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1. Introduction

1.1 Background

The OCP area of Twin Creeks is located on the Sunshine Coast, approximately 12 km northeast of Gibsons. The OCP area is bounded by the community of Langdale to the south, Howe Sound to the east and the Mt Steel Mountain Range to the North.

The Sunshine Coast is typical of many areas in south-coastal British Columbia, being subject to a number of geohazards conditioned by steep terrain and a maritime climate:

- Steep mountain slopes are sources of potential landslide activity that may affect lower slopes;
- Creeks may be subject to flooding and may serve as conduits for debris flow events;
- The sea presents a coastal erosion and littoral flood hazard;
- Tall coastal bluffs present an erosion and landslide hazard; and
- Earthquakes present a landslip and liquefaction hazard.

1.2 Project Scope

The Sunshine Coast Regional District (SCRD) has retained Kerr Wood Leidal Associates Ltd. (KWL) to produce a Geotechnical Hazards Report for the Twin Creeks OCP area based on the RFP closed in August 2014.

The work scope was to assess and recommend revisions to the existing Development Permit Areas (DPAs) included in the Official Community Plan pertaining to the area of Twin Creeks. The study provides the SCRD with technical guidance on possible amendments to existing DPAs.

The project involves a number of key goals that include:

- Develop a consistent DPA framework based on natural hazards, and provide a rationale for development based on the current guidelines and regulations (e.g., *Flood Hazard Area Land Use Management Guidelines*, *Guidelines for Legislated Landslide Assessments for Residential Developments in BC*, *Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC*, BC Building Code, the Riparian Areas Regulation, and the SCRD Risk Assessment and Liability Policy); and
- Propose DPAs based on the assessment framework, utilizing a combination of GIS base mapping files, air photo interpretation, and prioritized field investigation.

1.3 Project Team

The project team includes:

- Erica Ellis, M.Sc., P.Geo., KWL (Project Manager);
- Mike Currie, M.Eng., P.Eng., KWL (Senior Technical Review);
- Chad Davey, M.Sc., KWL (Fluvial Geomorphologist);

- Scott Cowan, KWL (Junior Geoscientist),G.I.T., CTech, and
- Pierre Friele, M.Sc., P.Geo., PG (WA), Cordilleran Geoscience (Senior Geoscientist).

2. Data Sources

2.1 Background Reports

A number of reports were reviewed in the course of this project, including:

- "*Twin Creeks Official Community Plan Geotechnical Reconnaissance Study*" (Thurber, 2001);
- *Twin Creek Area Official Community Plan* (SCRD, 2005);
- "*Hazard Risk and Vulnerability Analysis for the Sunshine Coast Regional District*" (EmergeX Planning, 2005);
- "*Box Canyon Hydro Project: Terrain Hazards Assessment*" (Knight Piesold, 2010); and
- Terrain Inventory maps for the Sunshine Coast.

Brief summaries of selected reports are provided below:

2.1.1 Thurber (2001)

This report summarized a reconnaissance geotechnical hazard evaluation for the southern portion of the current Twin Creeks OCP area. The hazards that were identified focused on slope stability and watercourse hazards (e.g. flooding and erosion, debris flows/floods). The work touched upon several areas of concern, including: debris flow hazards along Bear, Cub and Ouillet Creeks, avulsion hazards along lower Bear, Twin and Ouillet Creeks, majority of upper slopes in the study area (slope stability), and undersized culverts along the Port Mellon Highway.

2.1.2 EmergeX Planning (2005)

EmergX Planning conducted a general risk assessment for the entire SCRD. Geological hazards were reviewed and historic events (e.g. flooding, landslides, etc.) were discussed. The resultant risk matrix from EmergeX analyses shows that natural hazards within the SCRD are frequent, high severity events: a significant risk to people and infrastructure if left unmitigated.

2.2 Orthophotos

Digital orthophotos (i.e. air photographs given a spatial position via orthorectification) from 2006, 2009 and 2014 were obtained from the SCRD and reviewed.

In general, the relatively small size of the creeks in combination with the forest canopy cover prevented detailed observations of the channels. Thus, the digital orthophotos were mainly used for:

- geographic reference;
- confirmation of previously identified hazards;
- noting land-use changes over time;
- confirmation of steep terrain indicating a potential start zone for slope failures; and
- assessment of creek confinement.

2.3 GIS Analysis

GIS data were obtained from the SCRD including:

- Topographic data:
  - 1 m contours (a small portion of the OCP area, near the ocean), and
  - TRIM digital elevation data (full coverage of OCP area).
- Creeks and rivers.
- Administrative data:
  - OCP Boundary (old and revised),
  - parcels, and
  - existing DPAs.
- Roads.
- Orthophotos (2006, 2009 and 2014).

In addition, the Provincial 1:50,000 scale DEM data were downloaded to provide full coverage of the watersheds that are contained within, or cross, the Twin Creeks OCP area.

3. Hazard Analysis

3.1 Background

3.1.1 Topography

The Twin Creeks OCP area is generally concave in vertical profile, rising from sea-level (Howe Sound) to elevations of 1,500 m at the divide (Steel Mountains). Development is relatively sparse within the OCP area, with the limited development typically occurring on gently sloping terrain (less than 30% slopes). Steeper slopes generally occur in the following locations:

- associated with local rock outcrops;
- along creek ravines; and
- along the coastal bluffs.

3.1.2 Climate and Hydrology

The study area lies within the Coastal Western Hemlock biogeoclimatic zone (Meidinger and Pojar, 1991). This zone experiences relatively cool summers and mild winters, with an annual precipitation range from 1,000 mm to 4,400 mm. Less than 15% of annual precipitation occurs as snowfall.

Local creeks have two runoff peaks: a summer snowmelt freshet that typically occurs between May and July, and a fall peak. Although monthly discharges are largest during the freshet, both the annual maximum instantaneous and annual maximum daily flood peaks typically occur as a result of rain or rain-on-snow runoff events from September through March.

