical Hazard Assessment – Steep Slope & Lock-Block Wall Construction.* Letter Report, 8 August 2019.
- Ryzuk Geotechnical Engineering & Materials Testing (2019). *Proposed Seawall – 11117 Chemainus Road – Ladysmith, BC. Preliminary Seawall Upgrades/Construction Memorandum.* Memorandum, 20 November 2019.
- TRE Environmental Services (2021). *Geotechnical Stability Assessment of PID 003-492-036 and Adjacent Land Parcels.* Letter Report, 23 November 2021.

3.2 DESKTOP MAPPING

Within the coastal slope stability study area, Stantec and Palmer conducted timeseries mapping of the coastline using historical air photos to estimate a rate of average annual coastal recession, distinguish areas of previous instability within the study area, gain understanding of local drivers of slope instability beyond coastal erosion, and guide the development of setback recommendations. Mapping scale was limited to the resolution of available imagery.

Three years of historical air photos were reviewed and mapped: 1932, 1974, and 2012. Air photos from 1932 and 1974 were viewed in stereo using a mirror stereoscope. Air photos from 2012 were viewed digitally in stereo using Summit Evolution software. Air photos from 1932 and 1974 were georectified to the 2012 air photo. Both the shoreline and potential landslide features were digitized in ArcGIS for each year.

In addition, oblique imagery and video for the coastline available for 1989 and 2004 from ShoreZone mapping (Coastal and Oceans Resources, 2021), 2017 CVRD drone imagery, 2019 GeoBC orthophotos, and Google Earth imagery (1985-2020) were reviewed. See **Table 1** for a summary of metadata (as available) for imagery used in the analysis.

A 1 m resolution light detection and ranging (LiDAR) digital elevation model (DEM) was generated for both the coastal slope stability area and the expanded study area using 2019 LiDAR from GeoBC (2022). These data were used to generate 1 m contours, a slope map, and a hillshade model to support analysis.

Landslides sufficiently large to map individually were digitized in ArcGIS on the LiDAR basemap and, in the coastal slope stability study area, compared to features identified in air photographs. A landslide polygon layer was created for larger retrogressive landslides in flat-over-steep terrain.

Table 1. Metadata for air photos used in the analysis

Source	Date (yyyy/mm/dd)	Roll	Frame	Nominal Scale	Range Total Root Mean Square Error in Georectification	Colour I / Black and White (B&W)	Comment
National Air Photo Library	1932/09/05	A4503	19-25	1:20,000	0.38 m – 4.35 m	B&W	-
University of British Columbia Air Photo Library	1974/10/07	BCC105	88-104	1:4,800	1.18 m – 7.55 m	C	-
ShoreZone	1989	-	-	-	-	C	Oblique video
ShoreZone	2004/07/29	-	-	-	-	C	Oblique video and photos
iGi Consulting Inc.	2012	-	-	0.3 m resolution	-	C	-
Cowichan Valley Regional District	2017/07/10	-	-	-	-	C	Drone imagery
Cowichan Valley Regional District	2019	-	-	0.15 m resolution	-	C	-
Google Earth	1985-2020	-	-	Varying	-	C	-

3.3 FIELDWORK

Stantec and Palmer carried out a two-day field reconnaissance to corroborate interpretations of coastal slope stability within the coastal slope stability study area, to gain insight into processes indistinguishable at the desktop level, and to facilitate targeted assessment of mapped potential landslides. More specifically, the field crew walked the beach within the study area and made non-invasive ground-based observations to identify any evidence of erosion, slope movement, or seepage, and to record shoreline conditions. Field investigation was limited to areas of public access (e.g., the provincially owned foreshore zone, public beach access points), excepting a single lot where property owners explicitly invited the Stantec and Palmer team to examine their slope. Field dates were scheduled during predicted tide windows near to, and lower than, the Lower Low Water Large Tide[3] for the region to enable greatest possible observation of the beach face (**Table 2**).

Table 2. Tides for Canadian Hydrographic Service Station Chemainus 07455 (Canadian Hydrographic Service, 2021).

Tides for Canadian Hydrographic Service Station Chemainus 07455	Height (metres above Chart Datum)
Predicted Low Tide – 27 May 2021	-0.04
Predicted Low Tide – 28 May 2021	-0.11
Lower Low Water Large Tide	-0.06
Lowest Astronomical Tide	-0.25

3.4 COASTAL SETBACK DISTANCES

Stantec and Palmer initially used the BC provincial flood hazard land use management guidelines (MFLNRORD, 2018) to calculate setback distances given a 1 m sea level rise (sea level rise was specified by the CVRD). However, this approach did not adequately address retrogressive landslides observed in the LiDAR imagery. Therefore, a modified Fahrböschung angle or angle of reach method (Heim, 1932) was adopted and applied using adapted approaches from Cruden, Tedder, and Thomson (1989) for establishing setbacks in the Interior Plains.

[3] The average of the lower low waters from each year over 19 years of tide predictions

The Fahrböschung angle was defined by Heim (1932) as the line connecting the crest of a landslide source to the toe of the deposit, measured along the approximate centerline of motion. It is described by:

$$TAN(\alpha) = \frac{H}{l} \quad (1)$$

Where α is the Fahrböschung angle, H is the vertical difference between the landslide crest and the base of the landslide toe, and l is the horizontal travel of the landslide between the same two points.

The Fahrböschung angle was calculated separately for all mapped retrogressive landslides. The lowest measured Fahrböschung angle was inferred to be the limit of possible retrogression of slopes as a result of landsliding and was used to establish setbacks in relatively homogenous terrain units.

Cross-sections were established within the study areas in a manner that accounted for shoreline/valley geometry and topographic variation. A plane was projected through each cross-section using the minimum calculated Fahrböschung angle from the horizontal location of predicted future water level given a 1 m sea level rise and assuming the elevation of the toe of the slope remained unchanged (**Figure 4**).

The water level for the 1 m sea level rise scenario relied on the intermediate sea level rise scenario (1.0 m sea level rise between 2000 and 2100) from Northwest Hydraulic Consultants (Northwest Hydraulic Consultants, 2019) and accounted for a Higher High Water Large Tide[4], the 200-year instantaneous maximum storm surge wave runup, global sea level rise, and regional sea level adjustment to account for isostatic and tectonic effects (Northwest Hydraulic Consultants, 2019).

The change in horizontal position of the current toe versus future toe of the slope is shown as R in **Figure 4**. If a change in future water level was not predicted to interact with the toe of the slope or if within the expanded study area, the Fahrböschung was projected from the existing toe.

The calculated setback was defined where the projected plane daylighted on the upslope portion of the cross-section. Beyond this calculated setback, Stantec and Palmer applied an additional 15 m (e.g., toe erosion allowance) to align with existing standards (Ontario Ministry of Natural Resources, 2001; MFLNRORD, 2018).

Both the calculated setback and the calculated setback plus 15 m are depicted in deliverable summaries (**Appendix D** and **Appendix E**).

As tsunami hazard within the Strait of Georgia is not considered to be significant, recommendations do not include tsunami setbacks and elevations.

[4] The average of the higher high waters from each year over 19 years of tide predictions

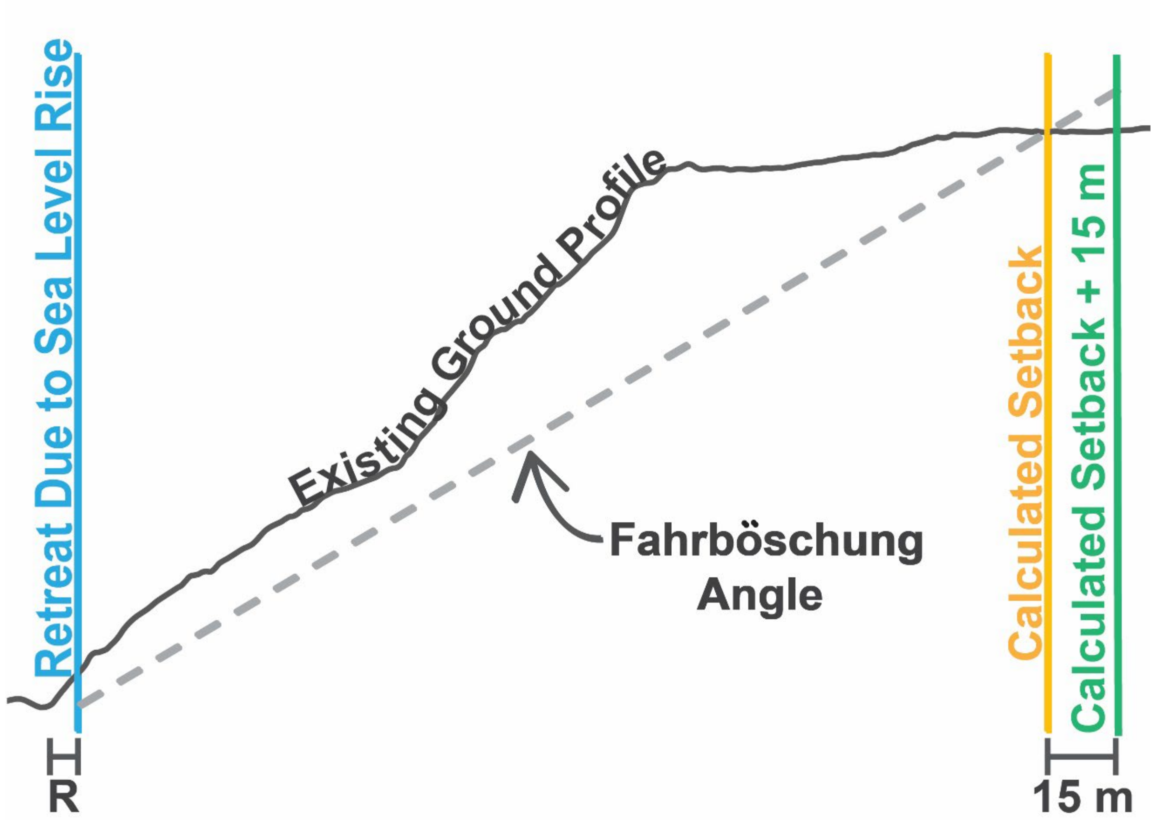

Figure 4. Diagram showing components contributing to recommended coastal slope stability setbacks.

3.5 HAZARD CALCULATIONS

Stantec and Palmer calculated an annual probability of occurrence (PO) for retrogressive landslides in flat-over-steep terrain, similar in character to historical mapped slides, within the coastal slope stability setback zone. A hazard term, $H_{T,S}$, for each landslide was calculated where $H_{T,S}$ is the product of the probability of occurrence of a landslide in time H_T, and space H_s:

$$H_{T,S} = H_T \times H_s \tag{2}$$

H_s was determined by dividing the area occupied by an individual landslide by the total area of the setback zone. H_T was determined by estimating an age range within which all mapped landslides occurred (based on morphology, vegetative cover, and field evidence), and assuming a stochastic distribution of ages for landslides within the overall range. Each landslide was assigned a random age within that range across 10 separate iterations of possible $H_{T,S}$. Each iteration was used to calculate a separate $H_{T,S}$, and the PO for each iteration was calculated as:

$$PO = 1 - \left(\left(1 - H_{T,S1}\right) \times \left(1 - H_{T,S2}\right) \times \dots \left(1 - H_{T,Sn}\right)\right) \tag{3}$$

The final reported PO was the average of all individual iterations of PO.

3.6 ASSUMPTIONS & LIMITATIONS

Interpretations made in this report are subject to the following limitations:

1. Desktop analyses were limited to the scale and resolution of available air photos and LiDAR data. Beyond this, lack of detection of slope stability features may have occurred due to the presence of dense vegetation, relatively lower LiDAR point density on the bluff and creek valley walls, and/or areas of shadow or over-exposure in the imagery.
2. Field access was limited to the provincially owned foreshore zone (i.e., the beach) and other public areas except for a single lot where property owners permitted crew access. Dense vegetation and/or other obstacles may have obscured interpretation of indicators of slope instability from the available vantage points.
3. Acquisition and assessment of subsurface information and detailed slope stability modeling were beyond the scope of this work.
4. PO calculations are based on the coastal slope stability study area.

4.0 RESULTS

4.1 DESKTOP MAPPING

4.1.1 Air Photo Review

Time series analysis of air photos was limited to the coastal slope stability study area. Air photos from 1932 were poor resolution, making it difficult to discern potential landslide features. Both 1974 and 2012 offered better resolution and enabled delineation of potential landslide features. However, confidence in the identified features was low due to dense vegetation cover on the coastal bluffs and due to the scale of the area of interest (i.e., a narrow band of bluffs [3 m to 140 m width along sampled cross-sections, 46 m width on average]). Potential landslide features were delineated where bluff geometry suggested past failures may have occurred (e.g., scalloped shape) and in areas of observed vegetation change where change was not obviously related to development. Based on the air photo review, the most potential landslide features were delineated between Boulder Point and Porter Creek and on valley walls at the mouth of Stocking and Porter Creeks.

Though the 1932 air photos are poor resolution, the air photo set provided valuable insight to the progression of development within the study area over time. Widespread land use change and limited opportunity for control points on the seaward portion of the imagery precluded accurate georeferencing of historical air photos. Local measurement of up to 5 m of potential coastal recession between air photo years is within the uncertainty of georeferencing and is not supported by qualitative comparison by Stantec and Palmer. Systematic coastal recession would have resulted in prominent erosional scars and unvegetated bluffs, neither of which were observed in the imagery. As such, no rate of average annual coastal recession was established.

4.1.2 LiDAR Review

The ability to confidently map small translational landslide features using LiDAR is limited. However, 14 retrogressive landslide features were identified within the coastal slope stability study area and 12 retrogressive landslide features were identified within the expanded study area (**Figure 5**). The delineated polygons represent landslide boundaries or the boundary of assemblages of landslides, and the areas within are interpreted to have experienced historic ground movement. Further retrogression of the identified landslide features is possible, depending on site-scale geological, geomorphological, and hydrological controls that cannot be assessed at this level of study.

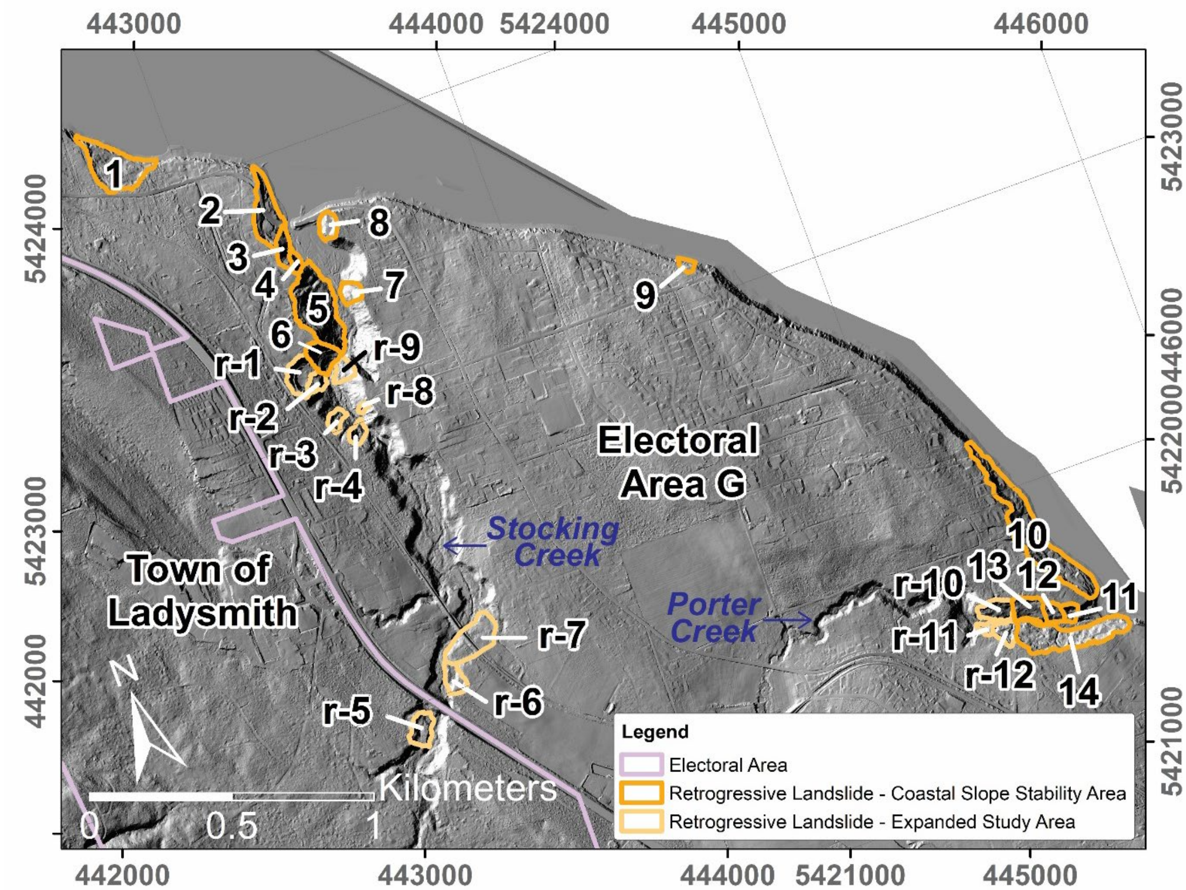

Figure 5. Mapped retrogressive landslides.

4.2 FIELDWORK

Fieldwork was conducted within the coastal slope stability study area. A summary of field observations is provided in the Field Observation Mapbook (Appendix B) and the corresponding photo log (Appendix C; photo locations shown in Appendix B). This documentation includes a summary of all higher confidence slope stability observations, photos of the beach face, and observed stormwater outfalls. Also included are notable observations from the CVRD-supplied geotechnical reports.

Coastal erosion within the coastal slope stability study area is predominantly mitigated by riprap revetments, lock block structures, or seawalls (**Figure 6**). Relatively few unprotected, natural shoreline segments remain. In the majority of remaining natural shoreline segments, erosion and undercutting (0.3 m to 1.8 m) was observed at the base of the bluff (**Figure 7**). In addition, failure of some mitigation works was observed (**Figure 8**).

Pistol butt trees are common. This growth pattern, where the base of the tree has thickened and curved, is a result of the tree attempting to maintain an upright position when subjected to relatively slow ground movement.

No outcrops of bedrock were observed. Surficial materials exposed along the shoreline were predominantly consolidated till with a silty sand matrix and pebble to cobble sized inclusions. A relatively higher clay content was observed in surficial materials textured on the west slope of Davis Lagoon, and a clay seam was observed at two locations between the Gardner Road and Clifcoe Road beach access. Seepage was observed at the clay seam at the western location. This location is indicated in the Field Observation Mapbook (**Appendix B**). The stratigraphy of the coastal bluff is exposed at a landslide located below the intersection of Stuart Road and Seaview Crescent. At the time of inspection, the failure was 20 m wide with a 6 m high scarp. Tills were observed to be overlain by gently dipping laminar sands. Above the laminations, a clay-rich deposit was observed (the eastern one of the two clay seams observed between Gardner Road and Clifcoe Road beach access points). A change in the till composition was noted where the lower extent of exposed till appeared to be more compact and of blue-grey appearance and the lower till was less compact and of a browner colour. Seepage was observed at the contact between the upper and lower portions of the till. Stratigraphy across the study area is expected to vary and the above-described section is expected to be representative only of the subsurface conditions immediately adjacent to the failure. However, review of groundwater well lithology data from the BC Groundwater Wells and Aquifers database reveals similar lithological descriptions throughout the study area (FrontCounterBC, 2021). In some instances, multiple clay layers are described (e.g., well tag 63710).

Figure 6. Example erosion mitigation observed along the study area shoreline.

Figure 7. Erosion and undercutting of natural shoreline segments.

Figure 8. Observed undercutting of a seawall within the study area with consolidated till visible below concrete footing (left). Shallow landslide and failed retaining wall/seawall (right).

Figure 9. Observed stratigraphy at the landslide below the intersection of Stuart Road and Seaview Crescent. Gently dipping laminar sands are shown on the left, transition from blue-grey (lower extent) to brown (upper extent) till shown on the right.

Numerous stormwater discharge and stream outlet points were observed along the bluff. Uncontrolled stormwater discharge onto the coastal bluff was observed at two locations: (1) at the above-described landslide below the intersection of Stuart Road and Seaview Crescent; and (2) at the Bazan Road beach access. Uncontrolled stormwater discharge at these locations was inferred to be contributing to local slope instability.

Bluff height varies across the study area. It is notably higher on the slopes within Davis Lagoon (approximately 30 m high) and from Boulder Point to just north of the junction of Rocky Beach Road and Oyster Way Road (approximately 20 m high). Interpretation of bluff slope stability was challenging in places due to dense vegetation and limited access. Both hydrophilic (water-loving) vegetation and seeps were observed in some locations. Observed seepage locations are identified in the Field Observation Mapbook (**Appendix B**).

The majority of landslides observed in the field were shallow landslides on over-steepened portions of the coastal bluff. Notable observed landslides that did not fit this description include:

- A landslide on the western slope of Davis Lagoon where a large block was deposited at the base of the slope. Field-textured surficial materials had higher relative clay content and seepage was observed on the slope (Photo 009 of the field photo log, **Appendix C**)
- A landslide observed on private property just south of Gardner Road beach access on a portion of the notably higher bluff segment (Photo 022 of the field photo log, **Appendix C**)
- The above-described failure below the intersection of Stuart Road and Seaview Crescent suspected to be related to uncontrolled stormwater drainage (Photo 023 of the field photo log, **Appendix C**)
- A failure adjacent to (immediately south of) the failure below the intersection of Stuart Road and Seaview Crescent (Photo 024 of the field photo log, **Appendix C**)

The landslides suggest adverse geology, seepage, and uncontrolled stormwater runoff also drive slope instability within the study area.

Driftwood accumulations at the base of the bluff are common (**Figure 10**). Although they help protect the shoreline from wave attack, they are transient features subject to longshore or offshore transport. Large woody debris can also contribute to shoreline erosion through percussive wear during high water levels.

Figure 10. Driftwood accumulations in the backshore.

Though no fieldwork was conducted for the expanded study area, based on review of public imagery, bedrock outcrops are present at Stocking Creek waterfall. In addition, according to groundwater well lithology data from the BC Groundwater Wells and Aquifers database when bedrock was encountered, depth to bedrock generally decreased in an inland direction within the expanded study area (**Figure 11**).

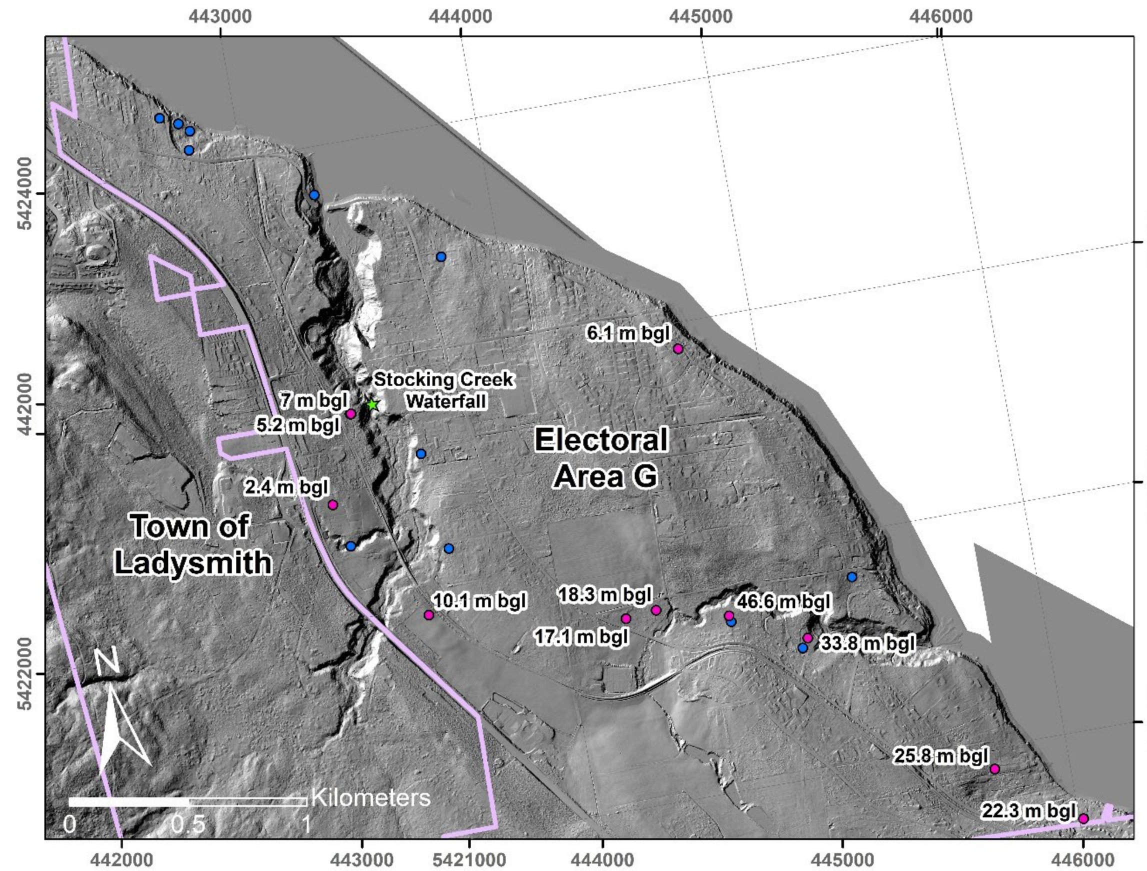

Figure 11. Water wells adjacent to the study area (FrontCounterBC, 2021). Water wells are shown in blue if no bedrock was encountered and shown in pink if bedrock was encountered. Water wells with record of bedrock are labeled with associated depth to bedrock in metres below ground level (m bgl). The location of Stocking Creek waterfall is also shown.

Stantec and Palmer also found public record of a shallow landslide that occurred in the expanded study area at the end of Knudsen Road (**Figure 12**). According to David Judson (personal communication, 17 January 2022), President of the Ladysmith Sportsmen Club, the failure occurred in 2007 following heavy winter precipitation on a slope over-steepened from the dumping of refuse. Failure is also attributed to an improperly built stormwater system (personal communication, Kate Miller, 4 February 2022).

Figure 12. The 2007 landslide viewed downhill from the end of Knudsen Road into Stocking Creek. Image from the Chemainus Rod and Gun Club (2022).

4.3 COASTAL SETBACK DISTANCES

Shallow surficial landslides were common along the coastal bluffs throughout the study area and are reported in the expanded study area. While these will continue to be an ongoing maintenance challenge for landowners, larger retrogressive landslides that involve considerable flat terrain inland of the crest of slope present a separate, more significant hazard. The recommended setback distances were defined by the lowest measured Fahrböschung angle for the retrogressive landslides delineated in the coastal slope stability study area (11.3°, **Table 3**). Though Landslides r-6 and r-7 in the expanded study area exhibit a lower Fahrböschung angle (8.9° and 5°, respectively), there remains uncertainty in the providence of the features (e.g., possible fluvial terrace) and we recommend further investigation of the feature prior to any revision of setbacks. Setbacks, shown as a dashed line adjacent to the feature, were adjusted at cross-section r-17 to ensure Landslide r-7 was captured within the setback zone.

Observed surficial geology was relatively consistent across the study area and Stantec and Palmer were unable to meaningfully differentiate areas of stable terrain from areas that included retrogressive landslides. No bedrock control was observed in the field, which otherwise may have reduced the setback for specific locations. However, based on both public imagery indicating rock outcropping at Stocking Creek waterfall and water well records (**Figure 11**; FrontCounterBC, 2021), we suspect bedrock is near surface on cross-section r-3 in the expanded study area. Confirmation of presence and depth to bedrock at this cross-section could justify a reduction of the recommended setback zone. The setback here is correspondingly mapped with a dashed line.

The reader is referred to **Appendix D** for a mapbook showing recommended development setbacks for the study areas and **Appendix E** for cross-sectional data used to develop setbacks. A one-metre sea level rise scenario may mean, for this study, that some properties are considered coastal where they may not have been previously (e.g., in Davis Lagoon).

Table 3. Fahrböschung angle for mapped landslides.

Landslide	H (m)	*l* (m)	Fahrböschung Angle (°)	Comments
1	27.7	138.0	11.3	
2	24.4	109.4	12.6	
3	30.4	61.0	26.5	
4	31.8	62.5	27.0	
5	41.9	140.7	16.6	
6	37.4	111.5	18.5	
7	34.0	70.7	25.7	
8	21.3	60.6	19.4	Potential low angle landslide (possible fluvial terrace)
9	14.1	42.7	18.3	
10	24.7	84.6	16.3	
11	21.0	67.2	17.4	
12	21.1	65.7	17.8	
13	19.6	67.9	16.1	
14	25.3	100.7	14.1	
r-1	36.7	142.9	14.4	Potential low angle landslide (possible fluvial terrace)
r-2	18.2	55.6	18.1	
r-3	29.3	71.7	22.2	
r-4	31.9	70.5	24.3	
r-5	18.0	73.6	13.7	Within the jurisdiction of the Town of Ladysmith
r-6	11.0	70.5	8.9	Potential relict, low angle landslide (possible fluvial terrace)
r-7	8.7	98.6	5.0	Potential relict, low angle landslide (possible fluvial terrace)
r-8	25	44.6	29.3	
r-9	25.5	67.3	20.8	
r-10	19.3	71.4	15.1	
r-11	18.4	38.0	25.8	
r-12	19.6	84.1	13.1	

4.4 PROBABILITY OF OCCURRENCE

Probability of occurrence was calculated within the coastal slope stability study area. Given the scope of work, Stantec and Palmer had limited ability to reliably determine the activity state of each landslide, particularly as most were pre-historic. The most recent landslide was estimated to have occurred within the last 5 years based on 2016 Google Earth imagery (**Figure 13**). The oldest landslide was estimated to have occurred within the last 500 years based on the muted features observed in LiDAR and gullying processes which have had sufficient time to divide the original landslide body (**Figure 13**). The remaining 12 landslides were variously estimated to be between 50 and hundreds of years old based on vegetative growth, the air photograph record, morphology on the LiDAR imagery, and our experience with similar landslides elsewhere.

H_T was therefore estimated for each landslide using a random distribution of activity states between five and 500 years (see the **Methods** section for an explanation).

The results of the PO calculation appear statistically robust with low variability (a standard deviation across 10 iterations of 0.00079).

The annualized PO of a landslide similar to those mapped within the calculated setback zone is estimated at 0.0019 (**Table 4**) or occurring with a return period of approximately 1:530. Typical residential buildings can be expected to last between 50 and 100 years. There is approximately a 9% chance a landslide of similar character and magnitude will occur within the study area in any run of 50 years and a 17% chance in 100 years (**Table 5**), less than 2% in any decade, or 61% in a run of 500 years.

PO informs the hazard term ($H_{T,S}$) of the risk equation where Risk (R) is defined as:

$$R = \sum(H_T * H_S)\,(E_{TS} * V * E_C) \qquad (4)$$

Where E is an element at risk (e.g. house, road, facility, individual); H_T is the temporal probability that a hazard that could impact E will occur; H_S is the spatial probability that that a hazard that occurs would reach E; E_{TS} is the probability that the location threatened by a hazard ($H_{T,S}$) will be occupied (this is held at 1 for homes and infrastructure); V is the vulnerability (e.g. probability of loss of life, proportion of loss of infrastructure) of element at risk; and E_C is the cost (e.g. number of lives, value of buildings, value social license) of the element at risk.

While risk is not calculated herein, Stantec and Palmer infer that the estimated annualized PO of 0.0019 within the coastal slope stability setback zone means that calculated risk is likely to be unacceptable according to the CVRD Natural Hazard Risk Tolerance Policy (CVRD, 2019).

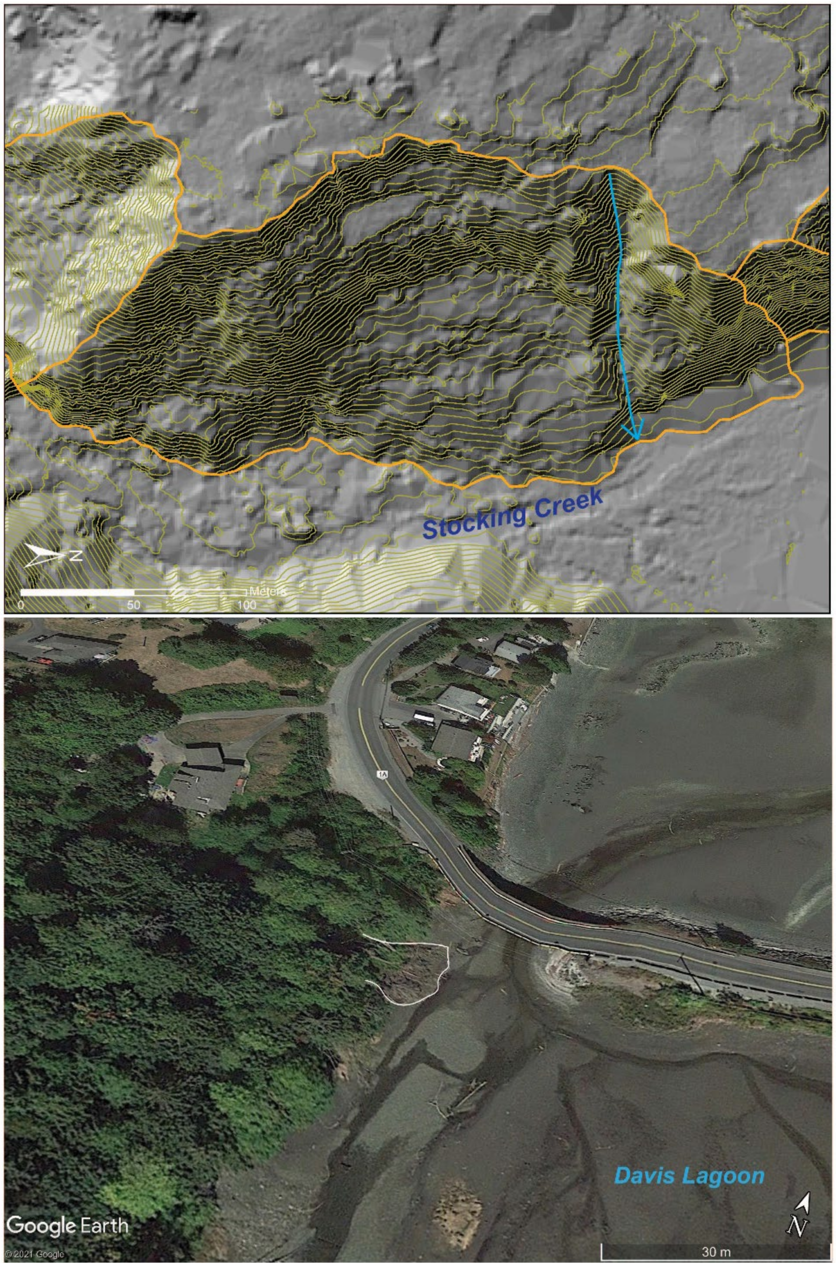

Figure 13. Landslide delineated in orange estimated to have been active within the last 500 years due to observed gully feature shown by blue arrow (above). Landslide estimated to have been active within the last 5 years due to observed deposit delineated in white in 2016 Google Earth imagery but not in available years of previous imagery (below).

Table 4. PO outcome for 10 randomly generated scenarios.

LS	Area (ha)	H_S	1	2	3	4	5	6	7	8	9	10
			H_T	H_T	H_T	H_T	H_T	H_T	H_T	H_T	H_T	H_T
1	2.59	0.028455	0.005682	0.002915	0.002326	0.004274	0.062500	0.045455	0.002695	0.002591	0.012346	0.004098
2	1.72	0.018966	0.003040	0.002525	0.002262	0.003003	0.002179	0.002695	0.004587	0.003663	0.003413	0.002976
3	0.57	0.006246	0.002941	0.002985	0.002217	0.005319	0.002387	0.008065	0.002242	0.003236	0.002075	0.005814
4	0.25	0.002729	0.083333	0.041667	0.003049	0.005435	0.002755	0.003448	0.055556	0.002096	0.062500	0.015873
5	3.44	0.037835	0.003155	0.002088	0.018519	0.003356	0.002976	0.002882	0.004149	0.003195	0.007692	0.007194
6	0.89	0.009776	0.003067	0.002053	0.002000	0.004149	0.004132	0.003717	0.002833	0.002985	0.003413	0.142857
7	0.46	0.005044	0.003367	0.009709	0.004484	0.016949	0.014085	0.050000	0.013889	0.007692	0.002551	0.005882
8	0.50	0.005471	0.005236	0.040000	0.027027	0.007937	0.002326	0.002604	0.033333	0.008130	0.007519	0.003236
9	0.20	0.002208	0.003086	0.003268	0.007519	0.002273	0.002183	0.013699	0.002950	0.020408	0.003012	0.003077
10	4.61	0.050644	0.006289	0.028571	0.002217	0.002907	0.025641	0.002740	0.017857	0.010000	0.002439	0.002825
11	0.30	0.003247	0.016667	0.007246	0.003922	0.066667	0.004149	0.007299	0.007692	0.003861	0.002203	0.007576
12	0.41	0.004545	0.015873	0.006667	0.004717	0.002000	0.003367	0.002137	0.002208	0.003984	0.009009	0.027027
13	0.85	0.009375	0.002132	0.008333	0.010101	0.007576	0.002545	0.004587	0.002375	0.002137	0.013158	0.003497
14	2.93	0.032199	0.002604	0.005882	0.002558	0.007874	0.007246	0.002146	0.004292	0.002141	0.010870	0.002924
		PO	**0.001215**	**0.002404**	**0.001361**	**0.001225**	**0.003664**	**0.002129**	**0.001871**	**0.001073**	**0.001628**	**0.002391**
											Average PO	**0.001896**
											Standard Deviation	**0.000791**

Table 5. Exceedance probability for retrogressive landslides in the flat-over-steep terrain within the calculated setback zone in the coastal slope stability study area.

	Number of Years				
	1	10	50	100	500
Exceedance Probability	0.001896	0.018802	0.090538	0.172880	0.612882
Exceedance Probability (%)	0.19	1.88	9.05	17.29	61.29

5.0 DISCUSSION & RECOMMENDATIONS

5.1 SETBACK DISTANCES

Most observed landslides were shallow failures on over-steepened portions of the coastal bluffs that represent long term property maintenance issues. Over-steepening can be driven by undercutting and erosion of the slope toe by coastal processes. In some areas, over-steepening is attributed to development activities (e.g., road cuts, beach access). In addition, adverse geology, seepage, and uncontrolled stormwater runoff are also interpreted to drive slope instability within the study area. These types of failures were challenging to identify at a desktop level and understanding of slope stability issues along the Saltair coastline was much improved through field reconnaissance. As stated in the **Results**, various structures help mitigate erosion along most of the coastline. Few natural shoreline segments remain; those that do are eroding. Shoreline protection measures may help to mitigate these effects. While hard structures serve to protect the immediate shoreline from erosion, they can refocus erosive energy elsewhere (e.g., adjacent natural shoreline segments) and can, over the longer term, contribute to shoreline degradation by starving the beach of its sediment source. Use of nature-based methods (e.g., Green Shores (Stewardship Centre for British Columbia, 2021), West Coast Environmental Law (2016)) are recommended to facilitate dissipation of wave energy, and reduction of storm surge and flooding. Nature-based approaches intend to restore habitat, maintain sediment transport processes, and avoid or reduce cumulative impacts associated with widespread shoreline hardening (including prevention of the landward transgression of natural habitats with sea level rise).

- Design of shoreline protection measures, whether nature-based or traditional, should be undertaken by a Qualified Professional[5].

[5] A member of the Engineers and Geoscientists of British Columbia whose expertise and training is appropriate for the relevant subject area

The largely pre-historic mappable retrogressive landslide record presents a less obvious but more significant hazard.

- Stantec and Palmer recommend that proposed development (or redevelopment) within the calculated setback areas should require detailed geotechnical assessment by a suitably Qualified Professional.
- Due to the potential implications of the calculated PO to setback areas in the context of the CVRD's Natural Hazard Risk Tolerance Policy (CVRD, 2019), Stantec and Palmer recommend a more detailed investigation prior to full adoption of the recommended setbacks into policy. Detailed investigation would aim to: i) provide meaningful differentiators to support smaller hazard zones in some areas (e.g., through subsurface investigation); and ii) better constrain the age of mapped retrogressive landslides (e.g., through radiocarbon dating, dendrochronological methods), potentially yielding a more accurate range of landslide age and, correspondingly, a more accurate PO.
- Gullies may deserve separate consideration by the CVRD (e.g., gully at cross-section r-47). Some gully processes are driven by surface water runoff; some may be driven by groundwater dynamics. The risks and associated management of gullying hazards can differ from management of landslide hazards.
- CVRD should consider the development of a guidance document that outlines specific criteria practitioners should meet to ensure their assessments sufficiently address potential natural hazards.
- Stantec and Palmer recommend similar investigations for other areas of non-bedrock flat-over-steep terrain within the CVRD (e.g., Cobble Hill, Mill Bay).

5.2 LANDUSE, DRAINAGE, AND VEGETATION

Stantec and Palmer understand the majority of runoff in Saltair is routed through ditches and culverts prior to discharge into a receiving water body, and that no sewer infrastructure exists. At the time of fieldwork, most observed discharge points along the coastal bluff appeared to successfully convey water down the slope, preventing discharge directly onto the slope. However, uncontrolled stormwater discharge onto the coastal bluff below the intersection of Stuart Road and Seaview Crescent and at Bazan Road Beach Access was observed and is likely contributing to localized slope instability and future property maintenance issues.

- Stantec and Palmer recommend the development and implementation of a stormwater management plan at these sites to avoid direct discharge to the slope and to avoid further exacerbating slope movement. Such a development plan may need to include other responsible stakeholders (e.g., Ministry of Transportation and Infrastructure).

Due to dense vegetation cover and limited access, there may be other uncontrolled discharge points that were not observed in the field.

- Stantec and Palmer recommend the review of all known discharge points to ensure stormwater is successfully conveyed down the coastal bluffs and prevents discharge directly to the slope.
- In addition, we recommend periodic inspection of discharge points to evaluate the ongoing efficacy of stormwater management strategies.

The CVRD provides several guidelines related to landuse, drainage, and vegetation within the Official Community Plan for the Ocean Shoreline Development Permit Area (e.g., limit area of impervious surfaces, site preparation should limit the need for vegetation removal). Additional considerations for landuse, drainage, and vegetation could include:

- Driveway and roof runoff or other concentrated surface runoff should not be directed towards the crest of the bluff. Redirecting water through drains or pipes to the bottom of the bluff or to a professionally identified safe place (e.g., stormwater storage area) can reduce potential slope instability.
- Installation of ponds and swimming pools in the study area should be avoided.
- Lawn irrigation systems should be discouraged.
- Septic fields should be sufficiently setback from the crest of the bluff as determined by a suitably Qualified Professional.
- Disturbance of the slope should be avoided.
- Materials should not be dumped over the bluff edge as they may cause damage to the slope, add weight to the slope, and disturb or smother existing vegetation.
- Prior to removing vegetation, interdependency effects should be considered where a group of plants growing together protect each other from disturbance by wind, erosion, and other natural processes (Menashe, 1993).
- If revegetation of slopes is needed to promote surface stability, efforts can be optimized through engagement of a landscape architect or designer who is qualified to provide a planting plan and to oversee installation.
- Native species are recommended for revegetation of coastal bluffs. A summary of native plants for the BC coast is provided by the Stewardship Centre for British Columbia (2016).
- Locating structures away from an eroding coastal bluff is the most effective action to ensure safety (Stewardship Centre for British Columbia, 2016).

An excellent overview of vegetation and drainage management is provided by the Stewardship Centre for British Columbia (2016).

6.0 CLOSURE

This report was prepared for the exclusive use of CVRD and their agents for specific application to the CVRD project area. Any use of this report or the material contained herein by third parties, or for other than the intended purpose, should first be approved in writing by Stantec and Palmer.

Use of this report is subject to the Statement of General Conditions included in **Appendix A**. It is the responsibility of CVRD, who is identified as "the Client" within the Statement of General Conditions, and their agents to review the conditions and notify Stantec should any of them not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report
- Basis of the report
- Standard of care
- Interpretation of site conditions
- Varying or unexpected site conditions
- Planning, design, or construction

We trust that this report meets your present requirements. This report was prepared by Hawley Beaugrand (Stantec) and reviewed by Robin McKillop (Palmer) and Rick Guthrie (Stantec). If you have any questions or require additional information, please contact the undersigned.

Regards,

STANTEC CONSULTING LTD. & PALMER

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Appendix A STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec's present understanding of the site-specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

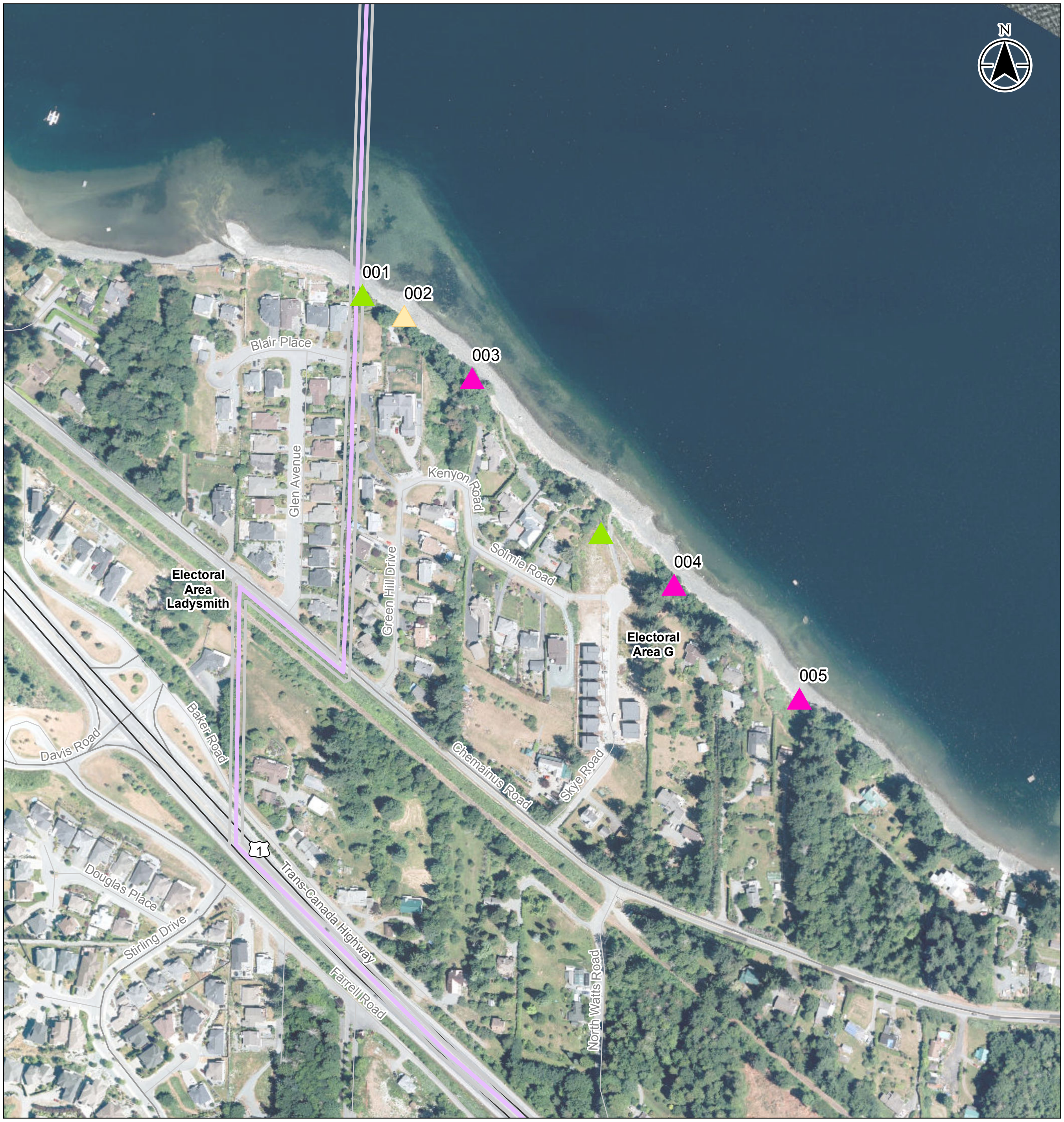
STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

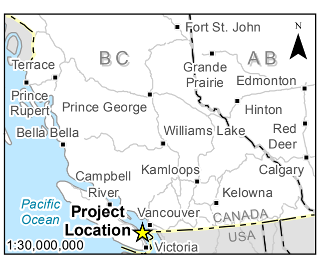
INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behaviour. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec will not be responsible to any party for damages incurred as a result of failing to notify Stantec that differing site or sub-surface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec, sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec cannot be responsible for site work carried out without being present.

Appendix B FIELD OBSERVATION MAPBOOK





Highway
Road
Local Street
Electoral Area Boundary
Beach Classification Point
Observed Slope Stability Issue
Stream Outlet

0 50 100 150 200 m
1:5,000 (at original document size of 8.5x11)

Stantec
Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.
B-1

Title
Field Observation Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. Observation labels refer to corresponding photo in the field photo log (Appendix C)
5. "Reported" locations represent notable observations from the CVRD-supplied geotechnical reports

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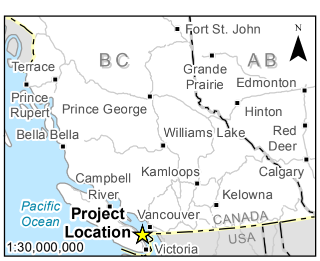

- Highway
- Road
- Local Street
- Watercourse
- Electoral Area Boundary
- Beach Classification Point
- Reported Slope Stability Issue/Reported Seepage
- Reported Slope Stability Issue
- Observed Slope Stability Issue
- Observed Slope Stability Issue/Observed Seepage
- Stream Outlet

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
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5. "Reported" locations represent notable observations from the CVRD-supplied geotechnical reports

Stantec Palmer

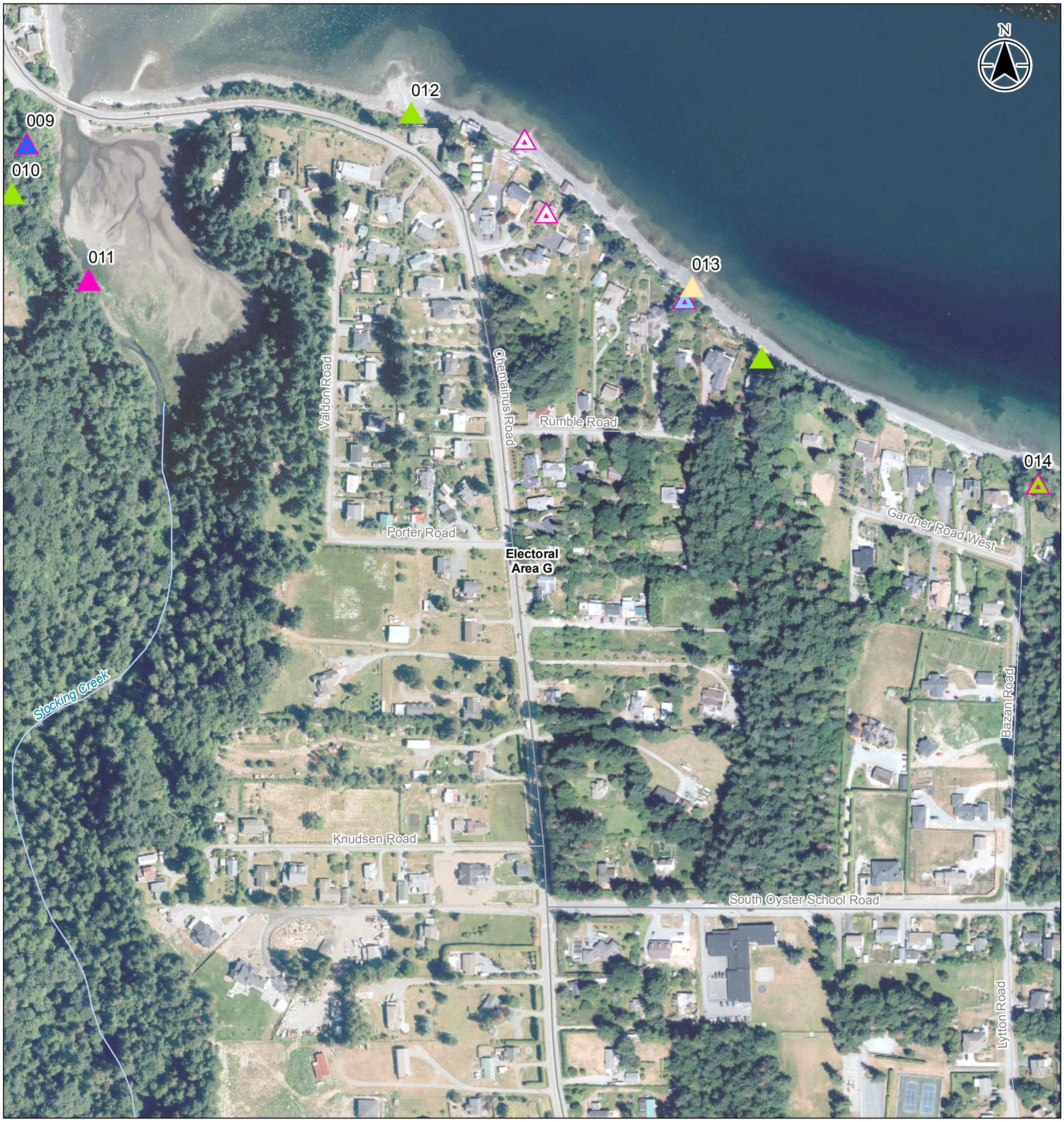
Project Location:
Saltair, BC
NTS 50K Grid: 092B13