3.1.3 Quaternary Geology

The surficial deposits along the Sunshine Coast are the product of multiple episodes of glaciation and deglaciation. The modern landscape is dominated by the deposits of the most recent cycle of glaciation. The last, or Fraser, glaciation began 29,000 years ago and reached its peak 14,500 years ago. The region was ice free by 13,000 years ago.

Outwash sediments associated with the advancing ice front, known as the Quadra Sands, are found throughout the Strait of Georgia at elevations up to 100 m. After 19,000 years ago, the outwash was overridden by the advancing ice margin, depositing till, known as Vashon Drift (a complex of till, glaciofluvial and glaciolacustrine sediments). After 14,000 years ago, glaciofluvial, glaciomarine and marine sediments were deposited up to an elevation of 180 m, indicating a relative sea level much higher than that of present day. These sediments are known as Capilano Formation. Following deglaciation, fluvial and mass wasting processes rapidly reworked glacial sediments. Process rates declined over time such that by no later than 6,000 years ago the landscape was similar to today. Post-glacial sediments, formed in modern fluvial, beach and bog environments, are referred to as Salish sediments.

Thus a typical succession of Quaternary sediment in the study area would consist of Quadra Sand overlain by Vashon Drift overlain by Capilano sediments and locally by Salish sediments. Close to the mouths of major creeks and rivers, the Capilano sediments consist of large gravelly deltas, locally exploited for their aggregate potential. Away from these fluvial settings and below the former marine limit, there are blankets of stoney clay and more localized sand and gravel beach strands. Total thickness of overburden ranges from nothing to 100 m or more.

3.2 Hazard Overview

As previously mentioned, the Sunshine Coast is subject to a number of geohazards resulting from steep terrain and a maritime climate. Hazards have been grouped into three main categories:

1. Coastal Zone Hazards;
2. Creek Hazards; and
3. Slope Hazards.

Hazards associated with the three zones are discussed below. The hazard screen maps are presented in Figure 3-3 through Figure 3-7 (Sheets 1 through 5).

3.3 Coastal Zone Hazards

Coastal hazards include flooding from a combination of regular tidal processes (e.g., storm surge, waves, etc.), but also could occur from rare seismically-induced events, such as seiche[1] and tsunami. In addition to flooding, coastal zone hazards include erosion and failure of coastal bluffs.

Current observations and climate change science indicate that sea level rise is currently occurring and that the rate of sea level rise is expected to increase in the near future (e.g., 20 years). Sea level rise compounds regular and rare coastal hazards, where the magnitude of the hazards will increase over time.

3.3.1 Coastal Zone Flooding

Coastal flooding can arise from the combination of a number of elements, including:

- astronomic tide;
- atmospheric (storm) surge;
- wind and wave setup;
- wave run-up; and
- sea level rise.

Tsunamis pose an additional threat that is superimposed on tidal and possibly storm effects.

Astronomic Tide

Tidal fluctuations occur daily, and the magnitude of high tides vary throughout the month (e.g., week by week) and seasonally throughout the year. Highest tides are usually experienced in the winter months; however, the peak tide level will vary slightly from year to year. The tide level recommended for assessment of coastal zone flooding is the Higher High Water, Large Tide (HHWLT), the average of the highest high waters, one from each of 19 years of predictions.

Recently, the term “King Tide” has been adopted in the Pacific Northwest. King Tide is reportedly a popular term used to refer to an especially high tide, or the highest tides of the year. King Tide is not a

[1] A standing wave in an enclosed or partially enclosed body of water.

scientific term, nor is it used in a scientific context. King Tides would occur when the moon and sun are aligned at extreme distances to the earth in both January and July, resulting in the largest tidal range seen over the course of a year. Alignments that result in relatively high tides occur during approximately three months each winter and again for three months in the summer. During these months, the high tides are higher than the average highest tides for three or four days. Use of the term 'King Tide' is reported to have originated in Australia, New Zealand and other Pacific nations and has been adapted for use in other parts of the world. King Tides would generally be lesser tide events than a HHWLT tide by definition.

In December 2012, a large tide/surge event was coined a "King Tide" for the region, that resulted in flooding in many parts of the Lower Mainland. This event also included a storm surge component, and strong wind generated to raise water levels further. The two images below illustrate flooding from the December 2012 event.

Coastal Flooding at Ambleside Park, West Vancouver (Image from Vancouver Sun)

Inundation at Kitsilano Pool, City of Vancouver

Atmospheric (Storm) Surge

Storm surge is caused by large prolonged low pressure storm systems. The low pressure system will locally raise water levels above normal tide levels. In the past two decades of observation, the maximum storm surge at Point Atkinson just exceeded 1 m, has reached values higher than 0.9 m several times, and is annually greater than 0.3 m. For the developed coastal areas of Howe Sound (Squamish), the suggested design annual exceedence probability (AEP) is 1 in 500 years (Table 6-1, Ausenco Sandwell, 2011a). The estimated 500-year return period storm surge is 1.3 m for the Strait of Georgia. It should be noted that a 200-year return period surge is only nominally less at 1.2 m.

Wind and Wave Setup

The wind setup is a rise of the water surface above the water level on the open coast due to the local action of wind stress on the water surface. This process acts to raise the overall water surface and is not the same as the wave effect. Wave setup is a shorter duration and more locally raising of the water surface similar to wind setup, but not associated with individual waves. This is not a site specific (e.g., shoreline specific) value, but rather a regional value based on the design wind speed and direction and could vary over the Sunshine Coast, but would not vary significantly from site to neighbouring site.

A wind setup analysis could be conducted by the Regional District based on a larger analysis; however, often these values are quite small for the wind experienced on the protected BC coast and can be lumped with wave processes.

Wave Runup

The wave runup is the vertical component of the total distance that the wave travels once meeting the shoreline. An appropriate setback (horizontal) should be applied to address wave runup on a site specific basis to avoid flooding and limit damage from spray.

Wave runup is a site specific value, and is driven by the design wind event, but is dependent on the orientation, shoreline slope and shoreline material. A general rule of thumb, is that the maximum sea state may be between 0.5 and 1.2 times the depth of water at the shoreline (e.g., seawall, dike, etc.), where sea state includes wind waves and swell (Ausenco Sandwell, 2011b). To minimize damage from waves and spray, structures should be set back from future HHWLT level, and considering climate change (Ausenco Sandwell, 2011c).