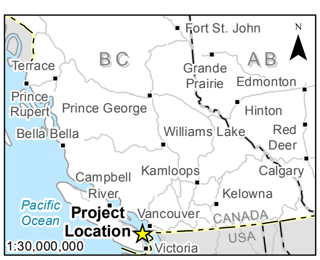
Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.
B-2

Title
Field Observation Mapbook





Road
Local Street
Watercourse

Electoral Area Boundary
Beach Classification Point
Observed Seepage & Reported Slope Stability Issue/Reported Seepage
Reported Slope Stability Issue
Observed Slope Stability Issue
Observed Slope Stability Issue/Observed Seepage
Stream Outlet
Observed Slope Stability Issue & Stream Outlet

0 50 100 150 200 m
1:5,000 (at original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. Observation labels refer to corresponding photo in the field photo log (Appendix C)
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Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.
B-3

Title
Field Observation Mapbook

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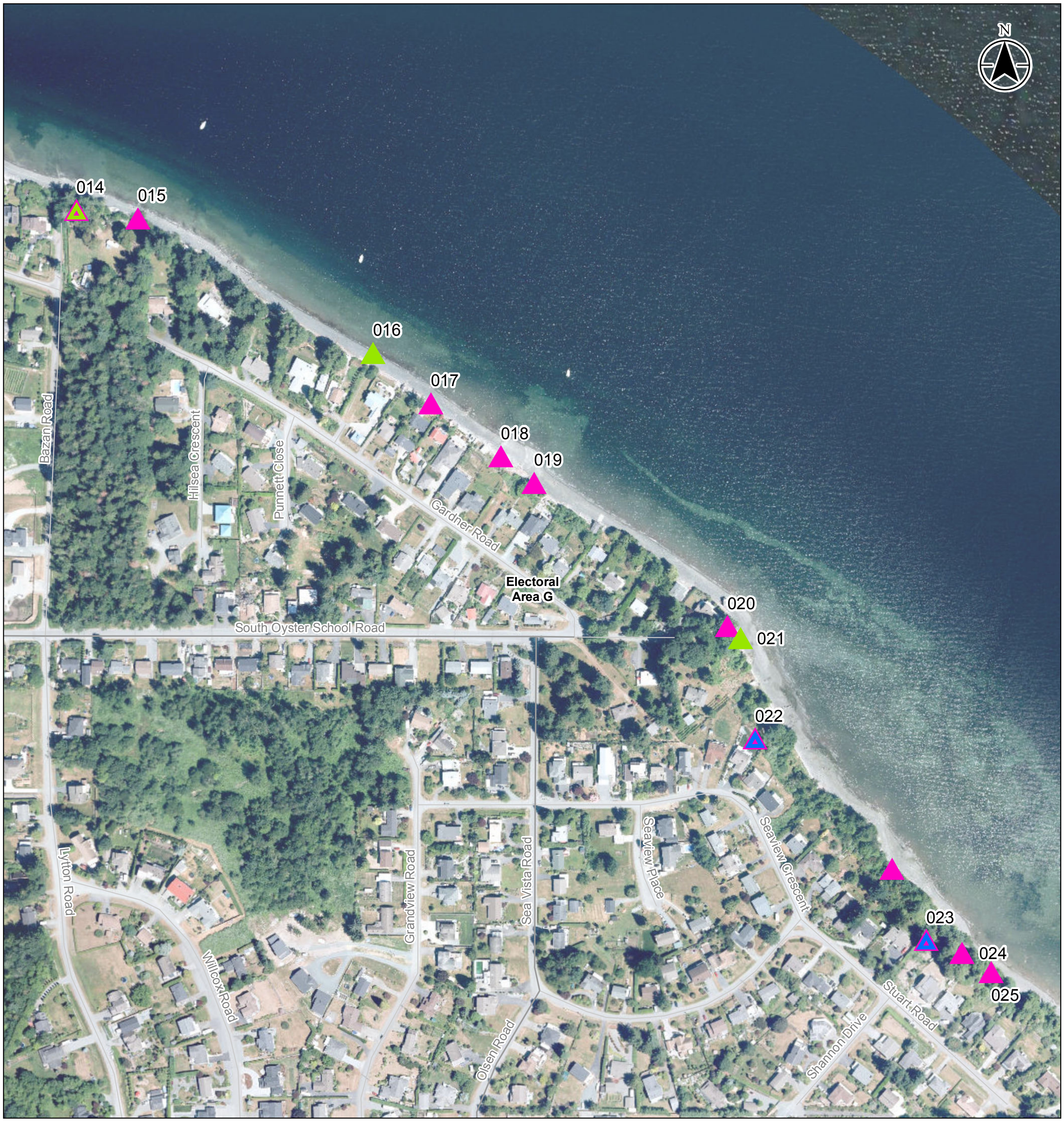

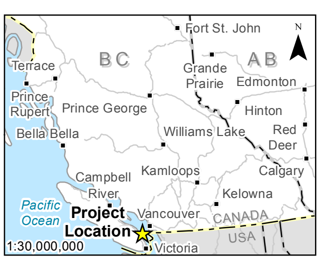

Road

Local Street

Electoral Area Boundary

Observed Slope Stability Issue

Observed Slope Stability Issue/Observed Seepage

Stream Outlet

Observed Slope Stability Issue & Stream Outlet

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.
B-4

Title
Field Observation Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. Observation labels refer to corresponding photo in the field photo log (Appendix C)
5. "Reported" locations represent notable observations from the CVRD-supplied geotechnical reports

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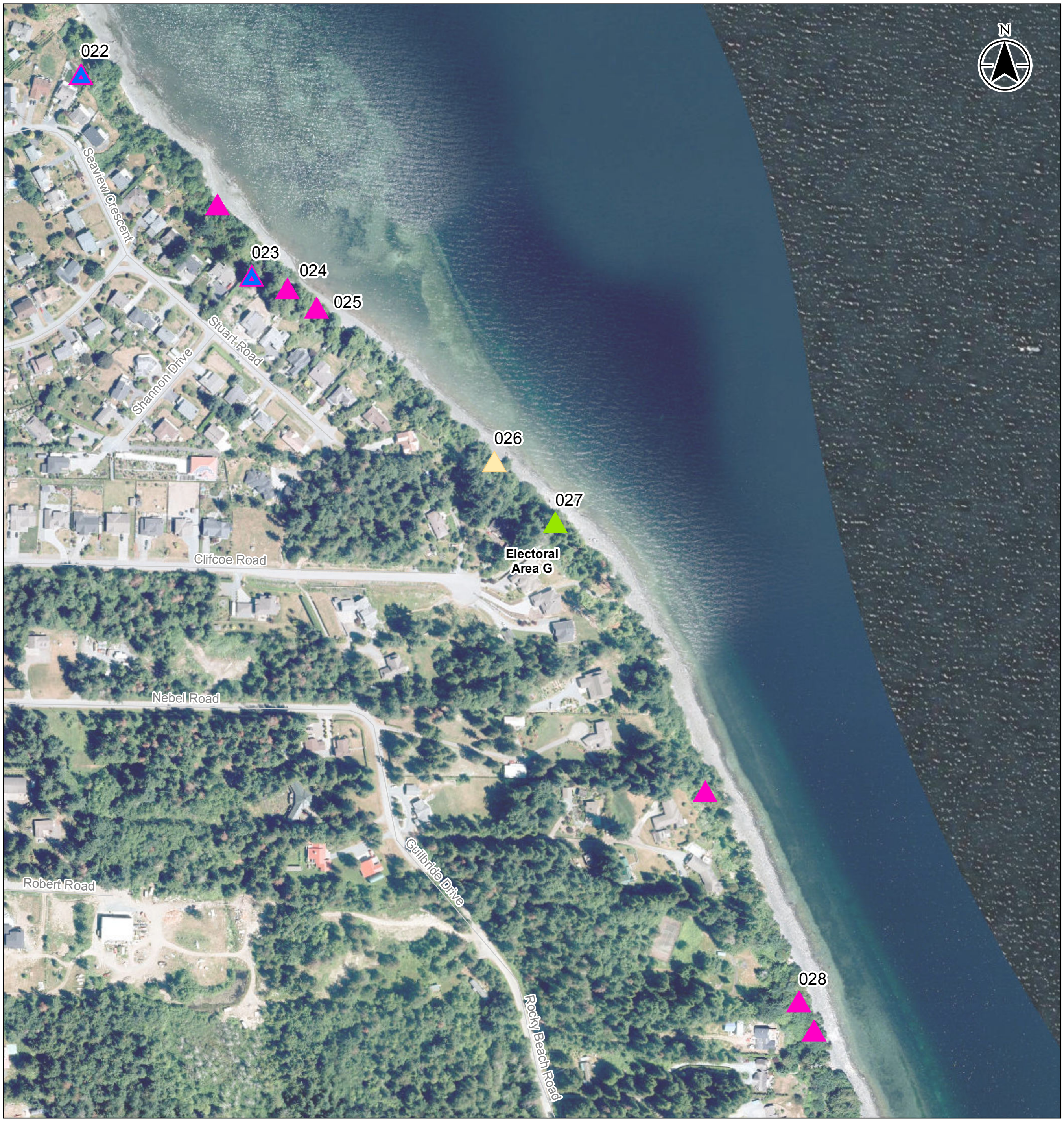

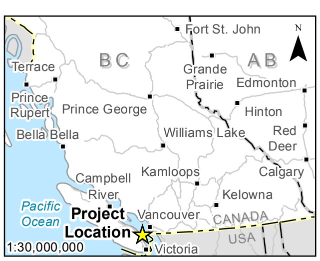

Local Street

Electoral Area Boundary

Beach Classification Point

Observed Slope Stability Issue

Observed Slope Stability Issue/Observed Seepage

Stream Outlet

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.
B-5

Title
Field Observation Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. Observation labels refer to corresponding photo in the field photo log (Appendix C)
5. "Reported" locations represent notable observations from the CVRD-supplied geotechnical reports

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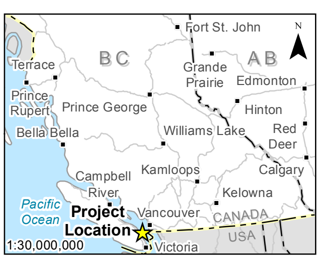

Road
Local Street
Watercourse
Electoral Area Boundary
Observed Slope Stability Issue
Stream Outlet

0 50 100 150 200 m
1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.
B-6

Title
Field Observation Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. Observation labels refer to corresponding photo in the field photo log (Appendix C)
5. "Reported" locations represent notable observations from the CVRD-supplied geotechnical reports

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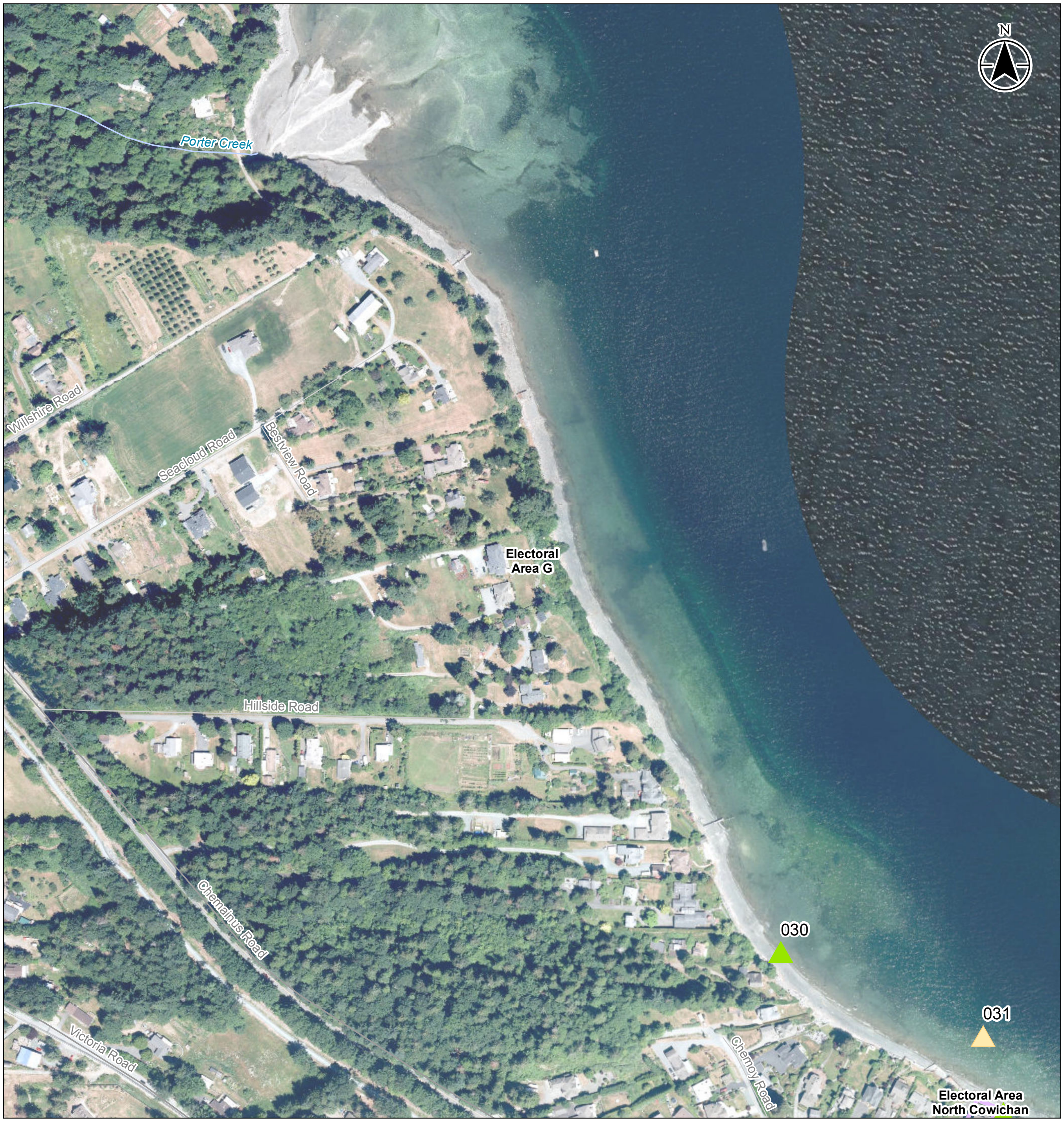

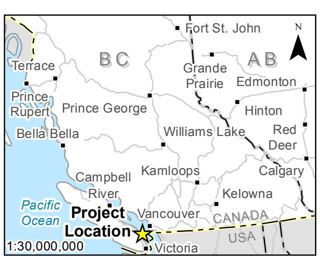

Road

Local Street

Watercourse

Electoral Area Boundary

Beach Classification Point

Stream Outlet

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.
B-7

Title
Field Observation Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. Observation labels refer to corresponding photo in the field photo log (Appendix C)
5. "Reported" locations represent notable observations from the CVRD-supplied geotechnical reports

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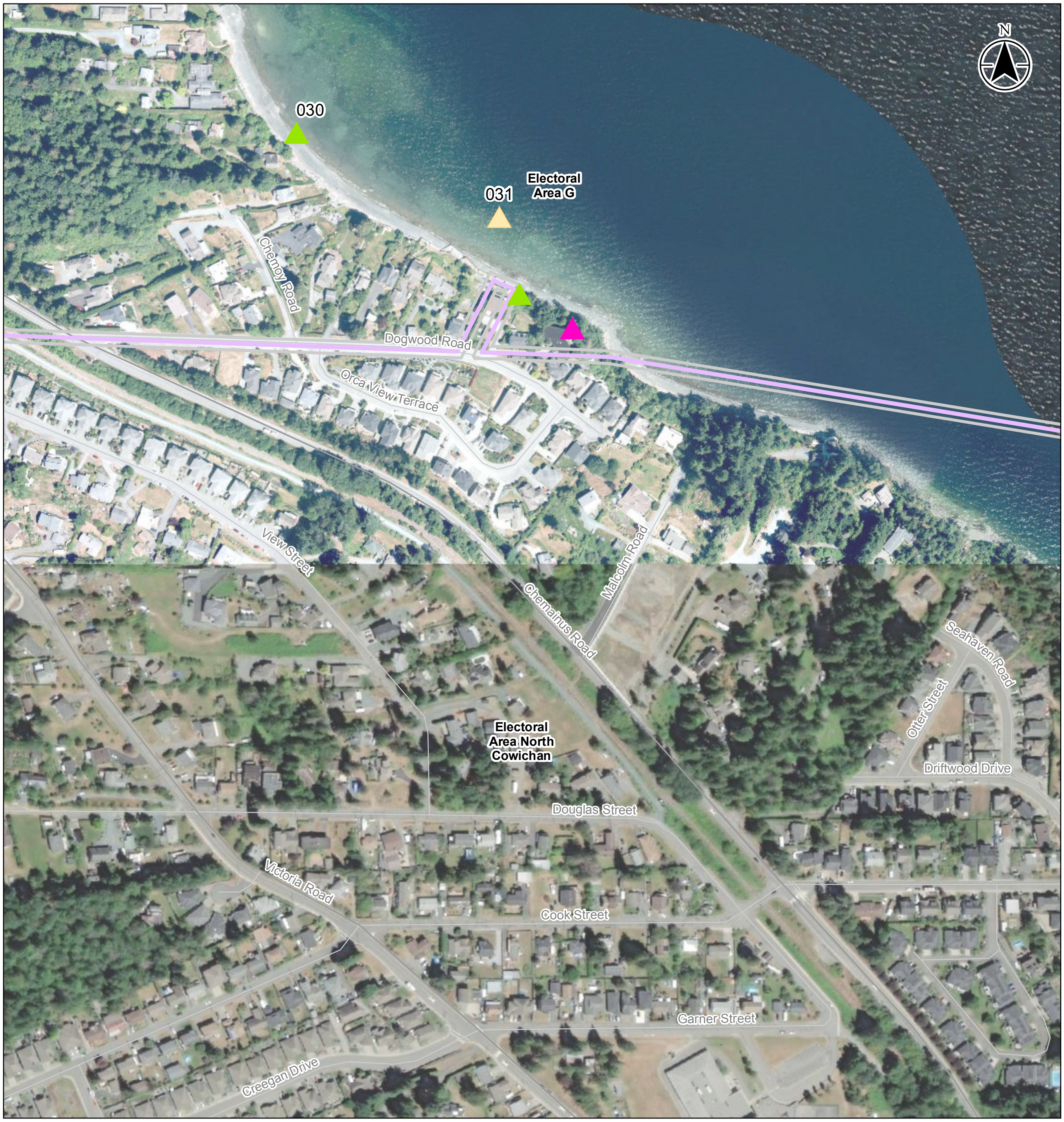

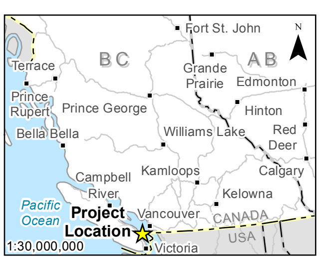

Road

Local Street

Electoral Area Boundary

Beach Classification Point

Observed Slope Stability Issue

Stream Outlet

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. Observation labels refer to corresponding photo in the field photo log (Appendix C)
5. "Reported" locations represent notable observations from the CVRD-supplied geotechnical reports

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.
B-8

Title
Field Observation Mapbook

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Appendix C FIELD PHOTO LOG

Photo 001: Stream outlet within large woody debris below pistol butt trees. Vertical shoreline of consolidated till with silty sand matrix and pebble to cobble sized inclusions. Undercutting of up to 0.5 m.

Photo 002: Photo of beach face at low tide looking SE. Upper beach face 4-degrees with D_{50} 45 mm. Scattered boulders observed. Oyster beds on lower beach face.

Photo 003: Shallow surficial failure approximately 5 m wide on 45-degree slope along an unprotected shoreline segment.

Photo 004: Suspected shallow surficial failure along unprotected shoreline segment. One-metre-high scarp at base of slope along shoreline comprised of suspected colluvium (loose, silty sand with pebble to cobble inclusions).

Photo 005: Translational debris slide. Person for scale. Landslide occurred during the 2020-2021 winter (J. Moore, personal communication, May 28, 2021). Approximately 2 m deep and 5 m wide on a 45-degree slope.

Photo 006: Looking NW across the beach at low tide. Upper beach face 3-degree slope with D_{50} of sand.

Photo 007: Stream outlet. Recent riprap installation at the toe of the slope/upper beach face. Adjacent natural segments of shoreline are actively eroding till.

Photo 008: Shallow landslide approximately 5 m wide and 10 m long on escarpment backing property.

Photo 009: Landslide with large block deposited at base of slope rotated to upslope facing position. Saturated upslope material fed by gully and/or seep. Observed material is till with higher clay content relative to shoreline exposures north of Davis Lagoon.

Photo 010: Stormwater outfall discharging to Davis Lagoon.

Photo 011: Numerous downed and pistol butt trees.

Photo 012: Stormwater outfall.

Photo 013: Looking SE across the beach. Upper shoreface 6-degree gradient with D_{50} of 25 mm.

Photo 014: Culvert failure and stormwater discharge onto slope at Bazan Road Beach Access.

Photo 015: Potential shallow landslide observed on natural shoreline segment. Toe of slopes is 1 m high, undercut erosive scarp.

Photo 016: Stormwater outfall discharging to beach at Skinner Road Beach Access.

Photo 017: Shallow slope failure and failed retaining wall. Failure is approximately 7 m wide and 0.5 m deep on 32-degree slope.

Photo 018: Shallow failure on 45-degree slope.

Photo 019: Retaining wall failure and slope bulging at toe.

Photo 020: Pistol butt trees at Gardner Road Beach Access.

Photo 021: Stormwater outfall discharging onto beach SE of Gardner Road Beach Access.

Photo 022: Pistol butt trees and seepage at exposed seam of clay silt. Observed 4 m wide, 0.6 m deep and 8 m long headscarp. Slope 31 to 39-degrees.

Photo 023: Uncontrolled stormwater discharge onto slope at intersection of Stuart Road and Seaview Crescent. Large 20 m wide failure with semi-circular 6 m high headscarp. Exposure of underlying stratigraphy. Seepage observed in the till.

Photo 024: Observed slope failure adjacent to (SE of) feature shown in Photo 023.

Photo 025: Retaining wall failure and toe of slope bulging.

Photo 026: Looking SE over the beach. The upper beach face has 6-degree slope and D_{50} of 30 mm.

Photo 027: Stormwater discharge at Clifcoe Road Beach Access.

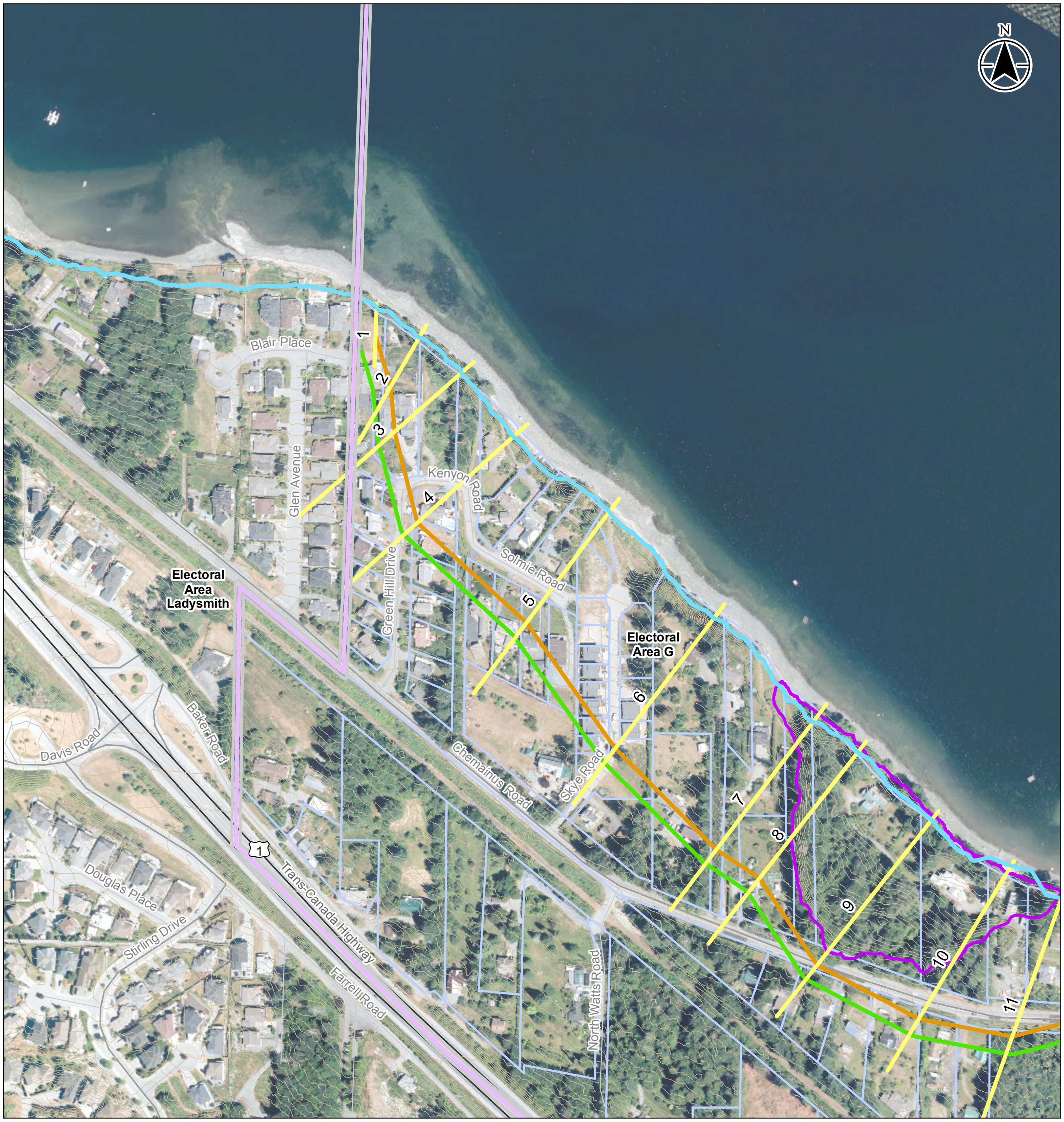
Photo 028: Failure on 39-degree slope. Upper portions of the slope near vertical. Downed tree and rootball exposed.

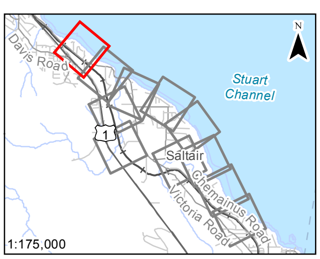
Photo 029: Shallow failure approximately 5 m wide with up to 1 m vertical displacement.

Photo 030: Stormwater discharge to beach.


Photo 031: Looking NW across the beach at low tide. Beach slope of 2-degrees and D_{50} of sand.

Appendix D COASTAL SLOPE STABILITY SETBACK MAPBOOK





Highway
Road
Local Street
1 m Contour
Parcel Boundary
Electoral Area Boundary
Mapped Landslide(s)
Water Level with 1 m Sea Level Rise
Cross-Section
Calculated Setback
Calculated Setback + 15 m

0 50 100 150 200 m
1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

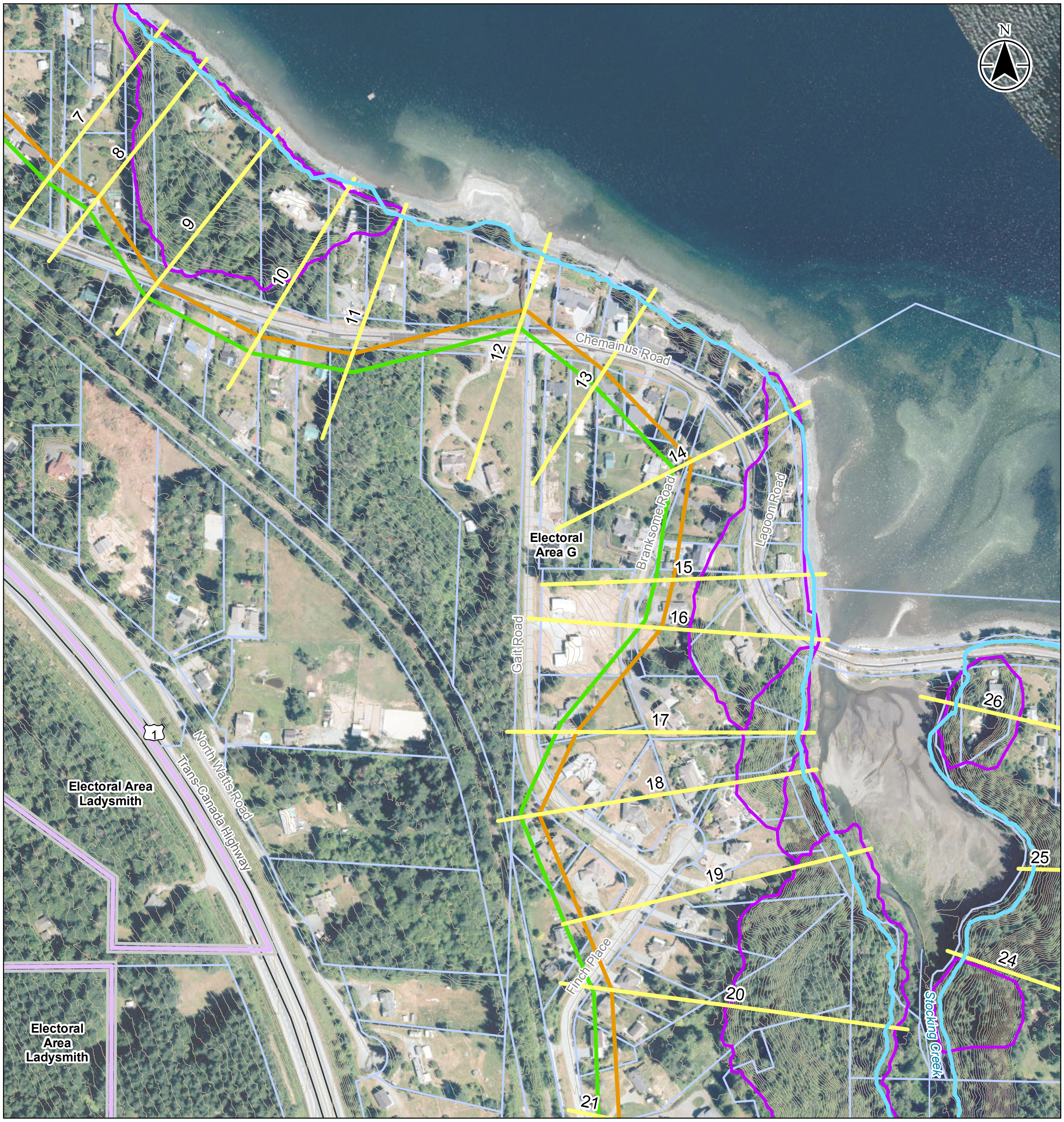
Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

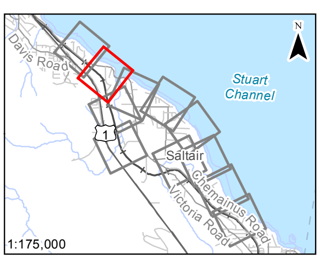
Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.
D-1

Title
Coastal Slope Stability Setback Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. One-metre contours generated from 2019 LiDAR





Highway
Road
Local Street
Watercourse
1 m Contour
Parcel Boundary
Electoral Area Boundary
Mapped Landslide(s)
Water Level with 1 m Sea Level Rise
Cross-Section
Calculated Setback
Calculated Setback + 15 m

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

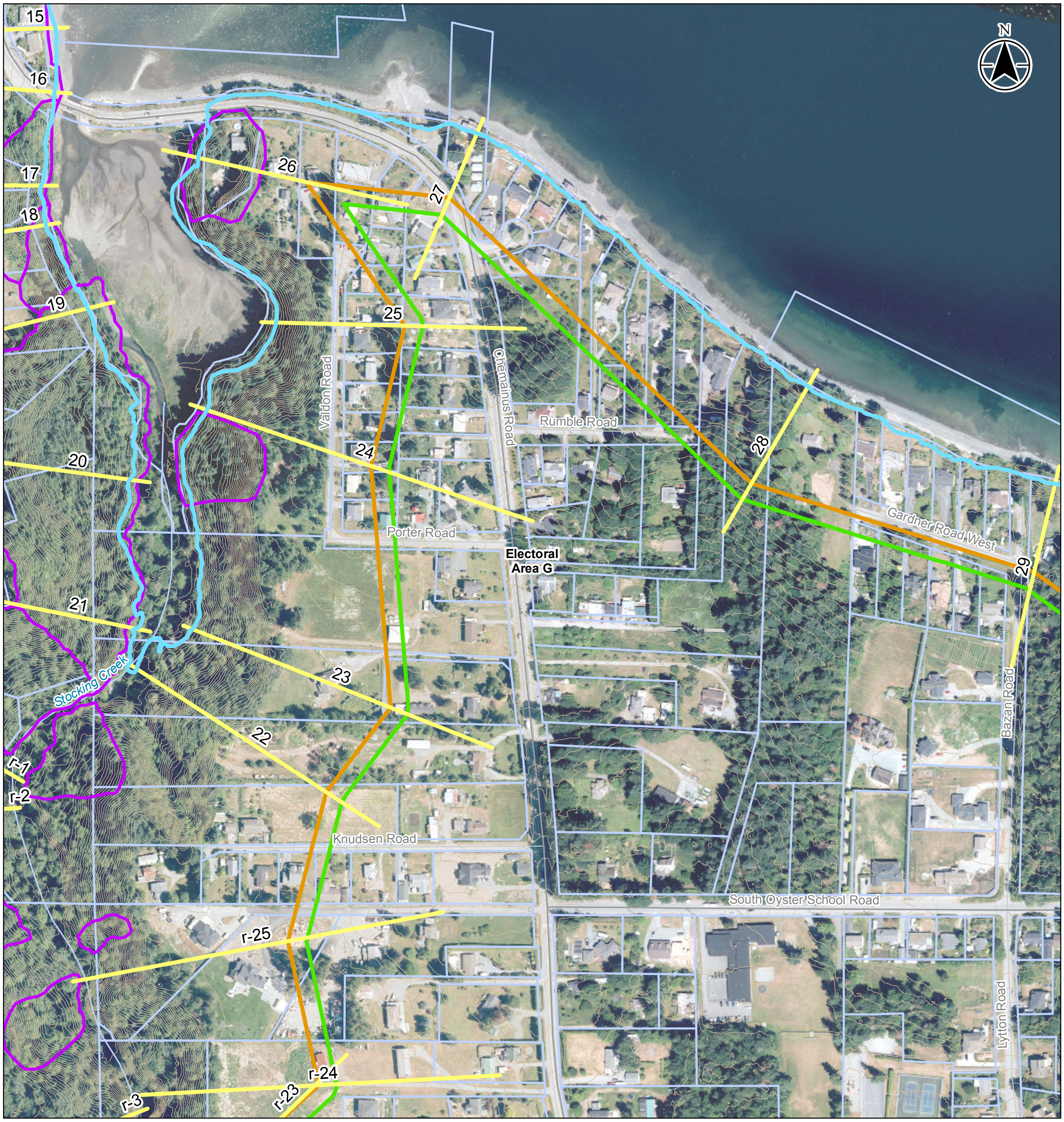
Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

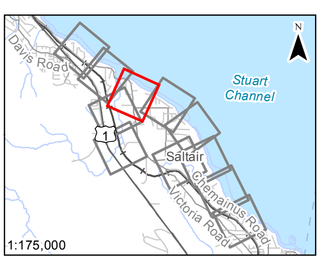
Figure No.
D-2

Title
Coastal Slope Stability Setback Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. One-metre contours generated from 2019 LiDAR

\\ca0183-pbagf01\workgroup\1232\projects\123315367\figures\reports\fig_123315367_CS_002_Coastal_Slope_Stability_Setback_Mapbook.mxd Revised: 2022-02-10 By: kelwong





- Road
- Local Street
- Watercourse
- 1 m Contour
- Parcel Boundary
- Electoral Area Boundary
- Mapped Landslide(s)
- Water Level with 1 m Sea Level Rise
- Cross-Section
- Calculated Setback
- Calculated Setback + 15 m

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

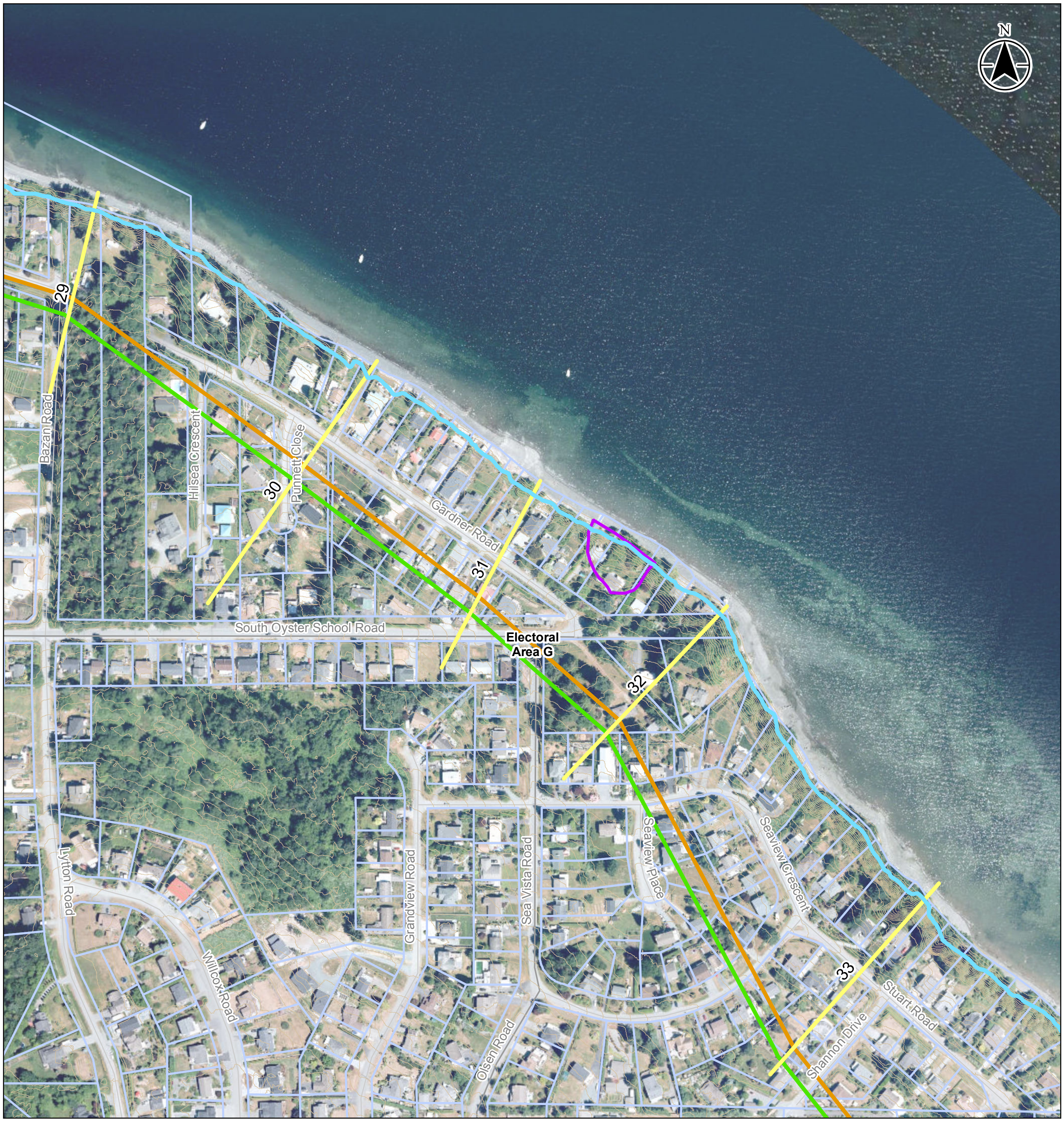
Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

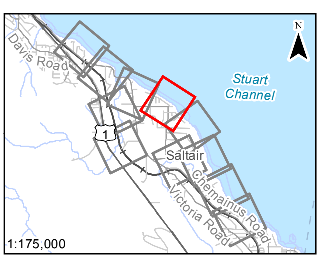
Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.
D-3

Title
Coastal Slope Stability Setback Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. One-metre contours generated from 2019 LiDAR





- Road
- Local Street
- 1 m Contour
- Parcel Boundary
- Electoral Area Boundary
- Mapped Landslide(s)
- Water Level with 1 m Sea Level Rise
- Cross-Section
- Calculated Setback
- Calculated Setback + 15 m

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

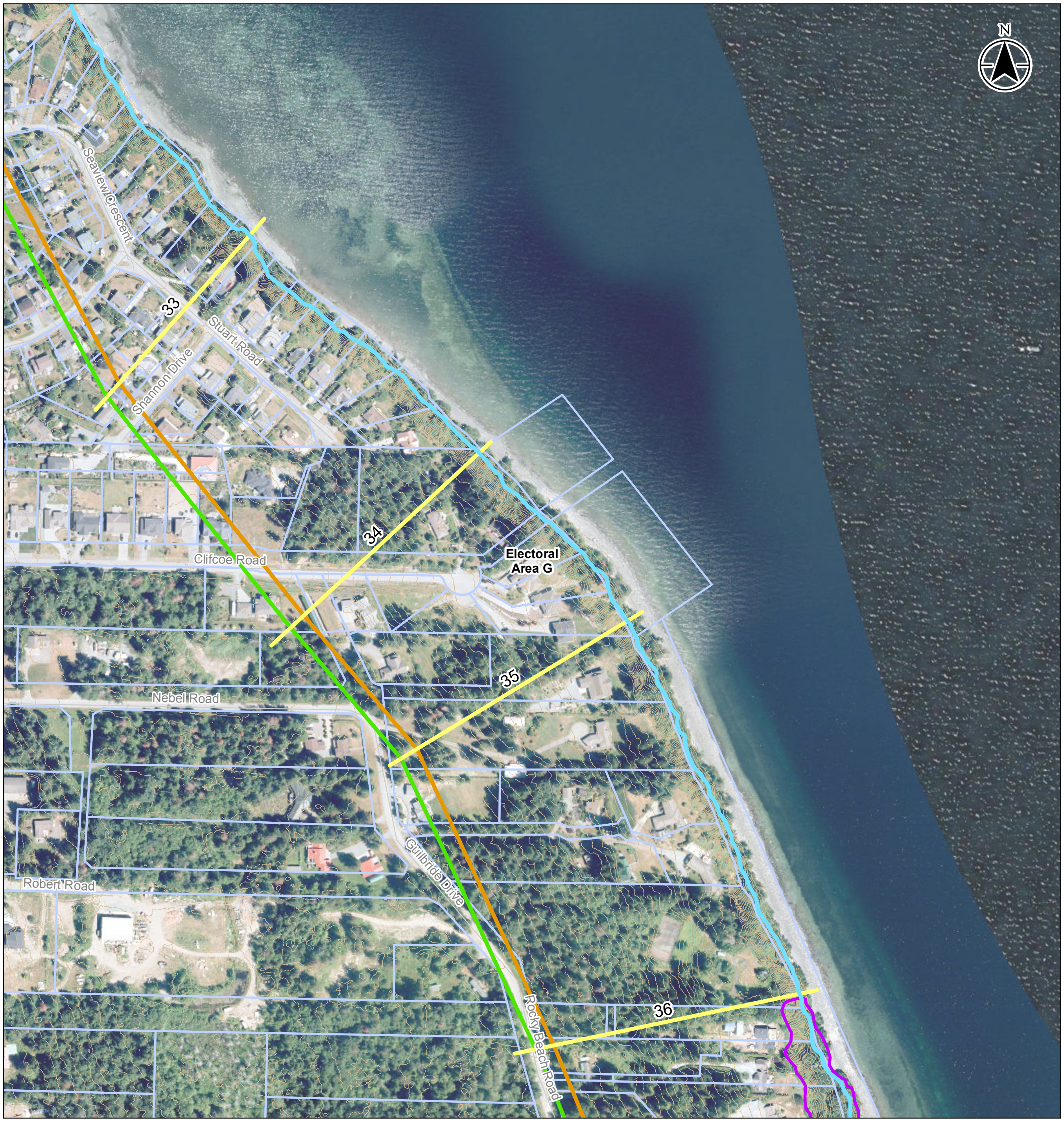
Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

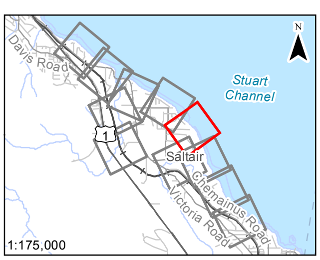
Figure No.
D-4

Title
Coastal Slope Stability Setback Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. One-metre contours generated from 2019 LiDAR

\\ca0183-pbagf01\workgroup\1232\projects\123315367\figures\reports\fig_123315367_CS_002_Coastal_Slope_Stability_Setback_Mapbook.mxd Revised: 2022-02-10 By: kelwong





- Local Street
- 1 m Contour
- Parcel Boundary
- Electoral Area Boundary
- Mapped Landslide(s)
- Water Level with 1 m Sea Level Rise
- Cross-Section
- Calculated Setback
- Calculated Setback + 15 m

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:	Project Number: 123315367
Saltair, BC	Prepared by KWONG on 20210818
NTS 50K Grid: 092B13	Requested by HBEAUGRAND on 20210818
	Checked by TCARDINAL on 20210903

Client/Project/Report

Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.

D-5

Title

Coastal Slope Stability Setback Mapbook

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. One-metre contours generated from 2019 LiDAR

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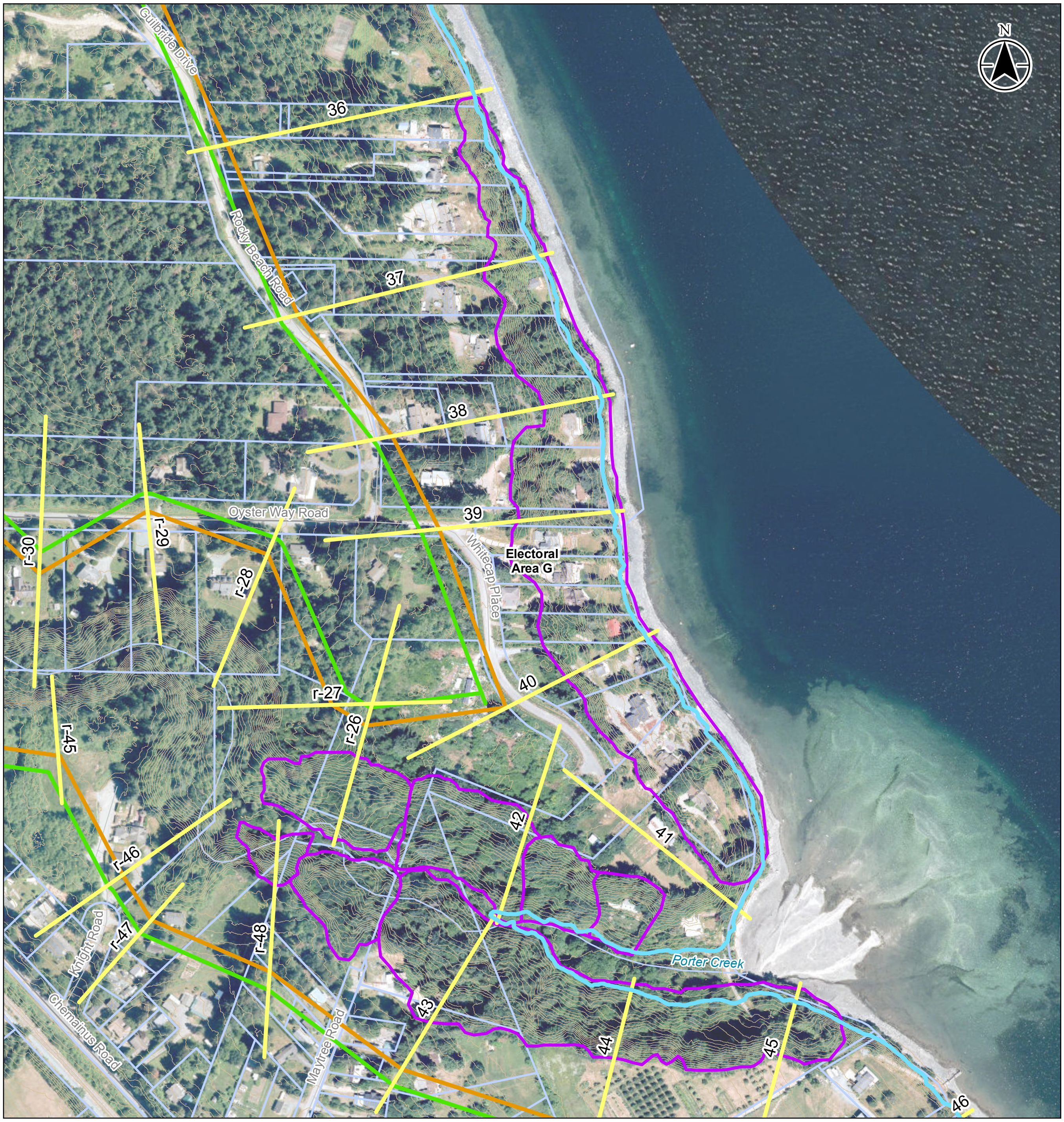
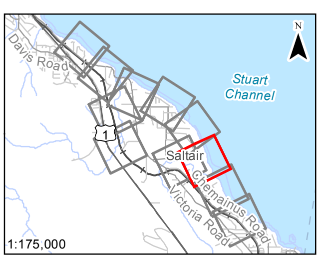




Road
Local Street
Watercourse
1 m Contour
Parcel Boundary
Electoral Area Boundary
Mapped Landslide(s)
Water Level with 1 m Sea Level Rise
Cross-Section
Calculated Setback
Calculated Setback + 15 m

0 50 100 150 200 m
1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

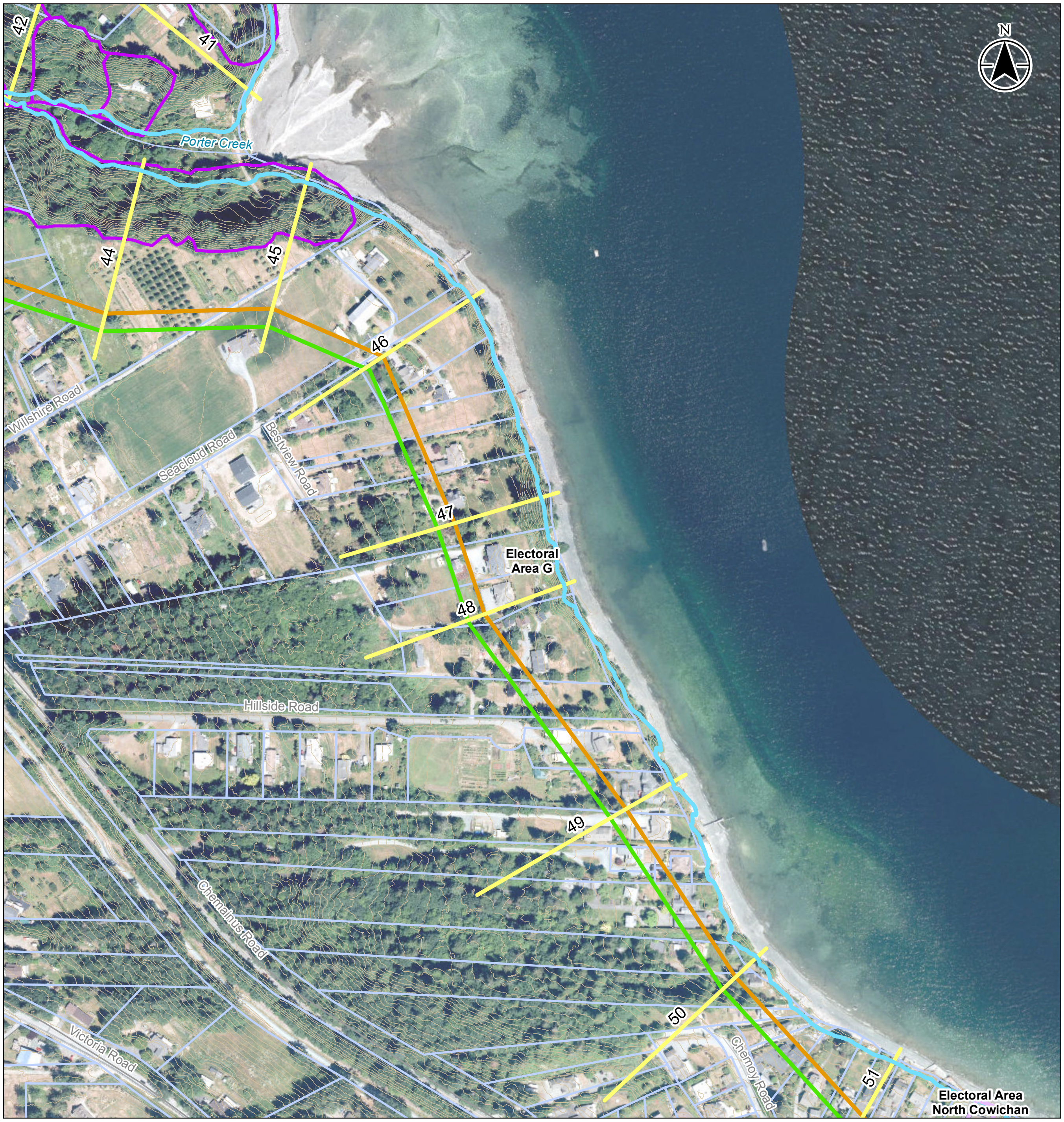
Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