Wave runup is a site specific value, which depends on wind aspect, subtidal depth, and shoreline condition and slope. This value would best be assessed for each site under a DPA technical report.

Sea Level Rise

Global sea level rise (SLR) allowances are suggested for the 2100 and 2200 year planning horizons (+1.0 m and +2.0 m, respectively). However, for structures with a short to medium-term design life, a reduced SLR allowance of +0.5 m is suggested (Ausenco Sandwell, 2011a). Typically, residential houses would represent a medium to long-term design life (50 to 100 years), given that renovations that do not alter the building foundation often prolong the life of a house. The regional adjustment is based on consideration of the local effect of vertical land movements (uplift or subsidence).

3.3.2 Coastal Flood Level and Sea Level Rise

The Ministry of Forests, Lands and Natural Resources Operations (MFLNRO) (Inspector of Dikes) has recently released three reports outlining guidelines for management of coastal flood hazard land use that incorporates consideration of sea level rise, sea dikes, and sea level rise policy (Ausenco Sandwell, 2011a,b,c). The reports outline coastal flood level components and incorporate allowances for flooding arising from tides, storms and associated waves, and sea level rise.

The report cites a potential sea level rise of about 1 m by the year 2100, and 2 m by the year 2200 (Ausenco Sandwell, 2011c). The rate at which sea level rises is also anticipated to increase over time, rather than remaining constant.

Ausenco Sandwell (2011) provides examples of preliminary flood levels for the year 2100 for selected locations around BC:

- For the Fraser River delta, the preliminary year 2100 flood level including freeboard is 6.2 m CGD[2].
- For Vancouver Harbour the preliminary year 2100 flood level including freeboard is 5.6 m CGD.

[2] Elevation referenced to Canadian Geodetic Vertical Datum.

Note that both of these levels have been developed assuming wave runup on a natural gravel-pebble beach shoreline, and both include a freeboard allowance of 1.0 m.

Additional, site-specific engineering work would be required to develop FCLs for the Sunshine Coast that incorporate sea level rise; such work is beyond the scope of the current project.

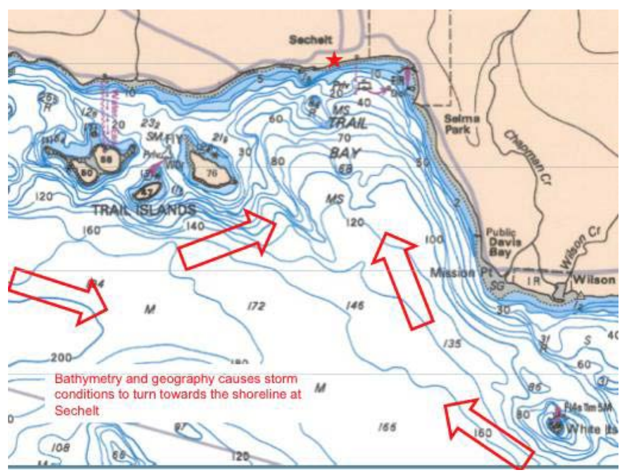
Example – Trail Bay Seawall

A high-level coastal flood hazard assessment recently was conducted for Trail Bay in Sechelt for the purposes of planning a long-term approach for the sea wall and shoreline area.

The Strait of Georgia dominates conditions at Trail Bay with west to northwest winds or southeast winds and the resulting wave environment. Other controlling conditions are summarized in Table 2-2.

Table 3-1: Summary of Trail Bay Meteorological and Oceanographic Conditions

	Description
Winds	SE, SW and W-NW gale and storm force winds 34-47 knots
Wave Heights	3 m (annual), 5 m (100-year storm)
Surge	0.7 m (annual) , 1.3 m (100-year storm)
Storm severity	Depends on chances of storm track, tide timing, surge and wind



Typical winds along the Strait of Georgia are modified as they approach Trail Bay and turn toward the shoreline. This results in wave crests aligning themselves more or less perpendicular with the shoreline. At high tide the waves break about 10-15 m horizontal from the top of the existing rock wall and at low tide waves break further out onto the gravel beach. During winter storms, surges can bring waves onto the top of the seawall. The wave run-up effect can result in substantial overtopping of the wall.

In Trail Bay, the seawall at 4.0 to 4.5 m elevation is overtopped annually. Raising the seawall to about 5.5 m GCD would provide protection and lower annual restoration costs annually. A seawall height of 8.0 m was proposed in the study to limit damage under sea level rise for the year 2060.

Tsunami

Hamilton and Wigen (1987) suggested that slumping of the Fraser delta could induce a tsunami of perhaps several metres height in Georgia Strait. However, Clague et al (1994) concluded that within low lying coastal wetland settings around Georgia Strait there is no evidence of tsunami deposits; therefore, had they occurred, the wave(s) would have been less than about 1 m in height.

Summary

To delineate the potential area of impact for coastal flooding, a conservative elevation of 8 m CGD is proposed for this project.

Typical coastal water level values for the near term quickly reach 6.15 m CGD as follows:

• High Tide:	2.05 m CGD;
• Storm Surge:	1.3 m CGD;
• Global Sea Level Rise to 2100:	1.0 m;
• Wave Effect Allowance:	1.2 m;
• Freeboard Allowance:	0.6 m;
• **TOTAL:**	**6.15 m CGD.**

Freeboard is applied to these values to allow for uncertainty that could be due to wave effects, etc., and further sea level rise allowances provide for a second metre for the year 2200. Accounting for the additional 1 m provides a planning elevation for assessment of 7.15 m CGD, rounded up to 8 m.

Basing the coastal flood hazard on the area encompassed by the 8 m CGD elevation is intended to identify any sites that should be assessed by a qualified professional to address flood hazards, but does not preclude development.