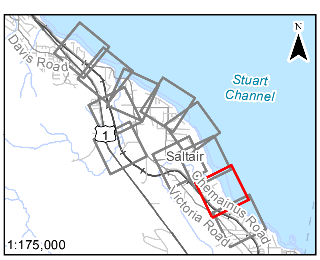
Figure No.
D-6

Title
Coastal Slope Stability Setback Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. One-metre contours generated from 2019 LiDAR

\\ca0183-pbagf01\workgroup\1232\projects\123315367\figures\reports\fig_123315367_CS_002_Coastal_Slope_Stability_Setback_Mapbook.mxd Revised: 2022-02-10 By: kelwong





Road	Electoral Area Boundary
Local Street	Mapped Landslide(s)
Watercourse	Water Level with 1 m Sea Level Rise
1 m Contour	Cross-Section
Parcel Boundary	Calculated Setback
	Calculated Setback + 15 m

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

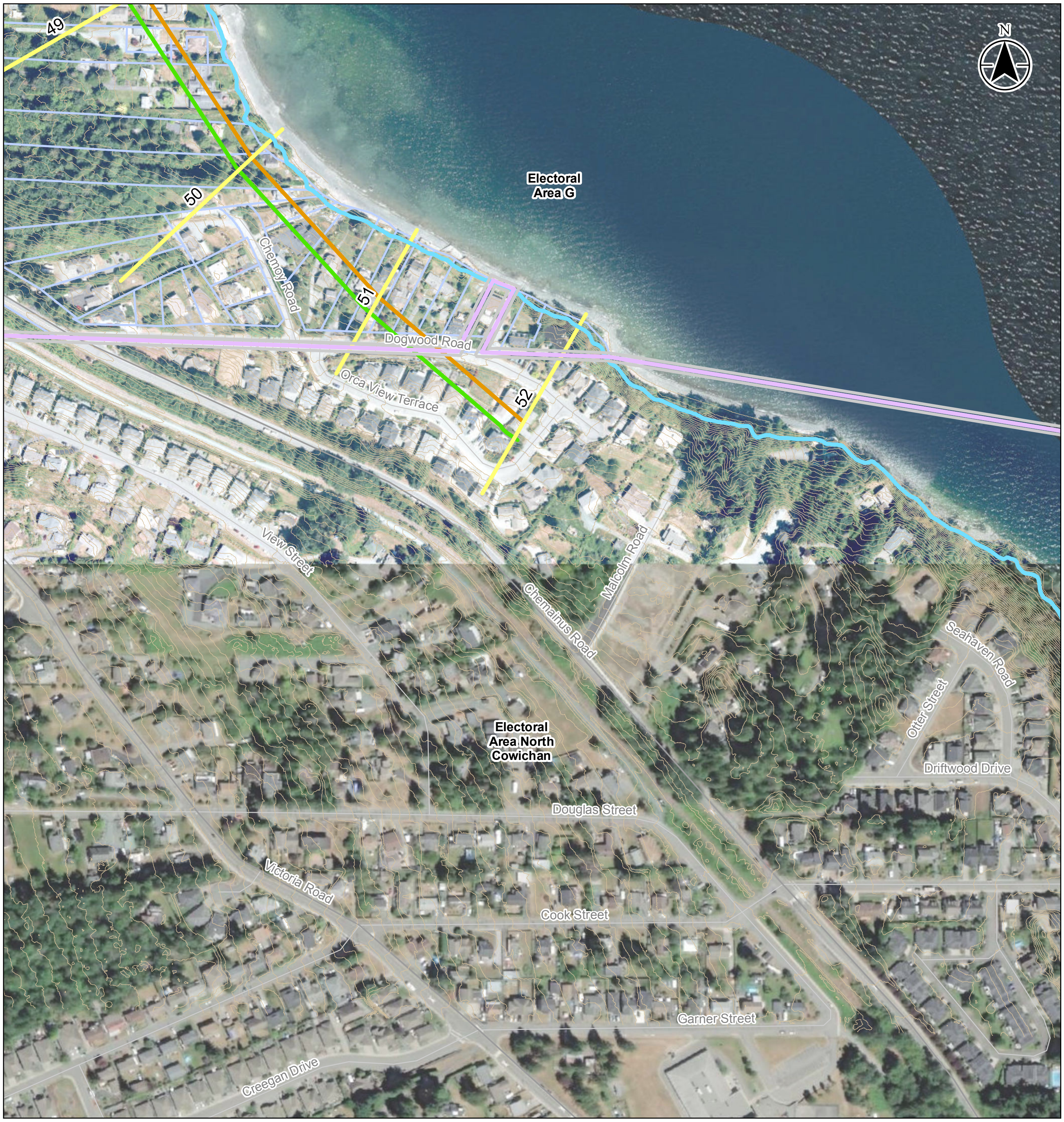
Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

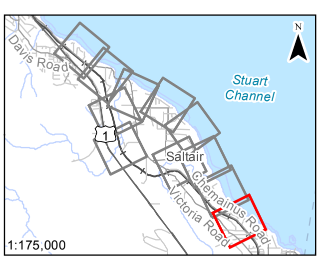
Figure No.
D-7

Title
Coastal Slope Stability Setback Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. One-metre contours generated from 2019 LiDAR

\\ca0183-pbagf01\workgroup\1232\projects\123315367\figures\reports\fig_123315367_CS_002_Coastal_Slope_Stability_Setback_Mapbook.mxd Revised: 2022-02-10 By: kelwong





Road

Local Street

1 m Contour

Parcel Boundary

Electoral Area Boundary

Water Level with 1 m Sea Level Rise

Cross-Section

Calculated Setback

Calculated Setback + 15 m

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Stantec Palmer.

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.
D-8

Title
Coastal Slope Stability Setback Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. One-metre contours generated from 2019 LiDAR

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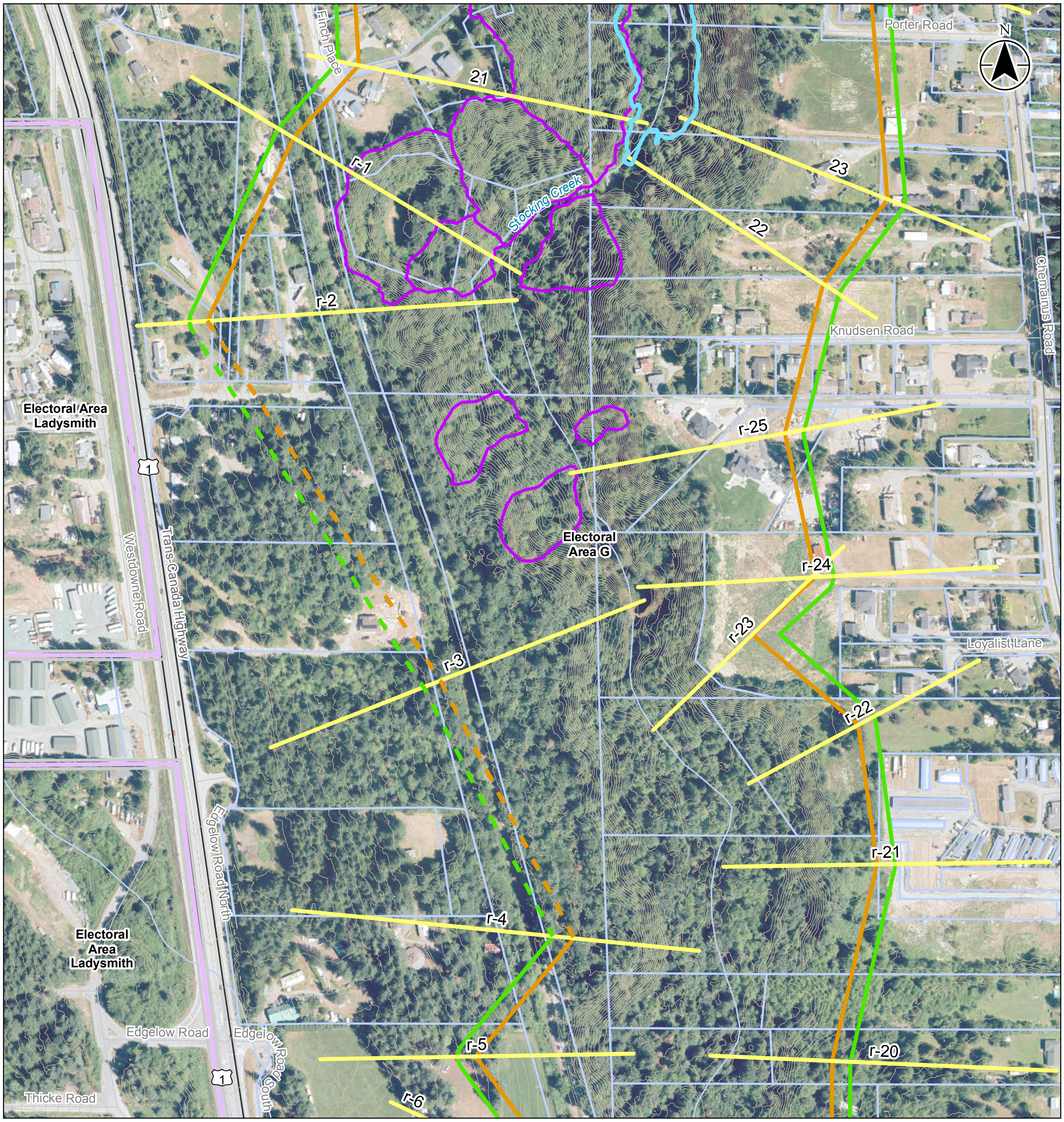

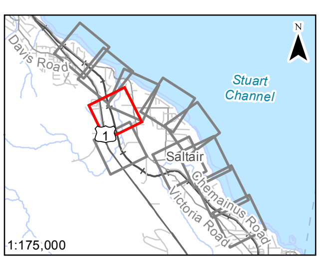

Legend	
Highway	Electoral Area Boundary
Road	Mapped Landslide(s)
Local Street	Water Level with 1 m Sea Level Rise
Watercourse	Cross-Section
1 m Contour	Calculated Setback
Parcel Boundary	Calculated Setback (Conditional)
	Calculated Setback + 15 m
	Calculated Setback + 15 m (Conditional)

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

Figure No.
D-9

Title
Coastal Slope Stability Setback Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. One-metre contours generated from 2019 LiDAR

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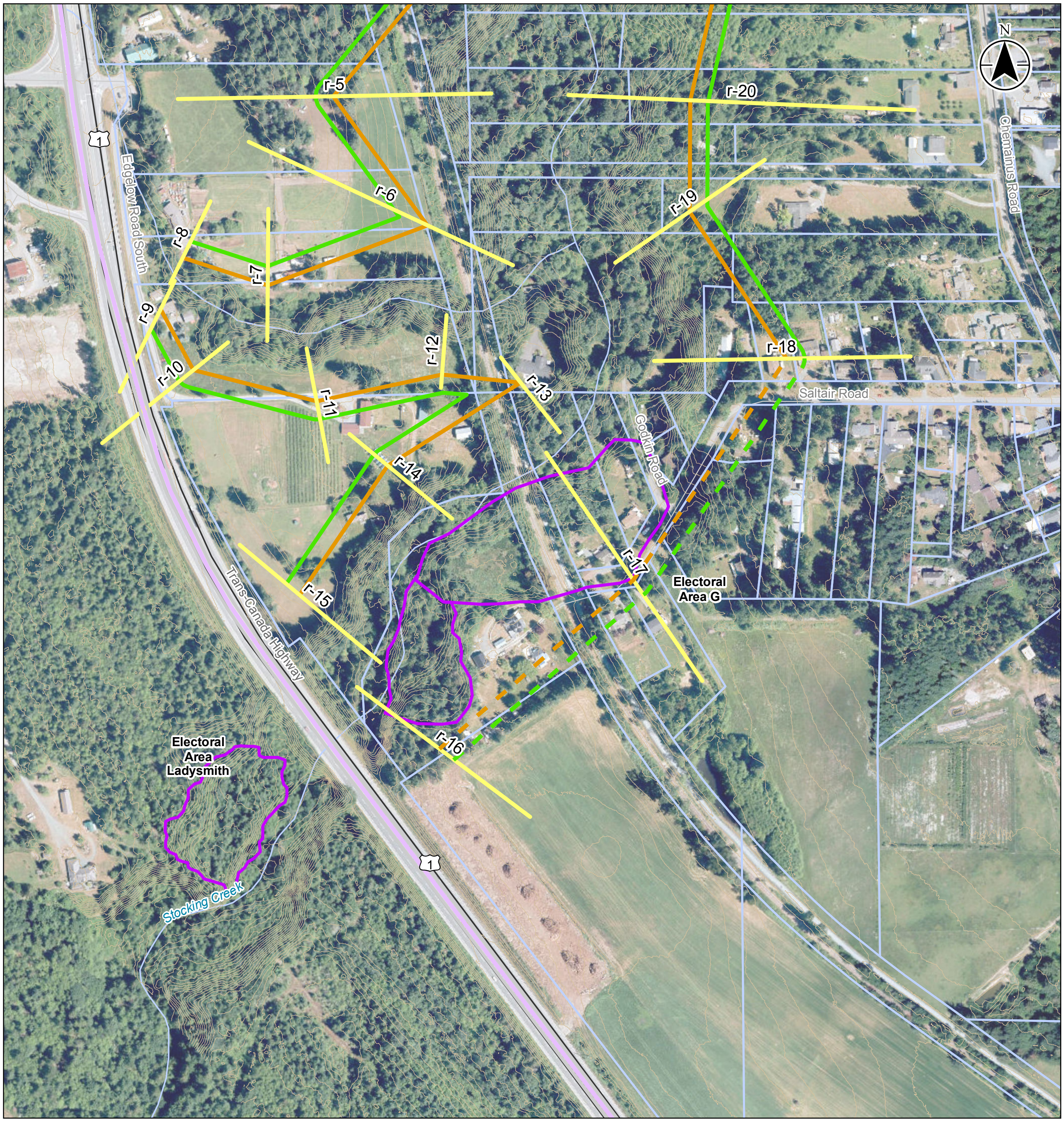
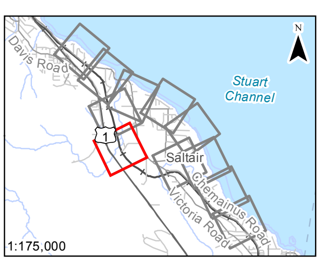




Highway
Road
Local Street
Watercourse
1 m Contour
Parcel Boundary
Electoral Area Boundary
Mapped Landslide(s)
Cross-Section
Calculated Setback
Calculated Setback (Conditional)
Calculated Setback + 15 m
Calculated Setback + 15 m (Conditional)

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

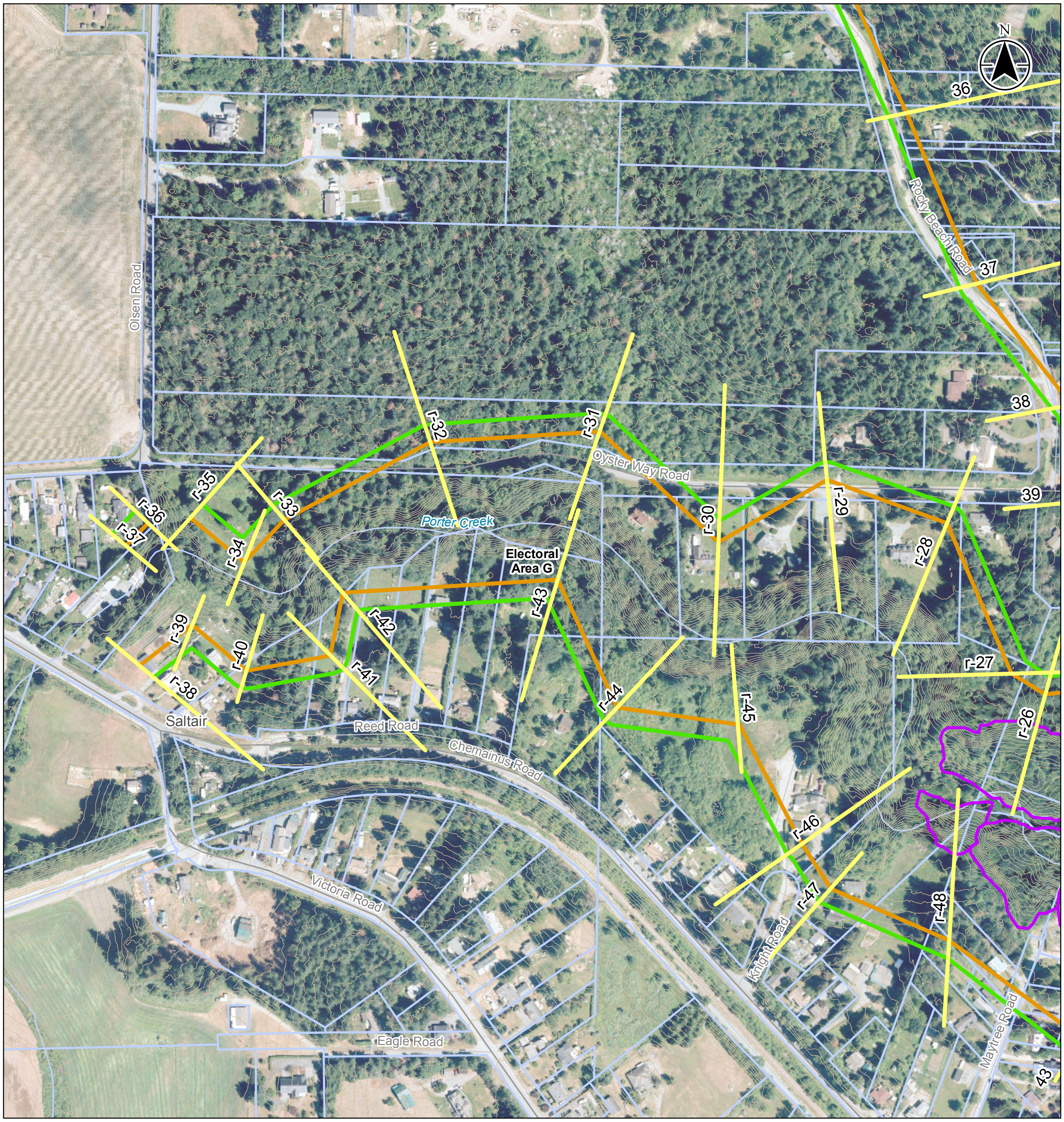
Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

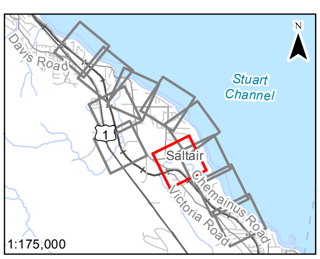
Figure No.
D-10

Title
Coastal Slope Stability Setback Mapbook

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. One-metre contours generated from 2019 LiDAR

\\ca0183-pbagf01\workgroup\1232\projects\123315367\figures\reports\fig_123315367_CS_002_Coastal_Slope_Stability_Setback_Mapbook.mxd Revised: 2022-02-10 By: kelwong





- Road
- Local Street
- Watercourse
- 1 m Contour
- Parcel Boundary
- Electoral Area Boundary
- Mapped Landslide(s)
- Cross-Section
- Calculated Setback
- Calculated Setback + 15 m

0 50 100 150 200 m

1:5,000 (at original document size of 8.5x11)

Stantec Palmer

Project Location:
Saltair, BC
NTS 50K Grid: 092B13

Project Number: 123315367
Prepared by KWONG on 20210818
Requested by HBEAUGRAND on 20210818
Checked by TCARDINAL on 20210903

Client/Project/Report
Cowichan Valley Regional District
Coastal Slope Stability Assessment

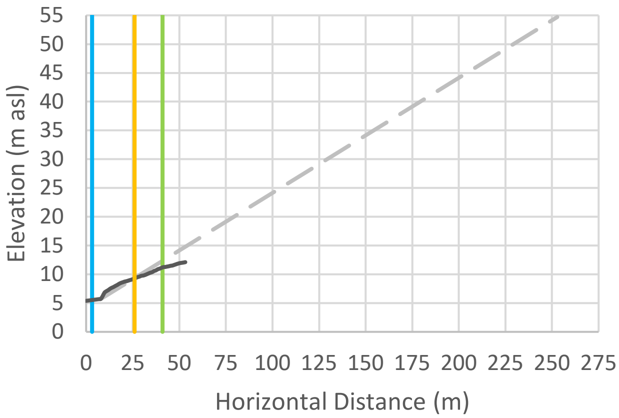
Figure No.
D-11

Title
Coastal Slope Stability Setback Mapbook

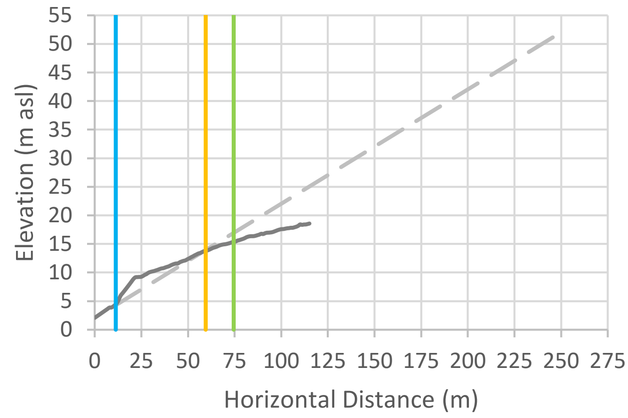
Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. Imagery: ESRI World Imagery
4. One-metre contours generated from 2019 LiDAR

\\ca0183-pbagf01\workgroup\1232\projects\123315367\figures\reports\fig_123315367_CS_002_Coastal_Slope_Stability_Setback_Mapbook.mxd Revised: 2022-02-10 By: kelwong

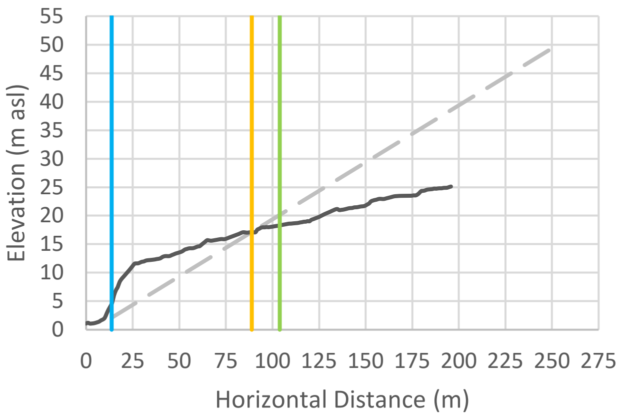
Appendix E COASTAL CROSS-SECTIONS AND RECOMMENDED SETBACKS



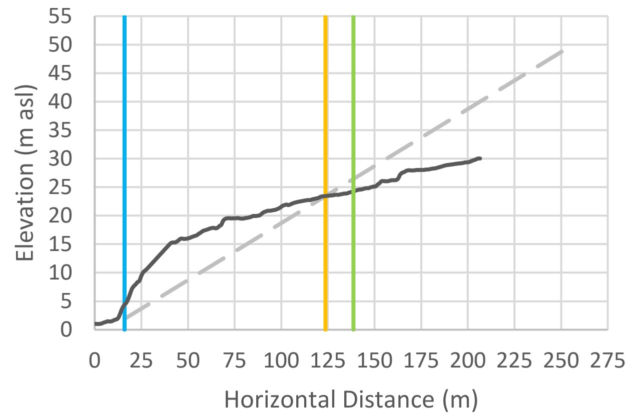
Cross-Section 1: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



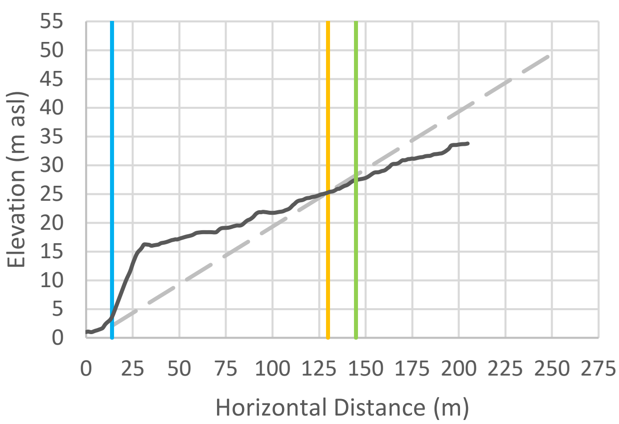
Cross-Section 2: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



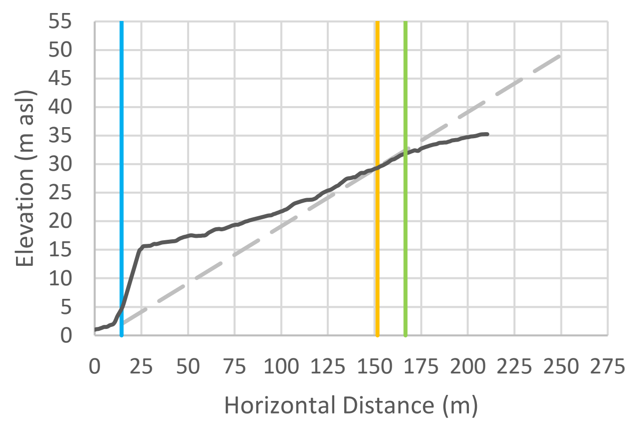
Cross-Section 3: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



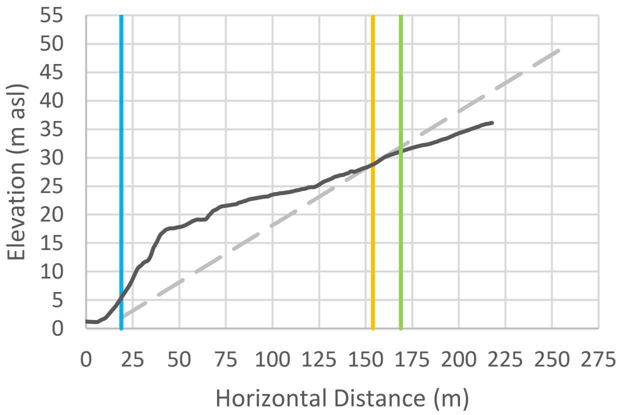
Cross-Section 4: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



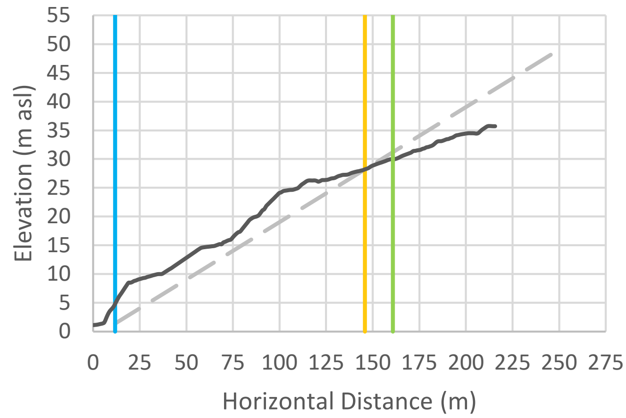
Cross-Section 5: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



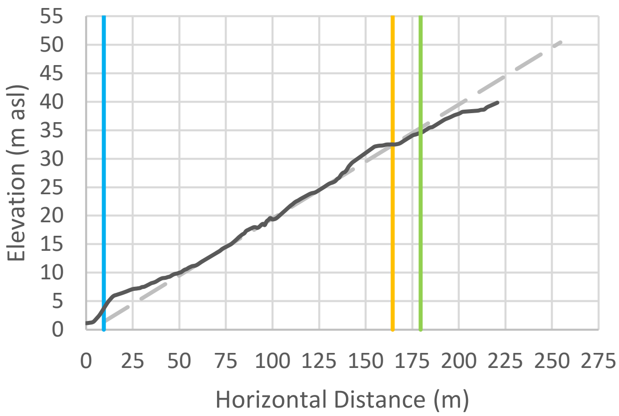
Cross-Section 6: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



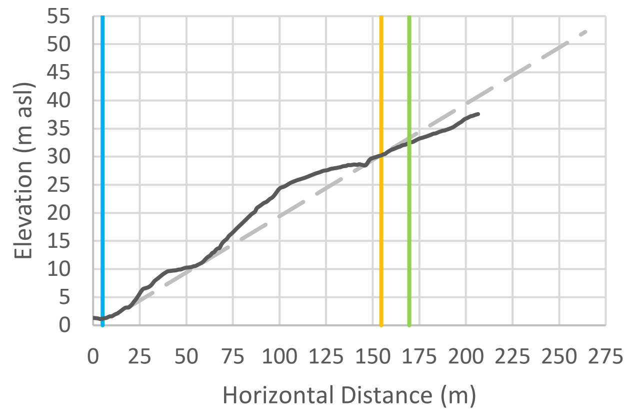
Cross-Section 7: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



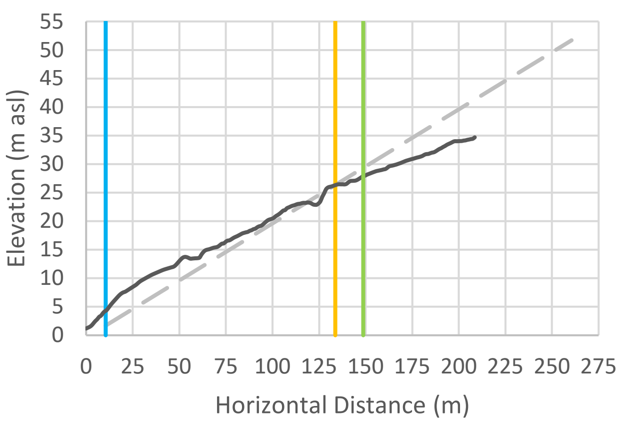
Cross-Section 8: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



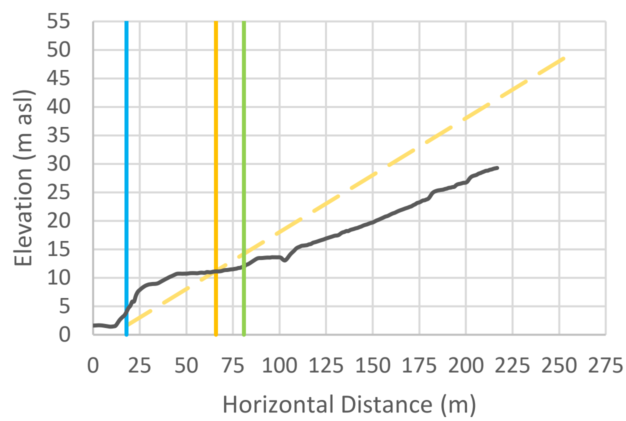
Cross-Section 9: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



Cross-Section 10: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



Cross-Section 11: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



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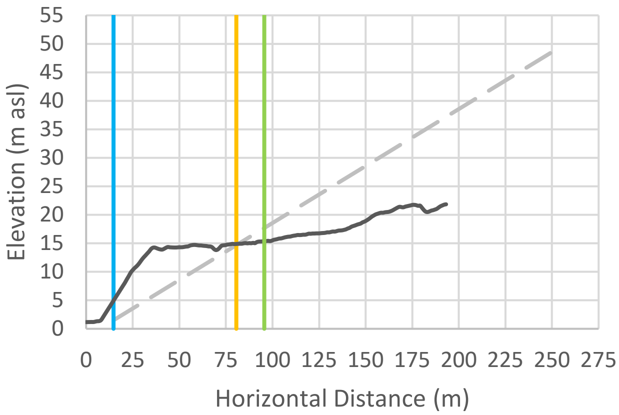
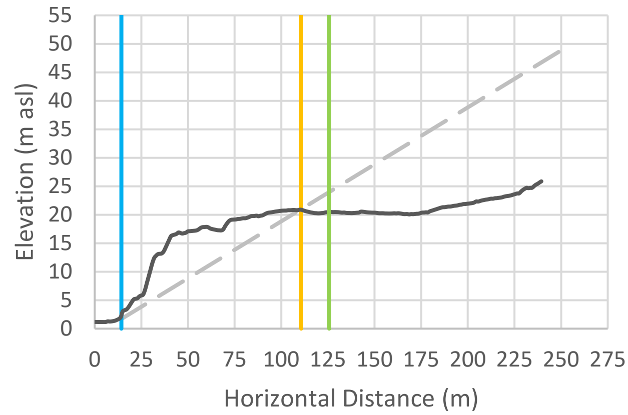
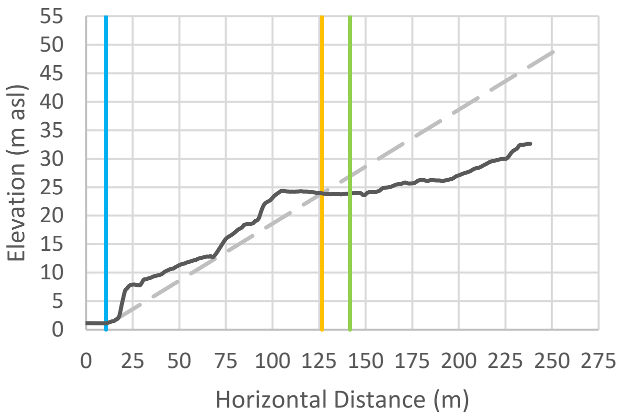


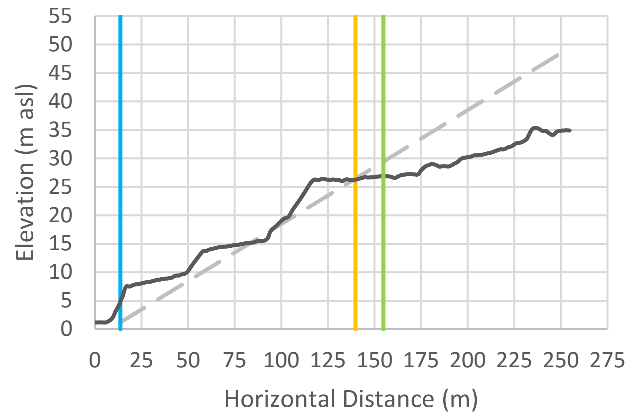
Cross-Section 13: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



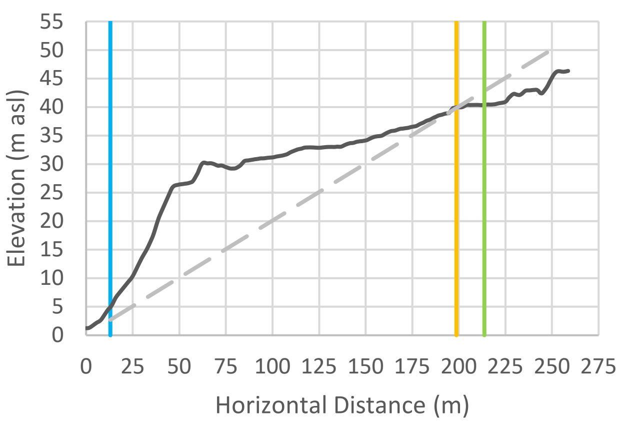
Cross-Section 14: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



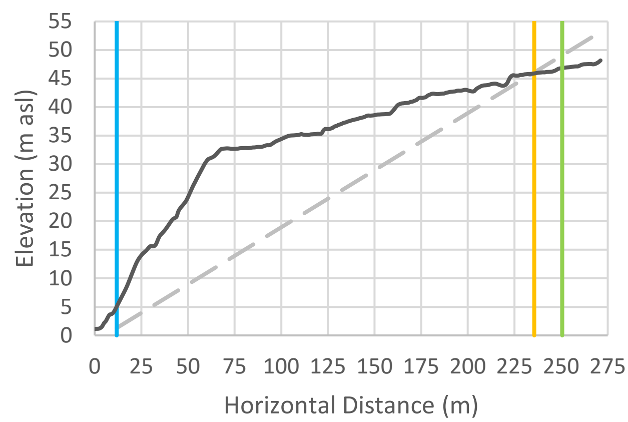
Cross-Section 15: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



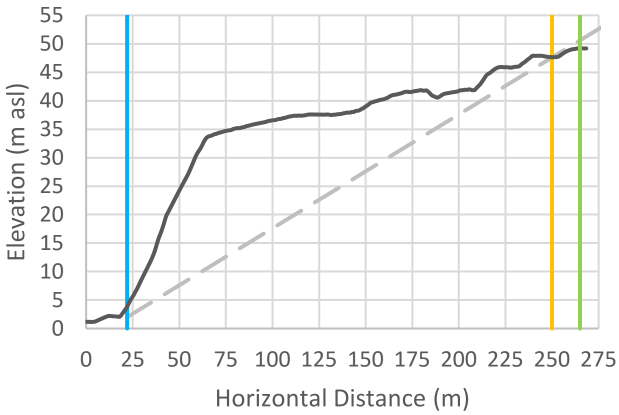
Cross-Section 16: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



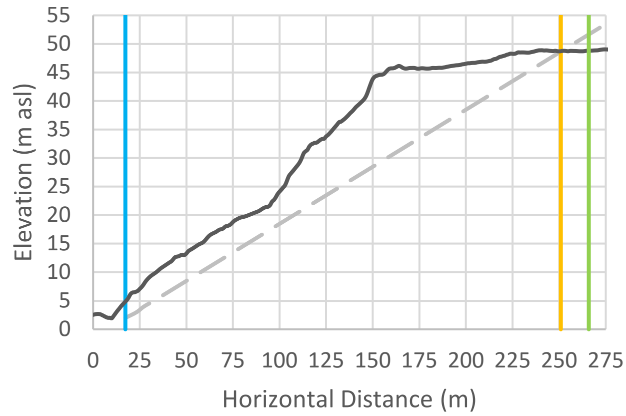
Cross-Section 17: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



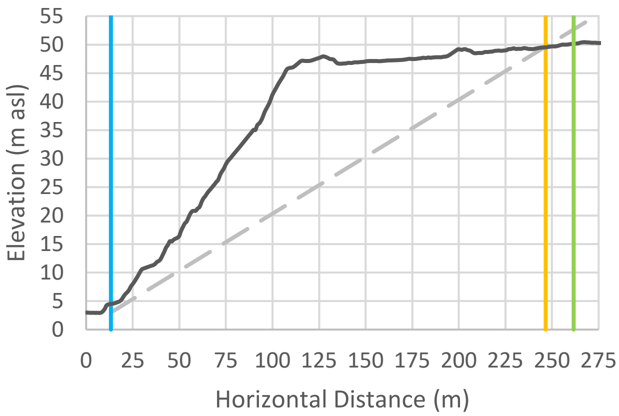
Cross-Section 18: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



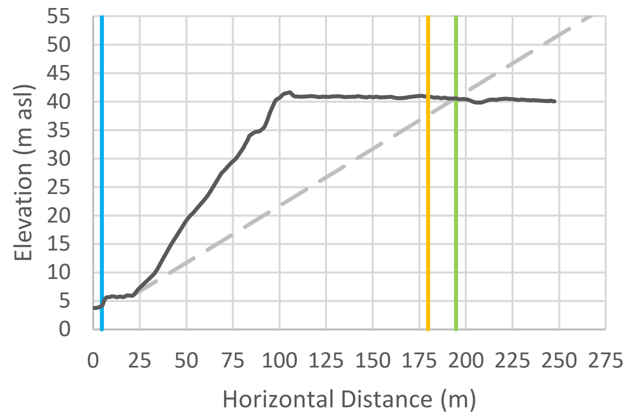
Cross-Section 19: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



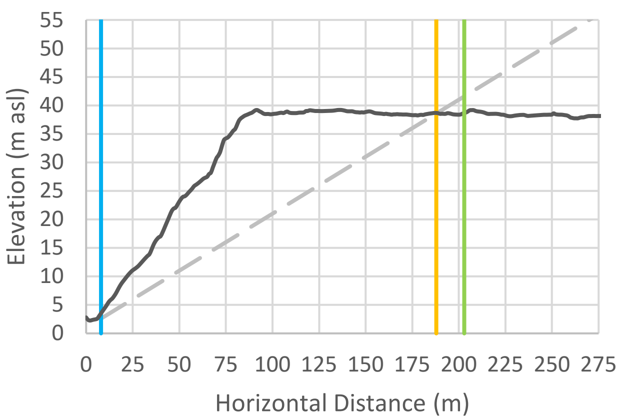
Cross-Section 20: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



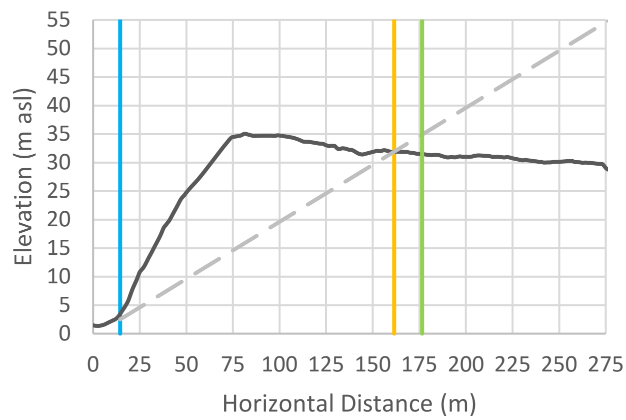
Cross-Section 21: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



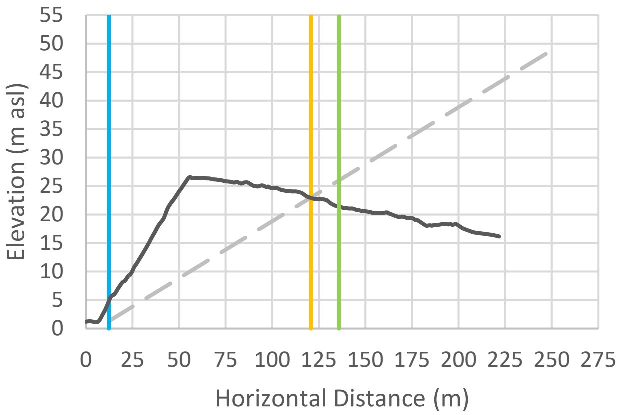
Cross-Section 22: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



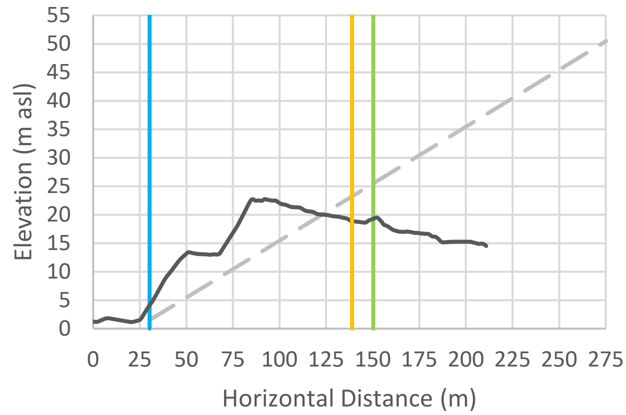
Cross-Section 23: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



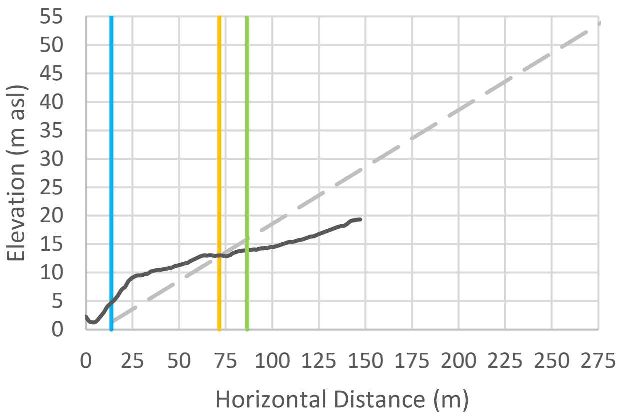
Cross-Section 24: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



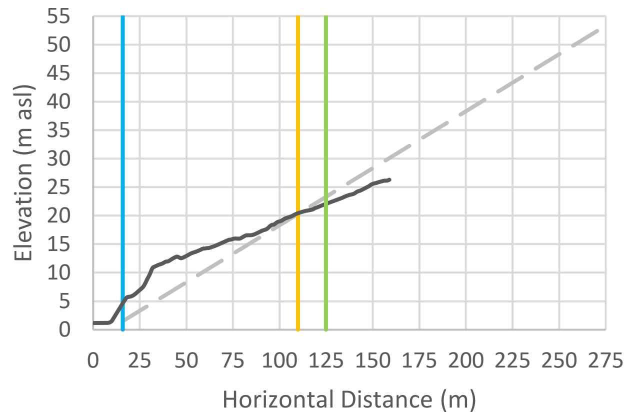
Cross-Section 25: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



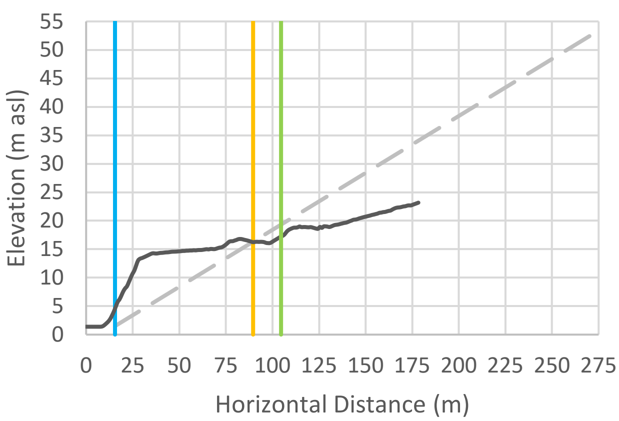
Cross-Section 26: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



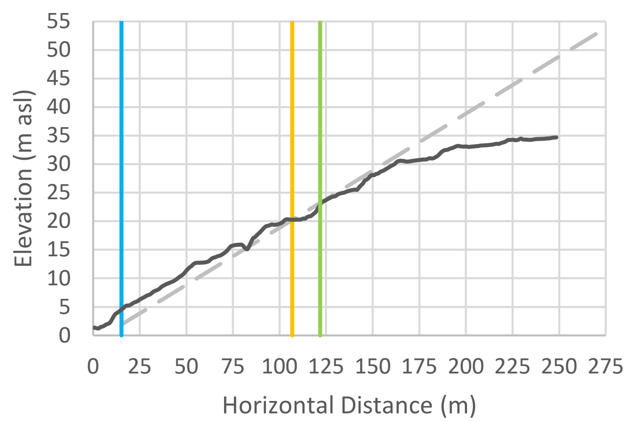
Cross-Section 27: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



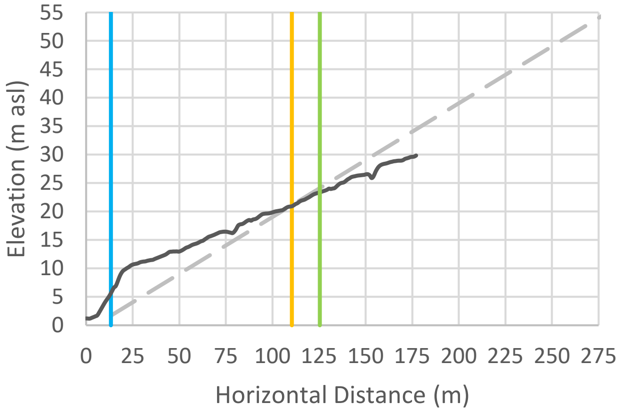
Cross-Section 28: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



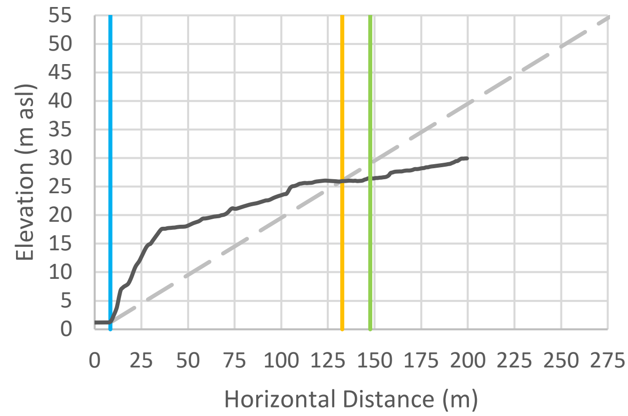
Cross-Section 29: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



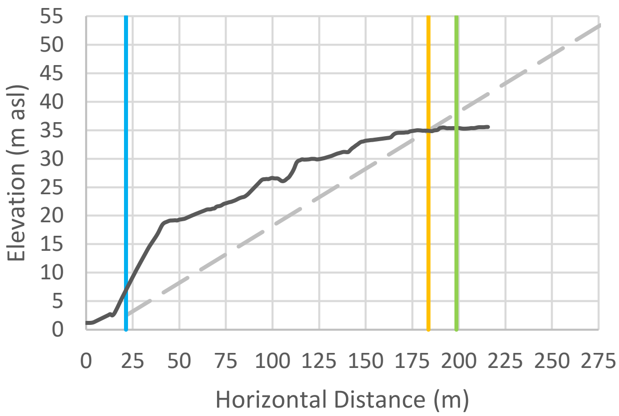
Cross-Section 30: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



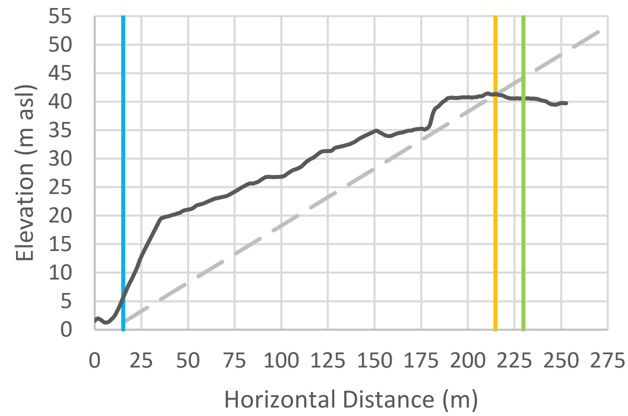
Cross-Section 31: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



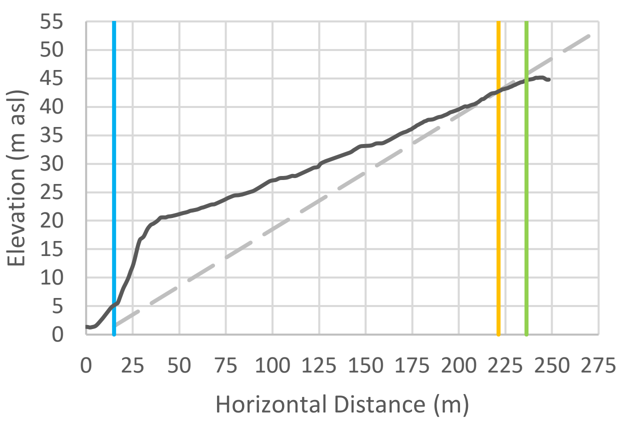
Cross-Section 32: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



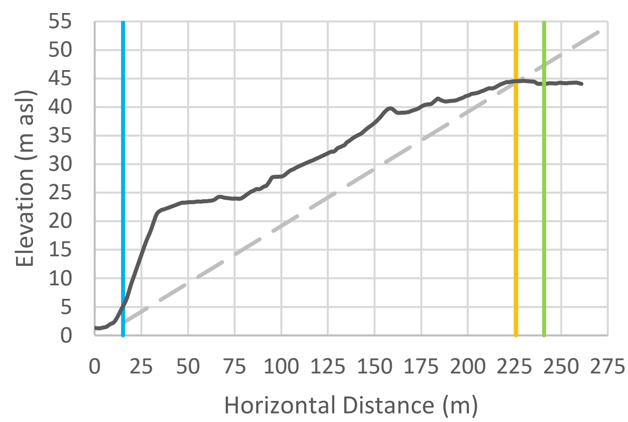
Cross-Section 33: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



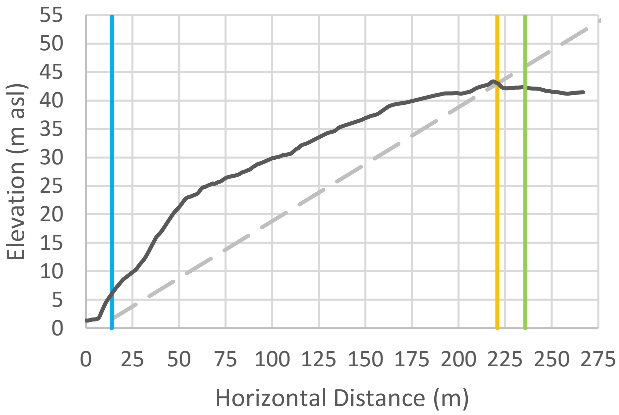
Cross-Section 34: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



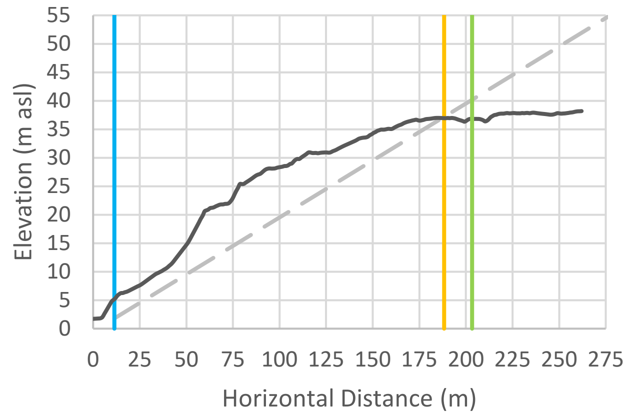
Cross-Section 35: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



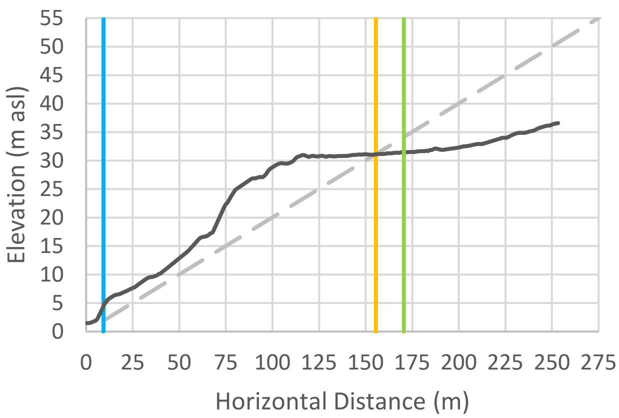
Cross-Section 36: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