3.3.3 Oceanfront Slopes

Coastal erosion and instability of coastal bluffs is a recognized issue globally. Erosion or failure of high soil slopes results in retreat of the top of bank, and possible risk to structures both at the top and/or toe of the failed slope. A rising sea level poses an increasing coastal erosion hazard, since the level at which storm-generated waves impact the shore will increase over time, exposing new portions of the slope to erosion.

For this project, oceanfront bluffs have been defined as steep slopes facing the ocean and subject to potential toe slope erosion at the high watermark, under present or future sea-level conditions. The location of oceanfront bluffs within the Twin Creeks OCP area was mapped using GIS. The crest of the oceanfront bluffs was defined by the slope break to steeper terrain, and was well defined by LIDAR survey. Slope height varies along the shoreline and can be as low as one to two metres.

In order to delineate a setback for slope hazards for oceanfront slopes, a future sea level reference level of 5 m was used to set an initial 15 m horizontal setback. From that point, a horizontal setback is applied equivalent to three times the total slope height (at that point) to determine the setback line. The 5 m reference level and 15 m setback is intended to address climate change and the effects of sea level rise. This is the general approach outlined in the provincial guidelines (Ausenco Sandwell, 2011).

3.4 Creek Hazards

3.4.1 Background

Steep mountain creeks may be subject to a spectrum of events, ranging from clear water floods to debris flows. Creek events are typically categorized by sediment concentration, with clear water floods having the lowest concentrations of sediment, debris floods having an intermediate concentrations and debris flows having the highest concentration.

Debris floods and debris flows are very rapid flows of water and debris along a steep channel (Hungr et al., 2001). The sediment may be transported in the form of massive surges. Flow velocities for debris flows may be 5 m/s to 10 m/s. These events leave sheets of poorly sorted debris ranging from sand to large boulders and logs. The peak discharge (flow rate) of debris floods and flows is commonly two to five times higher than that of 200 year return period water floods (Jakob and Jordan, 2001).

These types of events would be expected to initiate in the upper watershed, along open slopes or within channels, and be conveyed along confined channels. As the channel gradient drops and/or the channel becomes less confined, sediment is deposited. Repeated deposition forms alluvial fans, but deposition may also occur at road crossings or other human modifications in the landscape, especially where transport capacity has been reduced by encroachment.

Potential for debris floods and debris flows is primarily dictated by the basin characteristics, including gradient, watershed size, channel length, and the underlying geology/lithology of the area. Smaller, steeper watersheds may be debris flow prone; whereas larger, gentler watersheds may only be vulnerable to flooding.

Poor land-use management can also contribute to debris flood and debris flow potential. A debris flow event occurred on Clough Creek in Roberts Creek in November 1983 (MOE, 1984). This event was attributed to logging practices in the upper watershed.

In most cases, the Twin Creek OCP area watercourses are confined within incised channels and ravines, and potential hazards are restricted to the immediate creek or river corridor. Areas with lower confinement usually are floodplain areas or small localized fans. In these areas, flood hazards can be more extensive and unpredictable channel relocation (avulsion) is possible due to debris blockages or sediment deposition. Avulsion events are also possible due to land-use management impacts or construction of undersized culvert crossings. Debris blockages at culvert crossings can result in overland flow paths that convey floodwaters along roads and into developed areas.

3.4.2 Defining the Dominant Creek Hazard

GIS data were used to assess the creeks draining through the Twin Creek OCP area for debris flow or debris flood potential. It has been shown that the Melton Ratio[3] can successfully discriminate between floods, debris floods and debris flow watersheds in BC (Millard et al., 2006). This is related to the physics of initiation, transport and deposition of these events (determined by the viscosity/rheology of the material).

The screening tool was applied in two ways:

1. For the entire watersheds, with the outlet at the ocean.
2. For the upper part of the watersheds, with outlets either at major tributary junctions or where the creeks cross the upper limit of existing development.

The results are displayed in Figure 3-1 and Figure 3-2, and summarized in Table 3-2.

[3] The Melton Ratio is defined as the ratio of total watershed relief to the square root of the drainage area.

Table 3-2: Summary of Screening for Creek Flood Processes

Creek Name	Process Category (Ocean Outlet)	Process Category (Tributary Junction or at Upper Limit of Existing Development)
Langdale Creek	Debris flood	Debris flood
Hutchison Creek	Debris flood	Debris flow
Ouillet Creek	Debris flood	Debris flow
Twin Creek	Debris flood	Debris flow
Bear Creek	Debris flood	Debris flow
Dakota Creek	Flood	Flood
McNair Creek	Debris flood	Debris flood
Mohawk Creek	Debris flow	Debris flow
Rainy River	Flood	Flood
Unnamed Creek #3	Debris flow	N/A[1]
Stolterfront Creek	Debris flow	N/A[1]
Bain Creek	Debris flow	N/A[1]
Unnamed Creek #4	Debris flow	N/A[1]
Unnamed Creek #5	Debris flow	N/A[1]
Harlequin Creek	Debris flow	Debris flow
McNab Creek	Flood	Flood
Unnamed Creek #6	Debris flow	N/A[1]
Unnamed Creek #7	Debris flow	N/A[1]
Potlatch Creek	Debris flood	Flood / Debris Flood
Unnamed Creek #8	Debris flow	Debris flow

Notes:
1. Very little or no drainage area upstream of existing development according to mapping.

As indicated by the results of the morphometric screening, of the 20 creeks included in Table 3-2, 14 may experience debris flows.

It should be noted that the morphometric screening alone is insufficient basis to determine the likelihood of a debris flood or debris flow event or the frequency with which they may occur, but will dictate a basis for future detailed investigation.

3.4.3 Ravines

Ravines are landforms associated with creeks that have become incised into thick deposits of surficial material. Typically there is an abrupt slope break from adjacent terrain onto a steep erosional slope. At the toe of slope there may or may not be a floodplain between the toe and the creek's natural boundary.

Since ravines are inherently associated with creeks, they are included within the creek hazard group.