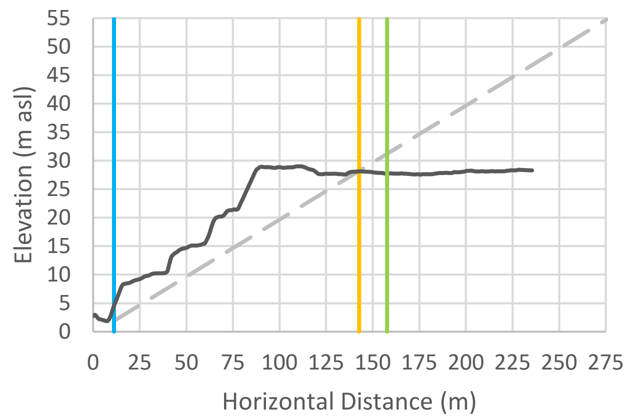
Cross-Section 37: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



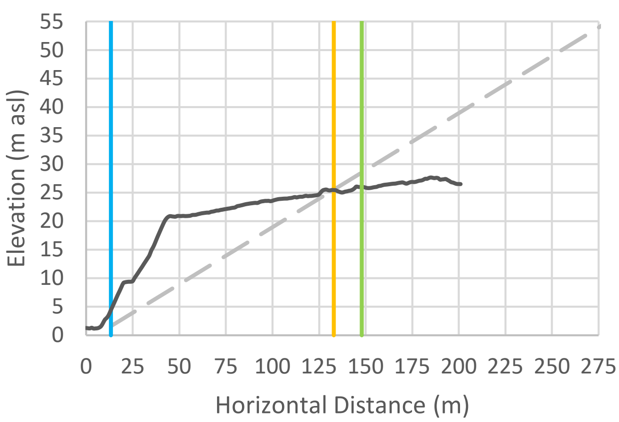
Cross-Section 38: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



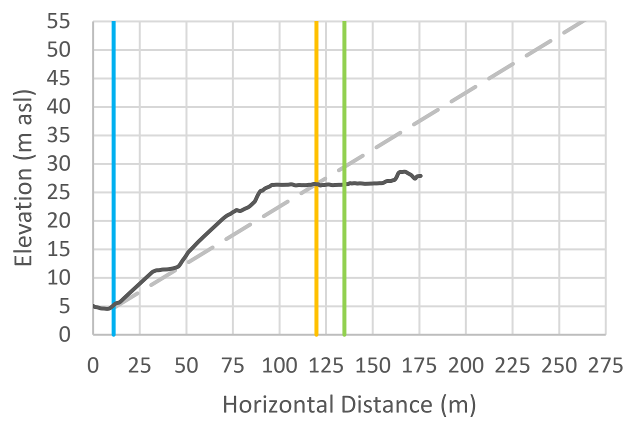
Cross-Section 39: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



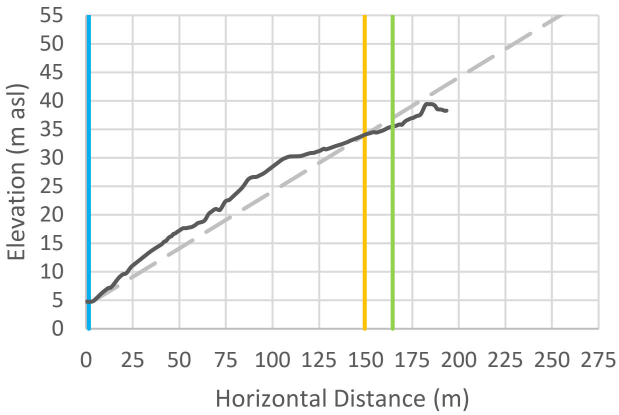
Cross-Section 40: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



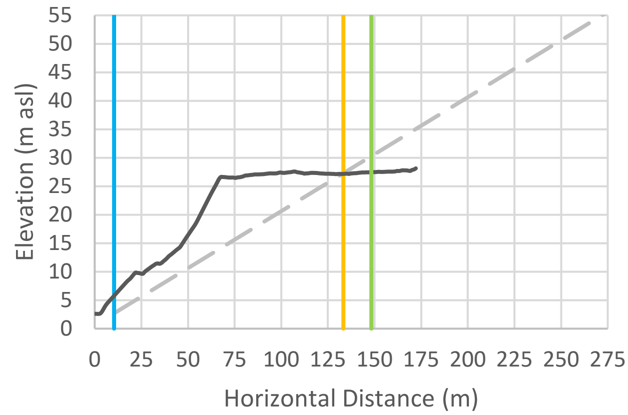
Cross-Section 41: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



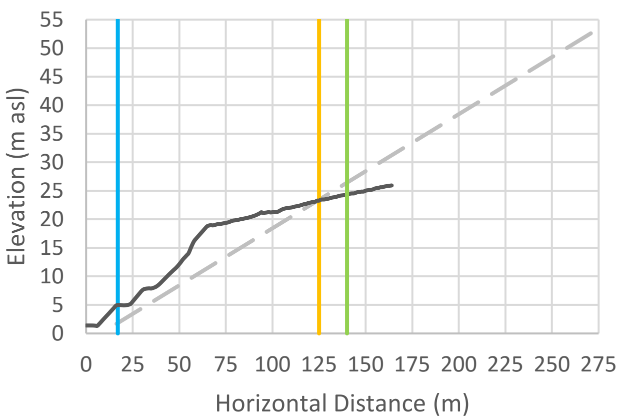
Cross-Section 42: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



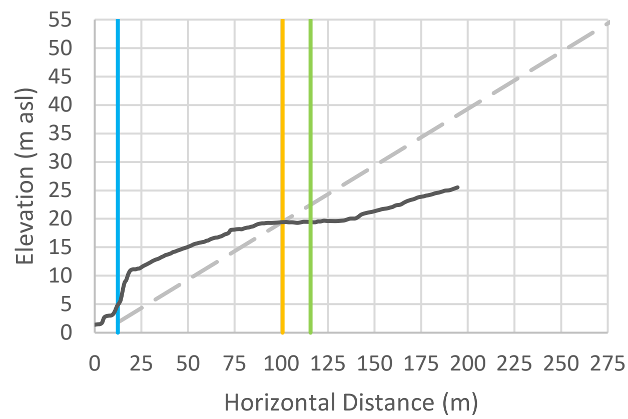
Cross-Section 43: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



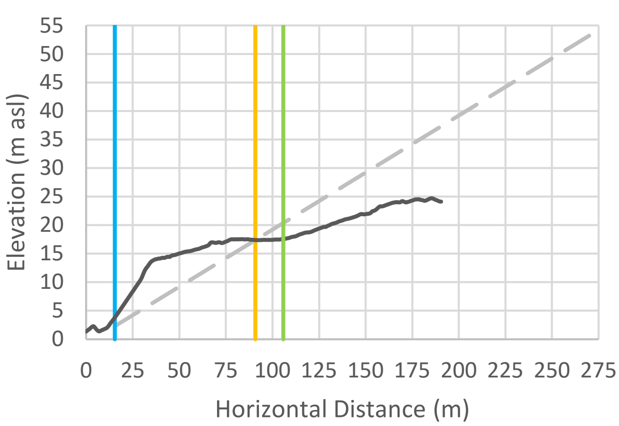
Cross-Section 44: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



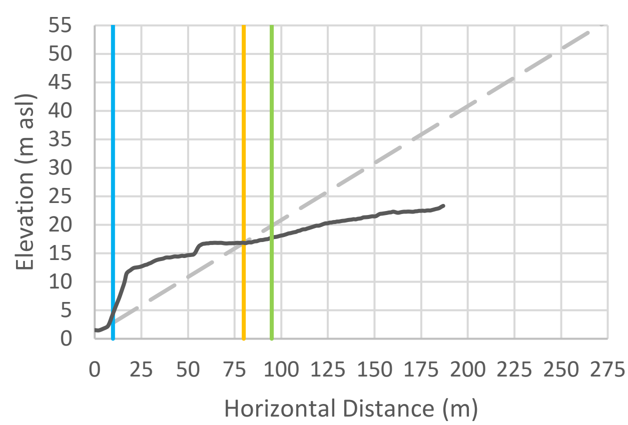
Cross-Section 45: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



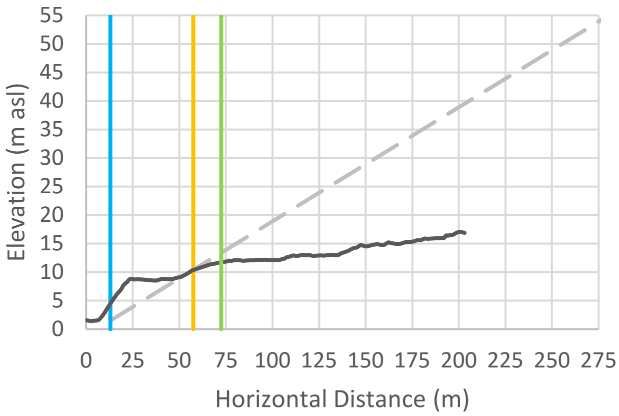
Cross-Section 46: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



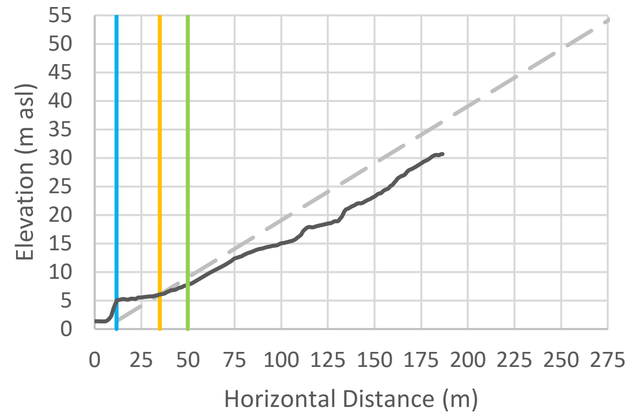
Cross-Section 47: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



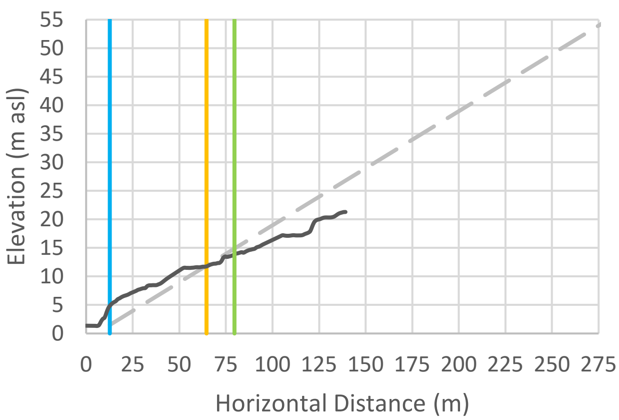
Cross-Section 48: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



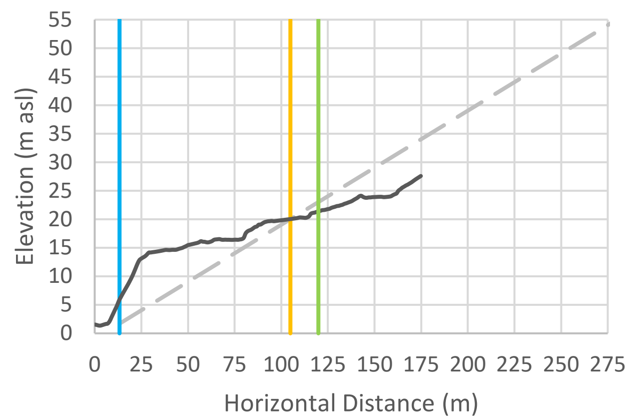
Cross-Section 49: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



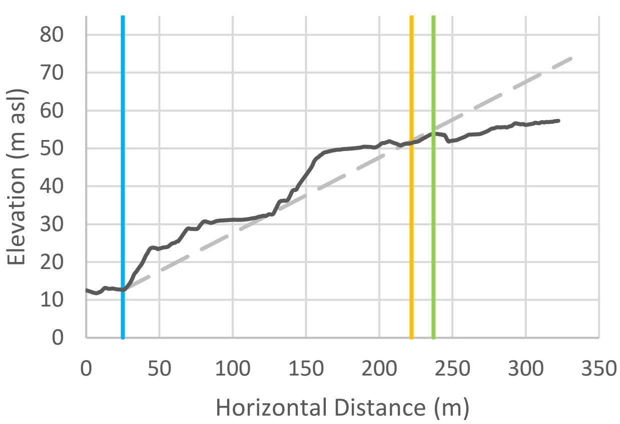
Cross-Section 50: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



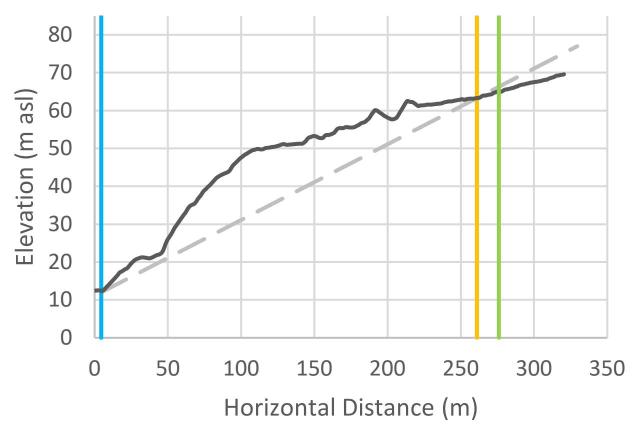
Cross-Section 51: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



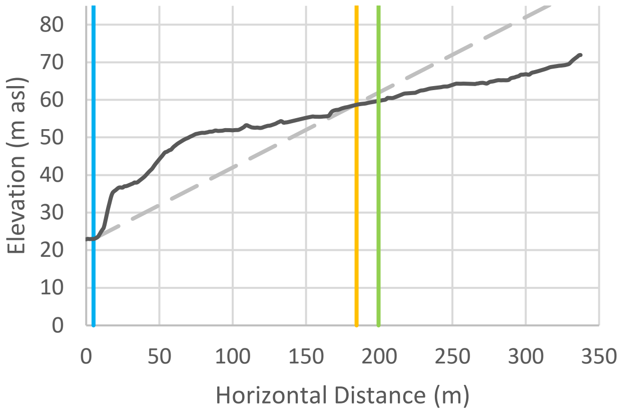
Cross-Section 52: Vertical exaggeration = 3. The black line is the cross-sectional data. The blue line is the Natural Boundary position with 1 m SLR, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



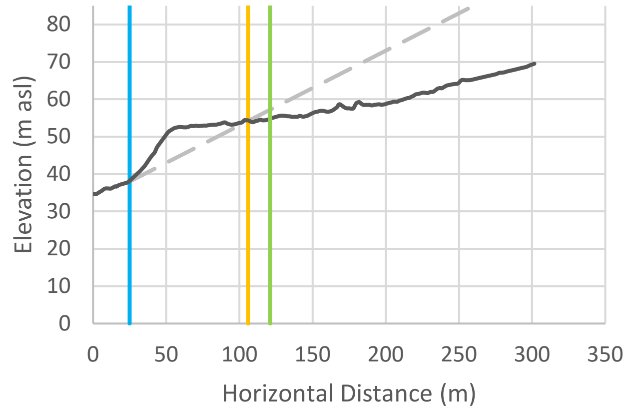
Cross-Section r-1: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



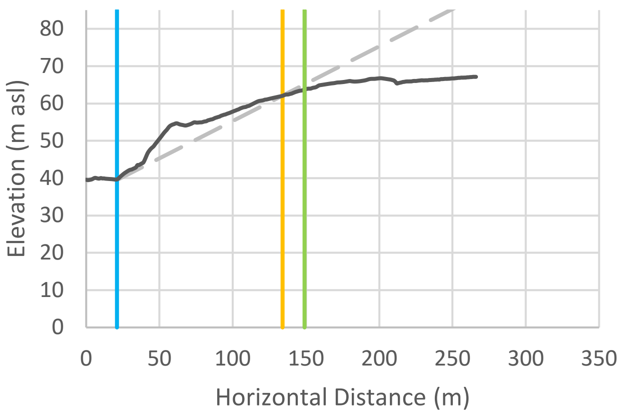
Cross-Section r-2: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



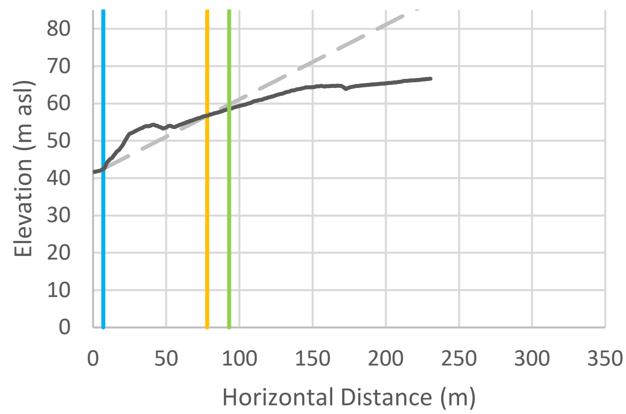
Cross-Section r-353: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



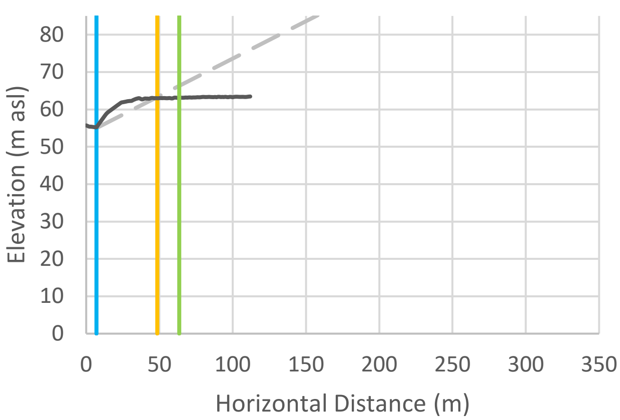
Cross-Section r-4: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



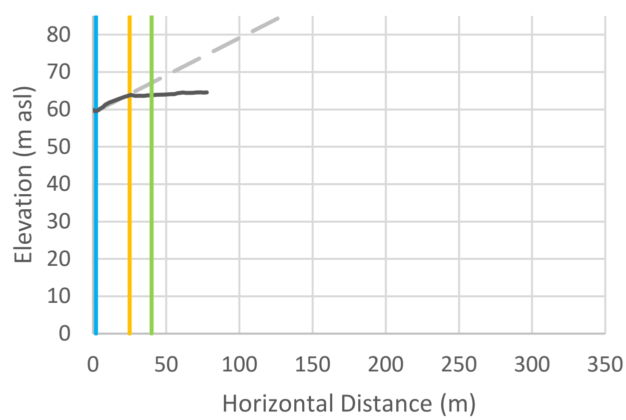
Cross-Section r-5: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



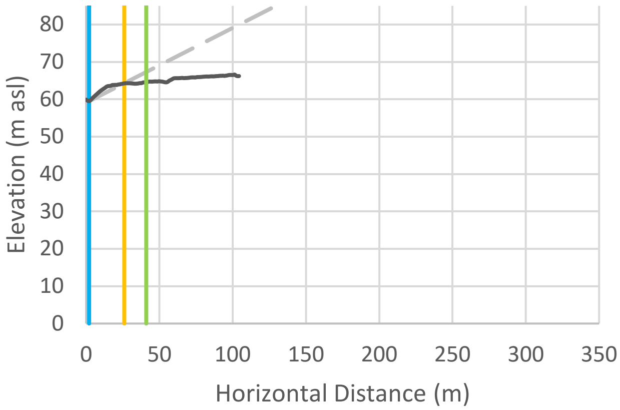
Cross-Section r-6: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



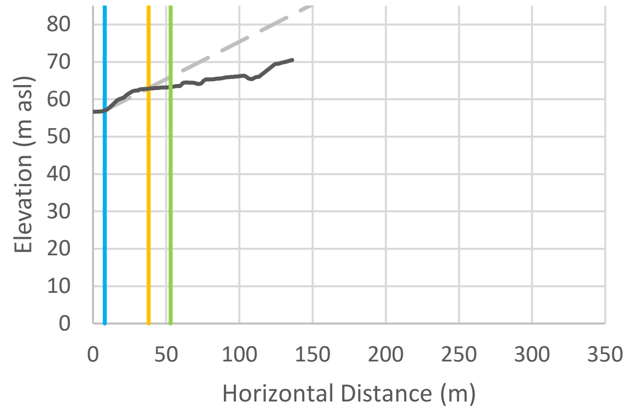
Cross-Section r-7: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



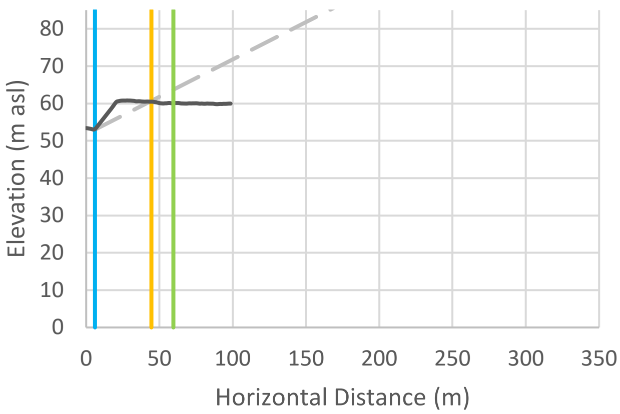
Cross-Section r-8: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



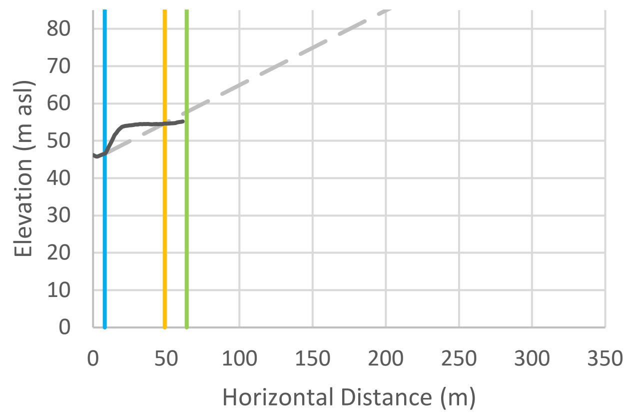
Cross-Section r-954: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



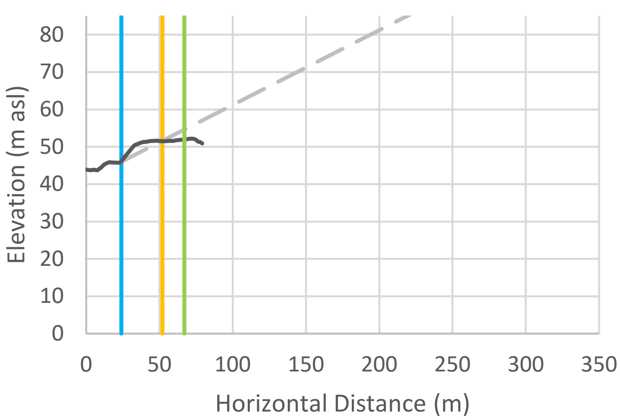
Cross-Section r-10: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



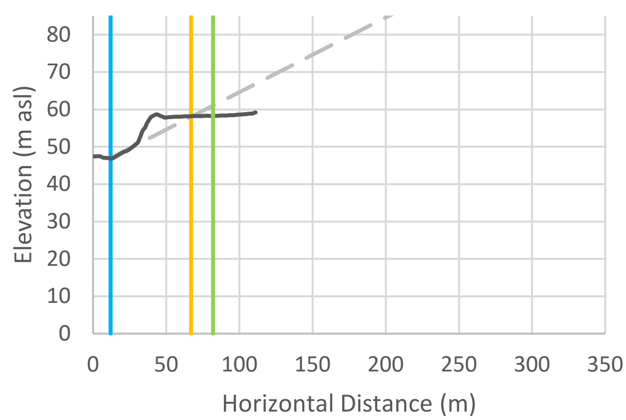
Cross-Section r-11: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



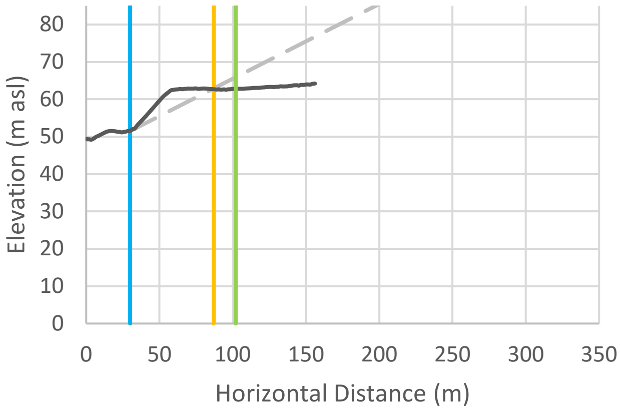
Cross-Section r-12: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



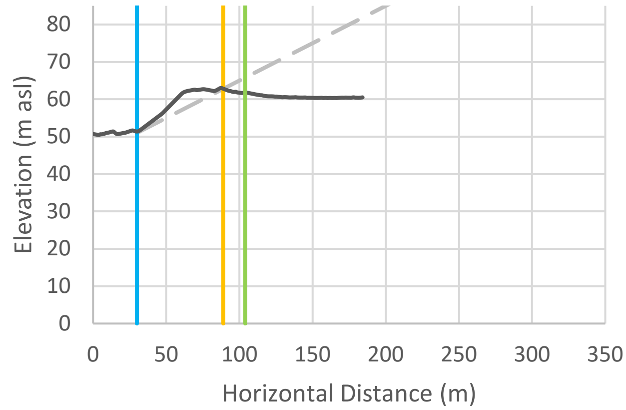
Cross-Section r-13: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



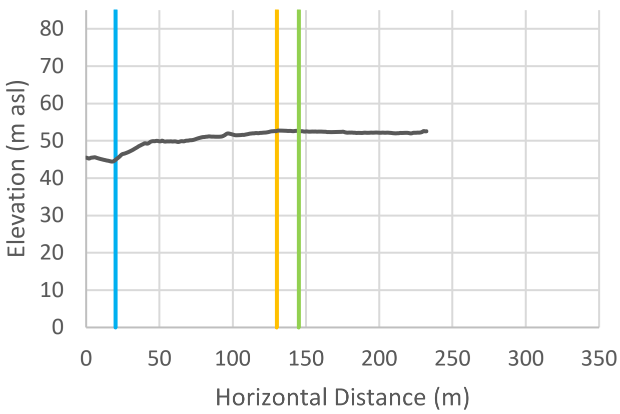
Cross-Section r-14: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