To be consistent with the Riparian Assessment Regulations (RAR), RAR definitions are followed:

- **Ravine:** a narrow, steep-sided valley that is commonly eroded by running water and has an average grade on either side greater than 3:1 measured between the high water mark of the watercourse contained in the valley and the top of the valley bank, being the point nearest the watercourse beyond which the average grade is less than 3:1 over a horizontal distance of at least 15 m measured perpendicularly to the watercourse; a narrow ravine is a ravine less than 60 m wide, and a wide ravine is a ravine with a width of 60 m or more.

- **Top of the Ravine Bank:** the first significant break in a ravine slope where the break occurs such that the grade beyond the break is flatter than 3:1 for a minimum distance of 15 m measured perpendicularly from the break, and the break does not include a bench within the ravine that could be developed.
- **Riparian Assessment Area:**
  - **for a stream**: the 30 m strip on both sides of the stream, measured from the high water mark;
  - **for a narrow ravine**: a strip on both sides of the stream measured from the high water mark to a point that is 30 m beyond the top of the ravine bank; and
  - **for a wide ravine**: a strip on both sides of the stream measured from the high water mark to a point that is 10 m beyond the top of the ravine bank.

Ravine crests were mapped in the GIS based on slope (by including areas of 30% or steeper terrain within the ravine), and also using slope breaks identified on the contour maps. Since creeks may or may not be incised in ravines, ravine crests are not necessarily continuous along creeks.

3.4.4 Floodplains, Fans and Channel Confinement

Flood hazards and channel avulsion occur in areas of low channel freeboard where the channel is not well confined by high ground on either side (i.e., floodplains and fan areas) LIDAR contour data (1 m contour interval) were reviewed to identify potential areas of low channel confinement, or fans, based on judgment.

3.4.5 Creek-Road Crossings

The majority of the major crossings in the OCP are reported to be Ministry of Transportation and Infrastructure (MOTI) assets, not Regional District structures.

Flooding and or avulsion may occur at road crossings (i.e., culverts and bridge openings) due to insufficient conveyance of creek flow, or blockage. An evaluation of the conveyance capacity of all creek crossings is beyond the scope of this project; rather, these locations are flagged for reference and to highlight the number of potential flood/avulsion sources that may exist within the OCP area given the drainage/road network density.

Avulsion at road crossings can often result in unexpected overland flooding, as roads and roadside ditches tend to convey floodwaters quickly and often directly to driveways and developments. An inventory of drainage infrastructure (e.g., size, material, age) could be developed to assist in master drainage planning and further revisions to DPA conditions.

The conveyance capacity of culverts and bridges should be designed for the process expected to occur within a selected design return period (i.e., water flood, debris flood or debris flow). The crossings are considered permanent. In forested settings a return period of 1/100 year would be recommended. However, in the residential setting, MOTI (2007) makes the following recommendations for return periods:

- **culverts with a span of less than 3 m**: design event return period between 1/50 and 1/100;
- **culverts with a span equal to or greater than 3 m**: design event return period between 1/100 and 1/200; and
- **bridges**: design event return period between 1/100 and 1/200.

The variation in MOTI-recommended return periods depends on consideration of the road classification (e.g., low volume, local, collector, arterial or freeway). Bridges have a recommended design event return period of 1/200 for all roads except low volume roads (MOTI, 2007).

Where debris floods are a possibility (e.g. Table 3-2), extra allowance should be provided for sediment and debris.

Where debris flows are anticipated (e.g. Table 3-2), analysis of the debris flow recurrence interval should be conducted, and findings should inform the design, before it is finalized.

Design of road crossings for return periods less than 200 years may have an impact on legislated flood assessments (APEGBC 2012) for residential areas.

3.5 Slope Hazards

Slope Thematic Mapping

DEM data were used to classify the terrain within the OCP based on slope steepness categories, after Howes and Kenk (1997). The LiDAR-based DEM was used where available, which yields 1 m by 1 m cells, and the 1:50,000 DEM was used for the remainder of the OCP (approximately 30 m by 30 m cells).

The following slope categories were used:

- 0 to 5%: plain;
- 5 to 30%: gentle;
- 30-50%: moderate;
- 50-60%: moderately steep (1);
- 60-70%: moderately steep (2); and
- >70%: steep.

(Note that 45° is equivalent to 100%.)

The slope classification was used to aid delineation of potential open slope landslide initiation areas, as well as ravine sidewalls and oceanfront slopes. LIDAR allowed accurate definition of these slope areas and slope breaks. In the areas beyond LIDAR coverage, definition of slope breaks is less accurate.

Many jurisdictions define development permit areas based solely on arbitrarily selected slope classes without reference to a particular hazard affecting the site. The intent of such slope-defined development permit areas is typically to govern residential growth based on environmental and other planning considerations, rather than purely geotechnical considerations. Further, there is no geotechnical basis for using slope alone to define DPAs for hazards.

The APEGBC (2008) Legislated Guidelines for Landslide Risk Assessment and Residential Development provide guidance for conducting seismic slope hazard assessments. The APEGBC guidelines use a screening process based on a factor of safety calculation. Factor of safety considers slope, but includes other variables also. Depending on the site conditions, lands that are gently-sloped could be seismically vulnerable, while lands that are steep could be seismically stable. Given the considerations outlined above, KWL has not recommended DPAs based on slope categories alone, without additional consideration of hazard mechanism.

3.5.1 Open Slope Failures and Associated Hazard Area

Open slope landslides typically start in steep terrain and run to the base of slope. In forestry practice, slope is one of the primary determinants of potential landslide activity, and is used to map slope instability potential when planning forestry activities. Several terrain attribute studies have found that steep terrain (>70%) has a significantly higher potential to generate landslides than less steep terrain.

Extensive areas of moderately steep (50-70%) and steep (>70%) terrain are located within the Twin Creeks OCP area. These areas are identified as potential landslide initiation areas.

Areas at the base of steep terrain may be affected by potential open slope failures occurring on the terrain upslope. There are various empirical methods to estimate how far a hypothetical landslide might travel, in order to determine how large an area might be impacted in the runout. For this project, landslide travel angles (the angle from crest to toe) have been used.

Corominas (1996) provides a set of travel angle equations based on a large data set of landslides from a global sample. The landslide travel angle was found to be proportional to the landslide size, or volume. Herein, travel angles are applied to predict areas within the Twin Creeks OCP area potentially affected by open slope landslide hazard.

Typical landslide dimensions have been assumed (length of slope by 50 m width by 1 m thickness), with resulting volumes rounded up to provide a degree of conservativeness. The equation for unobstructed (or channelized) failures was applied to predict a landslide travel angle based on estimated landslide volume. This angle then was projected from the top of the steep slope area to the ground intersection point at the base of slope. The terrain between the crest and the toe is estimated to be the area of potential impact. The results of this method have been compared to the method proposed by Horel (2007) and found to be conservative.

3.5.2 Seismically-Initiated Slope Failures

The study area is vulnerable to seismicity from a Cascadia subduction zone earthquake as well as more frequently-occurring crustal earthquakes. The National Building Code (2005) and the BC Building Code (2006) require building design to conform to the 2% in 50 year return period event. This standard is also referenced by APEGBC (2008).

APEGBC (2008) states:

> "*earthquakes can destabilize slopes leading to landslides, can cause liquefaction leading to landslides and/or can cause slope displacements. Therefore, seismic slope stability analysis, or seismic slope displacement analysis (collectively referred to as seismic slope analysis) may be required as part of the landslide analysis.*"

It must be emphasized that the seismic slope stability analysis applies to the design of foundations and engineered slopes.

The assessment of natural landslides potentially affecting a site considers the frequency and magnitude of historic and prehistoric landslides, as revealed through the historic record, peer-reviewed publications, anecdotal evidence and geologic fieldwork. The historical record extends back thousands of years and over many earthquake cycles, thereby implicitly including seismicity as a triggering agent.

Seismic slope analysis requires comparatively detailed knowledge of subsurface bedrock, soil and groundwater conditions. The required factor of safety calculation references many data sources, including:

- seismic hazard maps and reports;

- ground motion data;
- seismic Site Class; and
- modal magnitude values of the design earthquake.

As previously discussed, seismic slope stability cannot be captured by a simple screening process, such as slope-based DPA.

A suitable hazard screen would consist of a seismic slope hazard map. A seismic slope hazard map has been created for Greater Victoria (McQuarrie and Bean, 2000), and is being developed by the National Research Council of Canada (NRCAN) for the District of North Vancouver.

In the interim until such a screening map is produced for the Twin Creeks OCP area, seismic slope assessments should be conducted as part of any other slope, ravine, or coastal slope detailed assessment, or as required under the BC Building Code based on soil type or Building Importance Factor. Seismic slope stability assessment should be conducted by a qualified professional, but could be addressed by local geotechnical expertise.

Figure 3-1: Screen for Hydrogeomorphic Processes (Outlet at Ocean)

Figure 3-2: Screen for Hydrogeomorphic Processes (Outlet at Tributary Junctions or at Upper Limit of Development)

Figure 3-3: Twin Creeks Hazard Screen (Sheet 1)

Figure 3-4: Twin Creeks Hazard Screen (Sheet 2)

Figure 3-5: Twin Creeks Hazard Screen (Sheet 3)

Figure 3-6: Twin Creeks Hazard Screen (Sheet 4)

Figure 3-7: Twin Creeks Hazard Screen (Sheet 5)

4. Proposed DPA Framework

4.1 Overview

The following sections outline the proposed development permit area (DPA) framework for hazardous areas in the Twin Creeks OCP area, based on the rationale outlined in the previous section. For the current OCP revision, a generalized, process-based approach to DPA delineation is proposed, with three main categories:

1. **Coastal Zone Hazards:** flooding and erosion / slope stability;
2. **Creek Hazards:** ravines, creek corridor flooding, debris flood/debris flow, floodplain areas, creek fans / avulsion risk, and flooding at road crossings; and
3. **Slope Hazards:** open slope failures, rockfall, and seismically induced failures.

Within each main process category, sub-categories are presented and discussed below. There may be spatial overlap between some DPA categories.

4.1.1 Uncertainty

The goal of the DPA boundary delineation, as provided in this report, is to apply a uniform criterion to screen for potential hazards. The likelihood or magnitude of possible hazards is not explicitly estimated.

In determining the DPA boundaries for the hazard categories, it is recognized that there is inherent uncertainty in the spatial data upon which the DPA categories have been based, as well as uncertainty in the extent of influence of possible hazards. Therefore, for future project purposes, surveys and professional assessment(s) may be needed to confirm lot layout, natural features, and setback determination on a site specific basis (e.g., top of ravine vs. setbacks).

4.2 DPA 1: Ocean Hazards

Ocean hazards include flooding of lower-lying terrain, and erosion and instability of oceanfront slopes. Slope stability issues on oceanfront slopes may arise as a result of coastal erosion (e.g., undermining of the toe), poor or mismanaged drainage, gradual weakening, or seismic shaking.

A rising sea-level has been considered in the development of the Ocean Hazards DPA 1A, but the impact of sea-level rise on ocean slope erosion and stability is difficult to anticipate. Consideration should be given to a regional study to define future coastal flood construction levels incorporating sea level rise.

4.2.1 DPA 1A: Coastal Flooding

The DPA extends from the coastal DPA boundary to 8 m CGD[4].

Within the DPA, it is envisioned that the SCRD may require that development applications include a coastal flood hazard assessment to define the coastal flood components by a qualified professional, or that development be sited above 8 m CGD.

[4] Elevation referenced to Canadian Geodetic Vertical Datum.