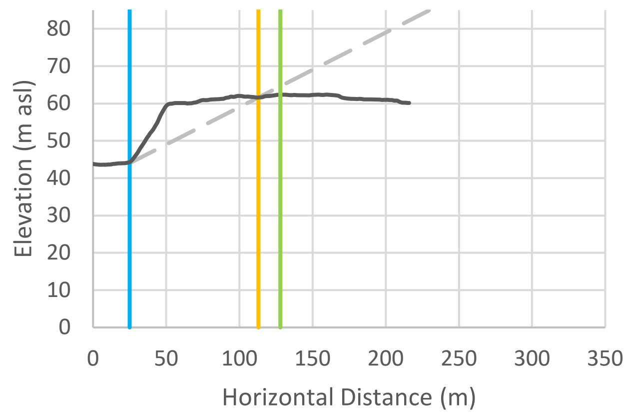
Cross-Section r-1555: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



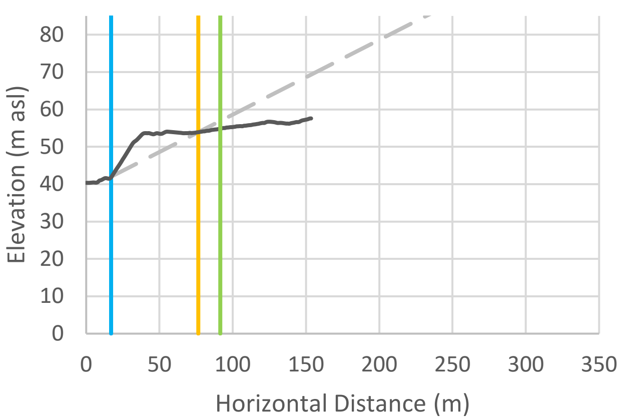
Cross-Section r-16: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



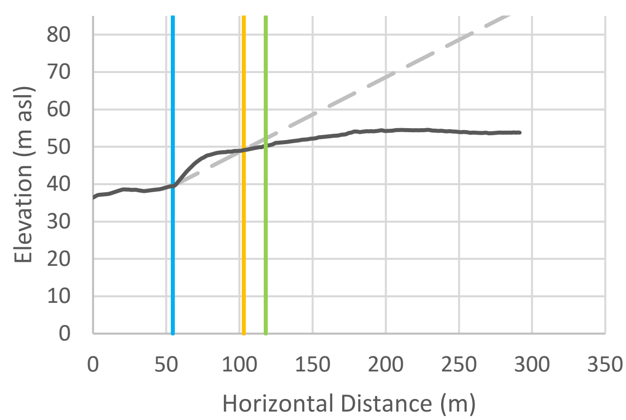
Cross-Section r-17: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



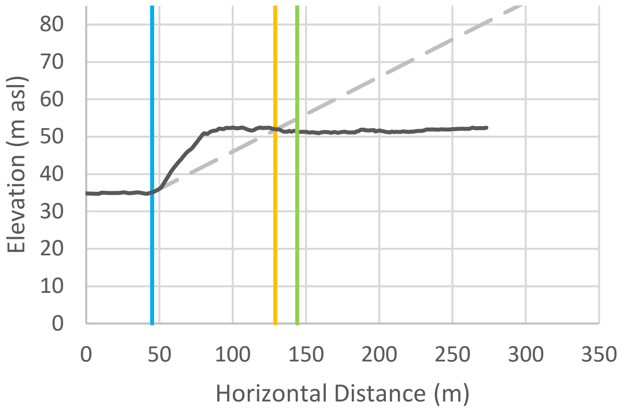
Cross-Section r-18: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



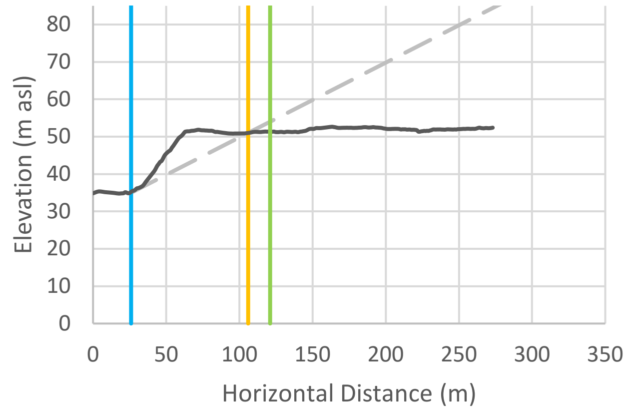
Cross-Section r-19: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



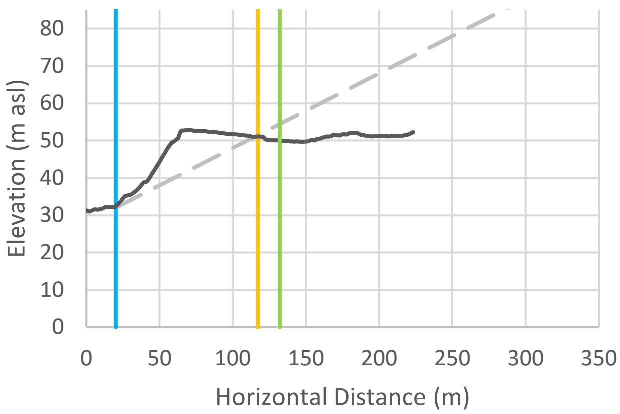
Cross-Section r-20: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



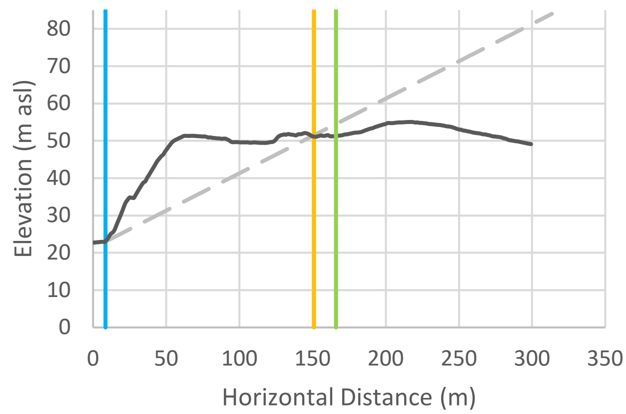
Cross-Section r-2156: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



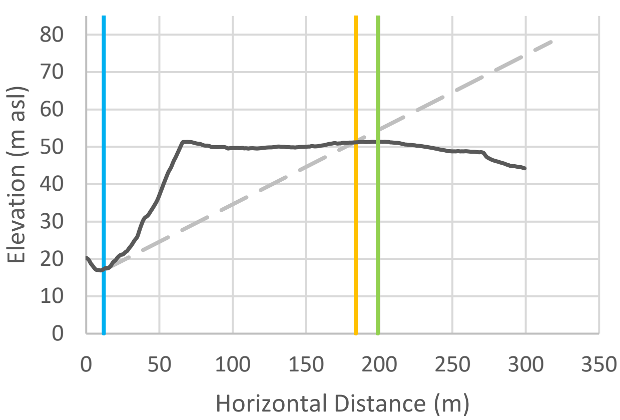
Cross-Section r-22: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



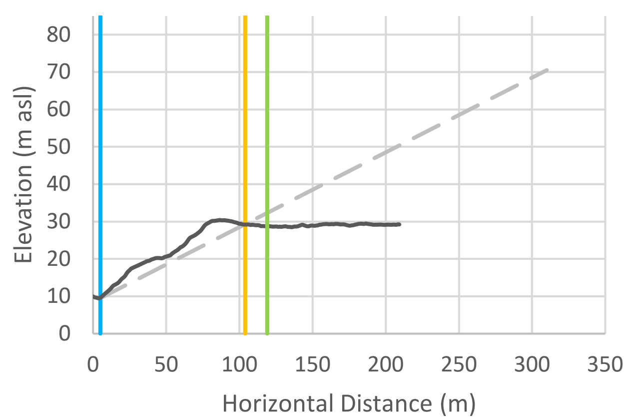
Cross-Section r-23: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



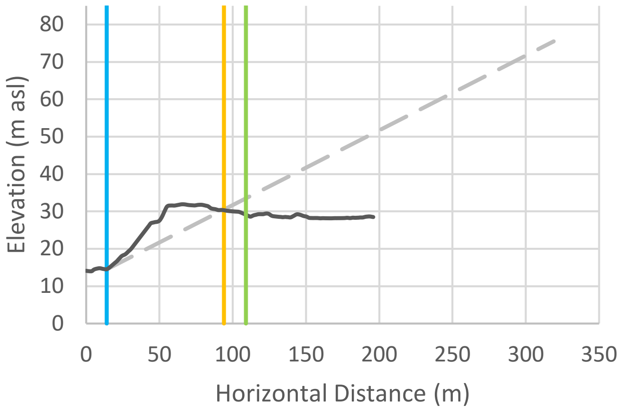
Cross-Section r-24: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



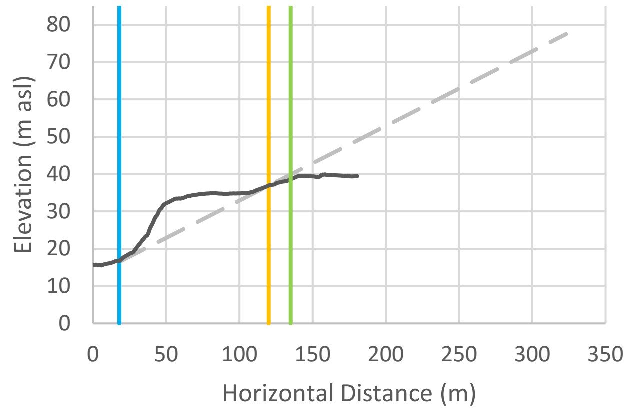
Cross-Section r-25: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



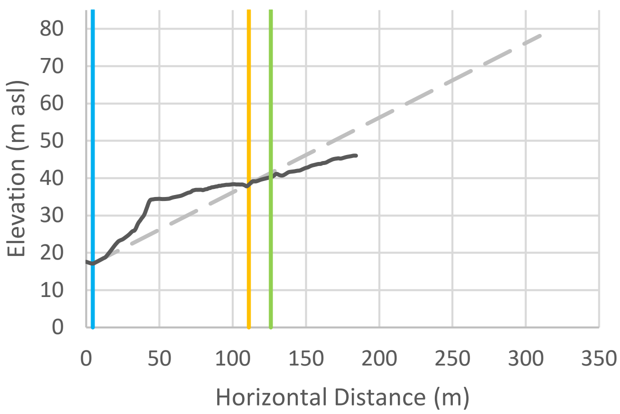
Cross-Section r-26: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



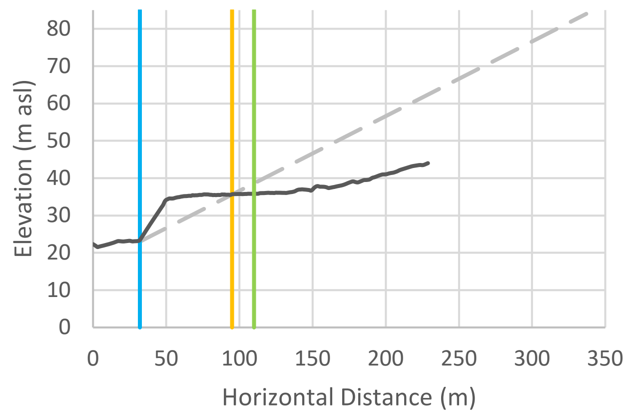
Cross-Section r-2757: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



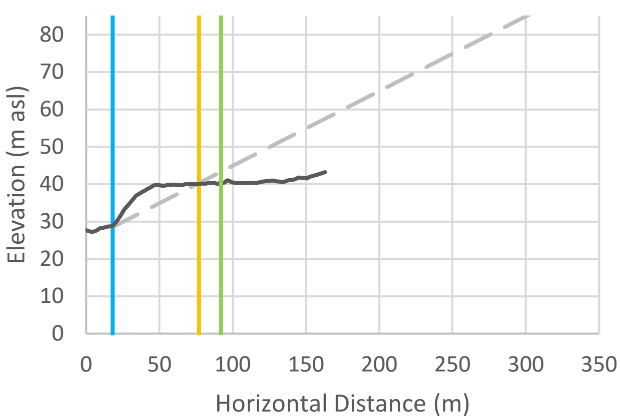
Cross-Section r-28: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



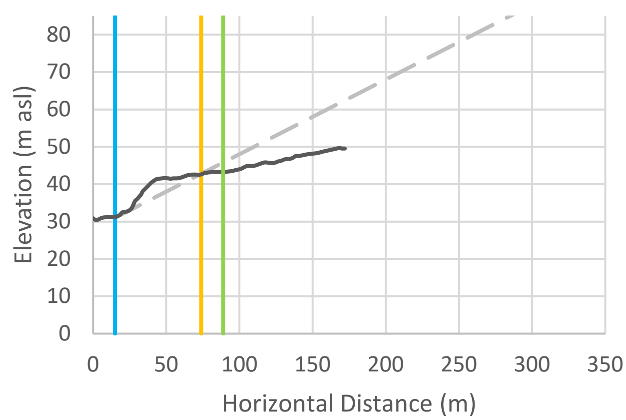
Cross-Section r-29: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



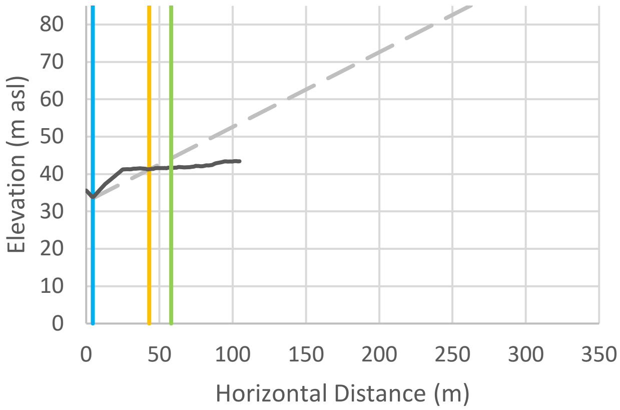
Cross-Section r-30: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



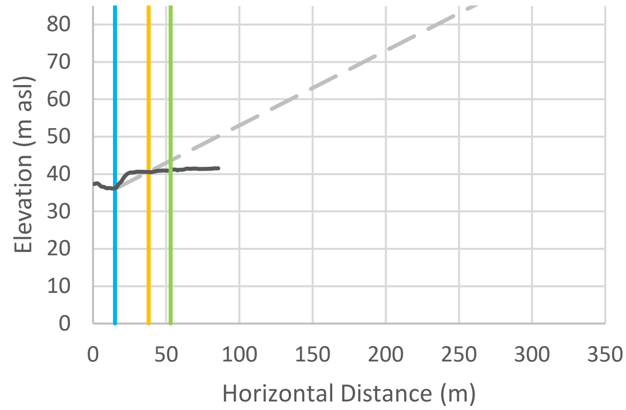
Cross-Section r-31: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



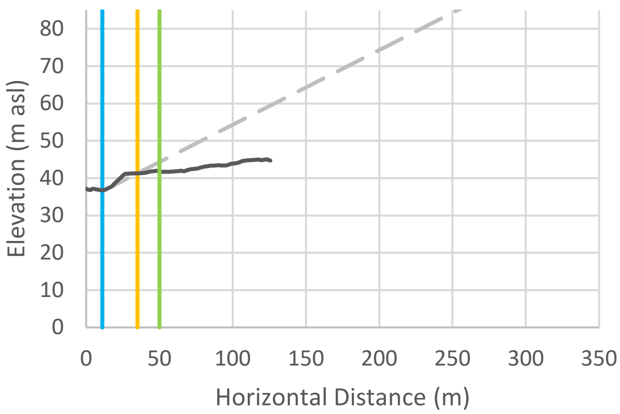
Cross-Section r-32: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



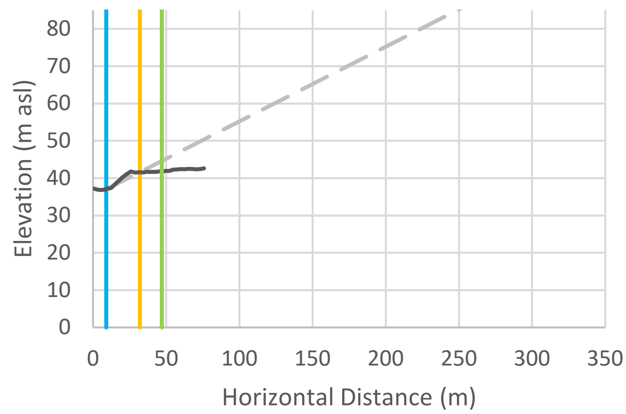
Cross-Section r-3358: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



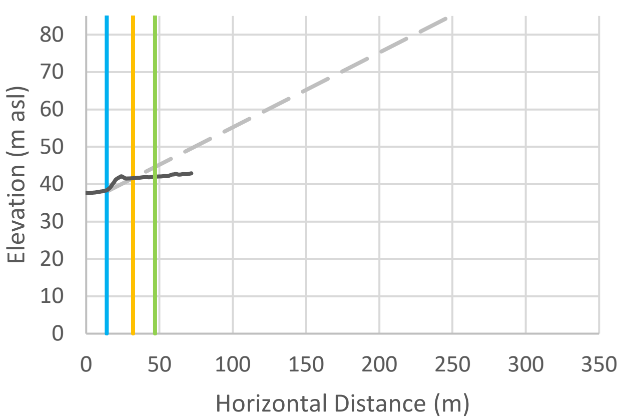
Cross-Section r-34: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



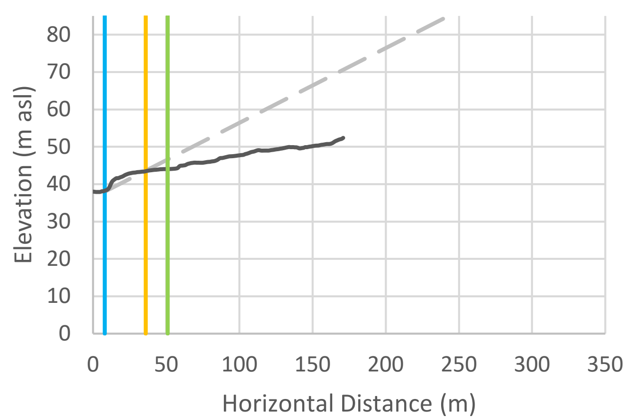
Cross-Section r-35: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



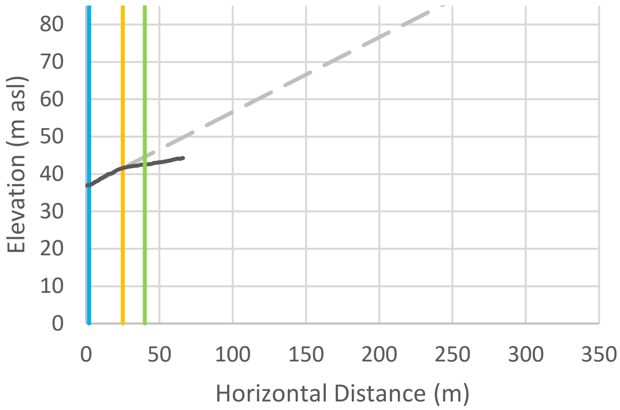
Cross-Section r-36: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



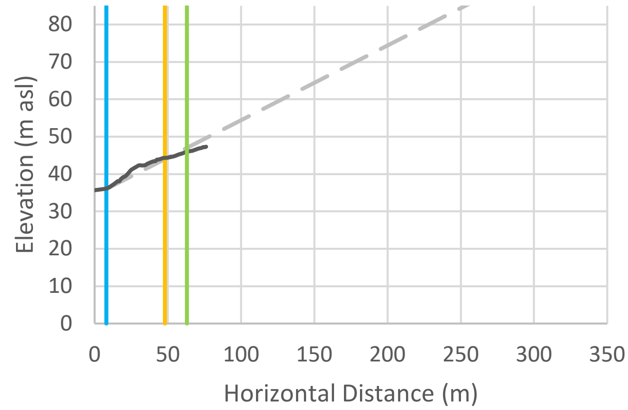
Cross-Section r-37: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



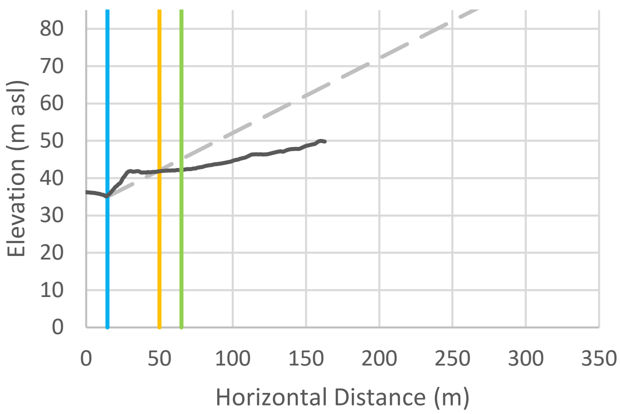
Cross-Section r-38: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



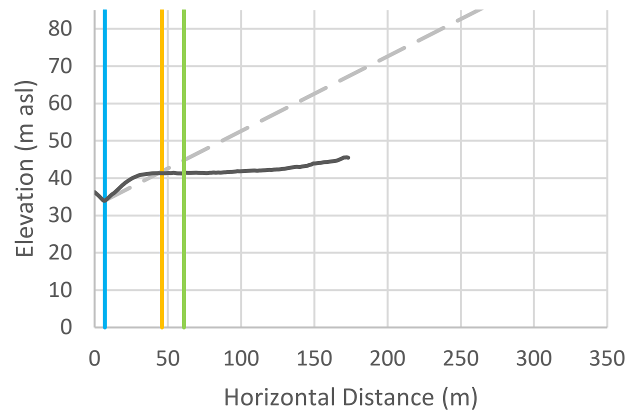
Cross-Section r-3959: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



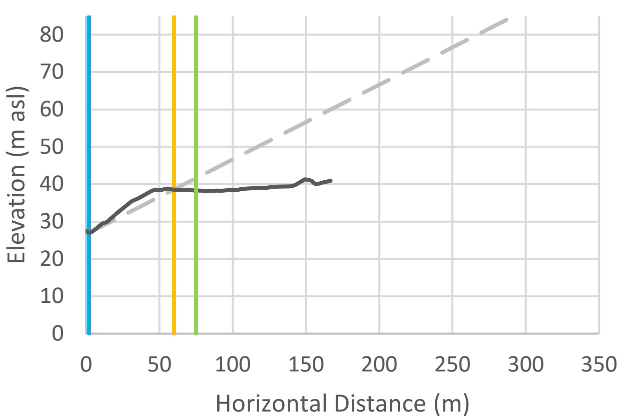
Cross-Section r-40: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



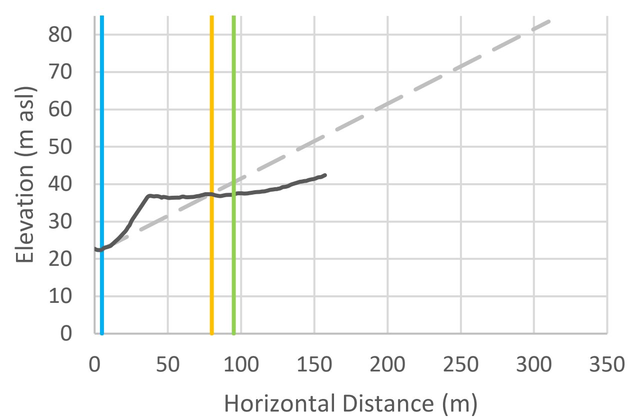
Cross-Section r-41: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



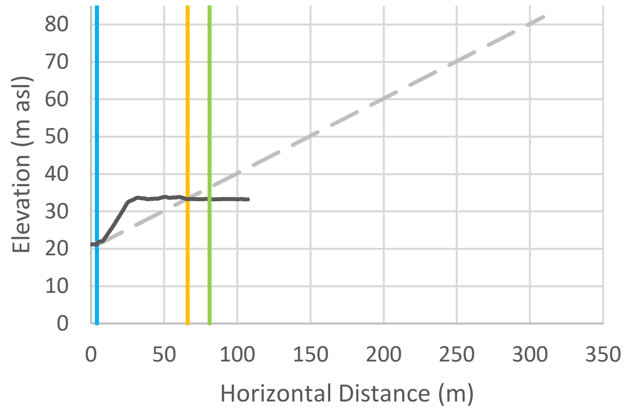
Cross-Section r-42: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



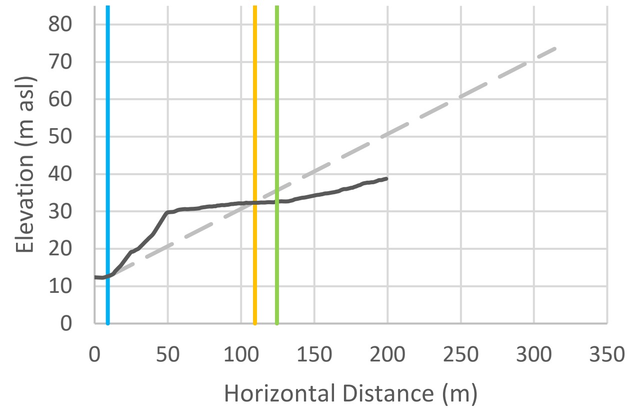
Cross-Section r-43: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



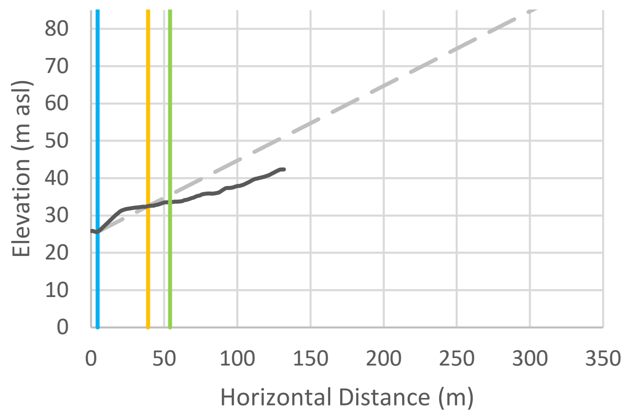
Cross-Section r-44: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



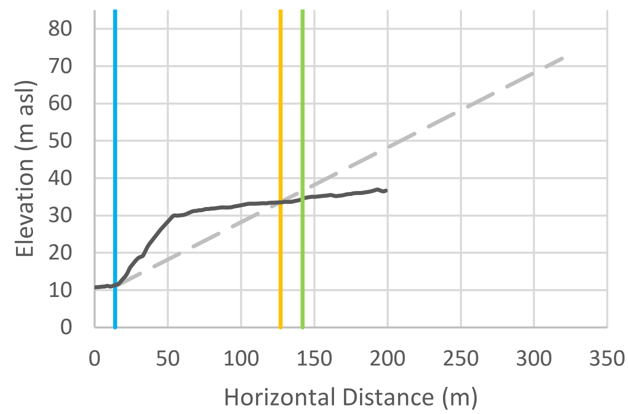
Cross-Section r-4560: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



Cross-Section r-46: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



Cross-Section r-47: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.



Cross-Section r-48: Vertical exaggeration = 2.5. The black line is the cross-sectional data. The blue line is the toe of slope, the orange line is the calculated setback, and the green line is the calculated setback plus 15 m.