4.2.2 DPA 1B: Coastal Slopes

Recent provincial guidelines address the need to provide setbacks under conditions of a rising sea level (Ausenco Sandwell, 2011b). For lots with coastal bluffs, the following guidance is provided:

> "*For lots containing coastal bluffs that are steeper than 3(H):1(V) and susceptible to erosion from the sea, setbacks shall be determined as follows:*
>
> 1. *If the future estimated Natural Boundary is located at least 15 m seaward of the toe of the bluff, then no action is required and the setback shall conform with guidelines suitable to terrestrial cliff hazards.*
> 2. *If the future estimated Natural Boundary is located 15 m or less seaward of the toe of the bluff, then the setback from the future estimated Natural Boundary will be located at a horizontal distance of at least 3 times the height of the bluff, measured from 15 m landwards from the location of the future estimated Natural Boundary.*
>
> *In some conditions, setbacks may require site-specific interpretation and could result in the use of a minimum distance measured back from the crest of the bluff. The setback may be modified provided the modification is supported by a report, giving consideration to the coastal erosion that may occur over the life of the project, prepared by a suitably qualified professional.*"

DPA 1B has been defined to be consistent with these guidelines, for locations where a steep ocean bluff was mapped (i.e., situation (2), above). As per the guidance cited above, the landward-side boundary of the coastal slopes DPA is defined by a combination of a 15 m horizontal buffer from the existing 5 m contour (a rough proxy for the future natural boundary), and a further horizontal offset of three times the slope height. The ocean-side boundary of the DPA is at the 5 m contour line, based on the level at which the slope setback analysis was developed. Short gaps in the resulting DPA have been linearly interpolated.

Many parts of Twin Creeks OCP area include a large coastal slope DPA. This is due to the steep existing slope geometry and distance required for the 3(H):1(V) to daylight to the bench above. Any development in these areas will likely be technically challenging and engineering investigations of these areas should be carefully considered.

It is envisioned that within the DPA the SCRD may require landslide risk assessment to determine building setbacks and foundation design.

4.3 DPA 2: Creek Hazards

Creek hazards include: flooding, debris floods, debris flow and slope instability associated with ravine sidewalls. The DPA mapping follows the Riparian Assessment Regulation (RAR).

Although it is beyond the scope of the current project, it should be noted that flooding at road culvert crossings could occur for a number of reasons, including: debris blockage, culvert failure, or undersized culvert. Depending on how well confined the creek is at the crossing, floodwaters may escape the creek corridor. All culvert or bridge crossing on private property should meet general MOTI criteria outlined in Section 3.4.

Creek-road crossings have been identified on the DPA mapping included in this report. It is envisioned that the SCRD might implement a requirement to review those crossings for Development Permit Applications in close proximity (e.g., 300 m) to creek-road crossings, and that this might be implemented as a Development Approval Information Area - General Condition in the OCP.

4.3.1 DPA 2A: Creek/River Corridor

DPA 2A has been delineated using a buffer width of 30 m on all streamlines included in the SCRD GIS mapping. On the ground, DPA 2A should be interpreted as extending 30 m from streamside natural boundary, consistent with the Riparian Areas Regulation definitions.

It should be noted that although a 30 m buffer is consistent with RAR, there remains the possibility that further-removed low-lying areas may experience flooding due to localized factors that are difficult to predict (e.g. creek blockages).

Within DPA 2A the SCRD may require riparian, flood, debris flood and debris flow hazard assessments (as appropriate).

4.3.2 DPA 2B: Ravines

Ravine areas have been defined using the crest lines mapped in the GIS.

A 30 m setback from ravine crests defines the area that falls within DPA 2B. A 15 m setback line is also indicated.

Based on consideration of stable angles of repose and the typical terrain seen in the Twin Creeks OCP area, the following approach is proposed:

- A minimum 15 m setback from ravine crest is suggested for all development.
- For ravines that are deeper than 15 m, it is suggested that the setback from ravine crest be 30 m, and that an engineering report from an appropriately qualified professional be required to reduce the setback.

As mapped, DPA 2B captures all properties within the 30 m setback. However, it is anticipated that property owners, with the help of the SCRD mapping, should be able to establish very quickly what the height of the ravine is adjacent to the property in question (by counting contours measured perpendicularly between the bottom of the ravine and the crest), and thereby determine which setback category is applicable to their property.

Within DPA 2B, it is envisioned that the SCRD would require a landslide assessment for ravine sidewalls.

4.3.3 DPA 2C: Floodplain

Floodplain areas are distinguished from the creek/river corridor based on their spatial extent: the creek/river corridor flood hazard applies to relatively well-confined creeks while DPA 2C applies where there is a large area of low-lying land susceptible to flooding located adjacent to watercourses (not captured in DPA 2A).

4.3.4 DPA 2D: Low Channel Confinement

DPA 2D delineates alluvial fans or areas of low channel confinement. Alluvial fans, or areas of low channel confinement, may exist at several locations on a single creek, although typically at the mouth. These areas are either current or former deposition zones that provide opportunities for channel avulsions to occur.

The available orthophotos and contour mapping have been used to identify potential areas of low channel confinement for DPA 2D.

Within DPA 2D, it is envisioned that the SCRD might require flood and erosion, and channel avulsion hazard assessment. Creek-road crossings should be considered as part of hazard assessment work.

4.4 DPA 3: Slope Hazards

Three sub-categories of slope hazards are identified that are applicable to the Twin Creeks OCP area:

- open slope failures,
- rockfall hazards, and
- seisimic-initated slope hazards.

Open slope failures and rockfall hazard sub-categories are included in a single DPA. It is important to note that this DPA encompasses areas in the OCP where slope hazards have the highest probability to occur. However, slope hazards may occur in other areas not identified here due to changes in land use, land disturbance or extreme precipitation events.

4.4.1 Open Slope Failures

Potential for open slope failures in the Twin Creeks OCP have been identified. Slope crest lines, where initiation of a landslide may occur, and potential landslide impact areas were estimated for slopes of 10 m in height or greater. Impact areas were estimated based on the landslide travel angle (see Section 3.5 for details).

Within DPA 3, it is envisioned that the SCRD may require landslide risk assessments.

4.4.2 Rockfall

Within the Twin Creeks OCP area there are no extensive, tall rock bluff areas that present a significant rockfall hazard. However, there are small, isolated steep areas that consist of low rock hummocks projecting from surficial material cover. These areas pose a low hazard and have not been mapped.

Areas of potential rockfall have been identified by slope scarp topography and aerial photo analysis. Areas of potential rockfall hazard coincide with the open slope failure areas delineated for DPA 3.

4.4.3 Seismic-Initiated Slope Hazards

Under the current guidelines for assessment of slope hazards developed by the Association of Professional Engineers and Geoscientists BC (2008), seismic-initiated slope hazards need to be considered.

No map-based screening tool is currently available to identify seismic slope hazard areas and therefore there is no basis for the development of a DPA for this specific hazard as part of this project.

It is envisioned that the SCRD might implement a “Development Approval Information Area - General Condition” in the Twin Creek OCP to address this hazard.

4.5 Proposed Revised DPAs for Twin Creeks OCP Area

Proposed revised DPA zones for the Twin Creeks OCP area are presented in Figure 4-1 through to Figure 4-5 (Sheets 1 to 5).

Figure 4-1: Proposed DPAs for Twin Creeks (Sheet 1)

Figure 4-2: Proposed DPAs for Twin Creeks (Sheet 2)

Figure 4-3: Proposed DPAs for Twin Creeks (Sheet 3)

Figure 4-4: Proposed DPAs for Twin Creeks (Sheet 4)

Figure 4-5: Proposed DPAs for Twin Creeks (Sheet 5)

5. Suggested Guidelines for Development

The following section provides suggested guidelines for development that may occur within the identified Twin Creeks DPAs.

The guidelines are intended to provide the SCRD with technical advice on hazard management, and they have been developed based on consideration of SCRD's existing OCP policies and guidance, as well as professional judgement of the identified hazards and what would constitute appropriate hazard assessments.

All professional assessments pertaining to Development Permit Areas should be consistent with applicable regulations and professional guidelines.

5.1 DPA 1: Ocean Hazards

The SCRD may require a Development Permit on lands identified as being within DPA 1 for the following activities:

- Subdivision as defined in the Land Title Act and Strata Property Act;
- Building Permit; and
- Land alteration, which includes, but is not limited to the removal and deposition of soils and aggregates, paving, removal of trees and the installation of septic fields.

As indicated below, different, specific hazards have been identified within the general category of "ocean hazards". It is suggested that applications for subdivision, Building Permit or land alteration within DPA 1 would include a report from an appropriately qualified Professional Engineer or Professional Geoscientist that considers all relevant potential ocean hazards.

5.1.1 DPA 1A – Coastal Flooding Guidelines

Guidelines to address coastal flood hazard and sea level rise recently released by the MFLNRO (Ausenco Sandwell, 2011b) define the coastal flood construction level (FCL) as the sum of a number of components (Table 5-1).

It is anticipated that a coastal flood hazard assessment triggered for DPA 1 will estimate the coastal FCL.

A regional study may be appropriate for the Sunshine Coast to better define tide, local sea level rise and storm surge. However, wave effects are site-specific (varying as the shoreline geometry and composition varies), and likely will require local engineering assessment.

Table 5-1: Coastal Flood Construction Level Components based on Ausenco Sandwell (2011).

Component	Note	Allowance
Tide	Higher High Water Large Tide.	2.05 m (CGD)
Sea Level Rise	Recommended allowance for Global Sea Level Rise: • 1 m for year 2100, 2 m for year 2200. Should be adjusted for regional ground movement (uplift or subsidence).	2.0 m
Storm Surge	Estimated storm surge associated with design storm event.	1.3 m (CGD)
Wave Effects	50% of estimated wave run-up for assumed design storm event. Wave effect varies based on shoreline geometry and composition.	To be determined locally
Freeboard	Nominal allowance	0.6 m
Flood Construction Level = Sum of all components.		

5.1.2 DPA 1B – Coastal Slopes Guidelines

Within DPA 1B, the SCRD may require a report from an appropriately qualified Professional Engineer or Professional Geoscientist. If applicable, it is envisioned that the report might include the following:

- Surveyed slope profiles with documentation of the limits of slope instability. Consideration should be given to the limits and types of instability and changes in stability that may be induced by forest clearing. The down-slope impact of forest clearing and land development also should be considered. As well, slope stability assessments should consider potential coastal erosion under conditions of future sea level rise.
- A detailed stability assessment indicating foreseeable slope failure modes and limiting factors of safety, and stability during seismic events.
- An assessment of shallow groundwater conditions and the anticipated effects of septic systems, footing drains, etc. on local slope stability;
- A recommendation of required setbacks based on slope height, erosion susceptibility, and stability from the crest of steep slopes, and a demonstration of suitability for the proposed use.
- A field definition of the setback from the top of a steep slope.
- If required, definition of the site-specific rock fall shadow area, including an indication of the appropriate buffer zone and required protective works.
- Appropriate land use recommendations such as restrictions on tree cutting, surface drainage, filling and excavation.
- If upland areas on the property are below 8 m (CGD), a coastal flood hazard assessment is required, that would include: estimation of coastal flood levels, consideration of future sea level rise and wave run-up effects as outlined in the Provincial Guidelines.
- Areas subject to coastal flooding shall require the definition of a flood construction level (FCL) that addresses the foreseeable coastal flood levels for the life of the development, and shall outline all protective measures required to achieve the FCL (e.g., engineered fill or foundations, coastal bank protection, etc.).

5.2 DPA 2: Creek/River Hazards

The SCRD may require a Development Permit on lands identified as being within DPA 2 for the following activities:

- Subdivision as defined in the Land Title Act and Strata Property Act;
- Building Permit; and
- Land alteration, which includes, but is not limited to the removal and deposition of soils and aggregates, paving, removal of trees and the installation of septic fields.

5.2.1 DPA 2A/C/D – Creek Corridor / Floodplain / Low Channel Confinement Guidelines

Within DPA 2A/C/D, the SCRD may require a report from an appropriately qualified Professional Engineer or Professional Geoscientist. If applicable, it is envisioned that the assessment by the qualified professional might include the following:

- A review of the property and analysis of the land located within the Development Permit Area as well as an analysis of the proposed developments including, but not limited to, building footprint, septic field and land alteration, including tree removal.
- Assessment of flooding and associated creek processes and hydrologic investigation at the time of subdivision or Building Permit or land alteration application. The assessment and investigation should include survey of the natural boundary of the creek, and degree of confinement (e.g., typical cross-sections) and should consider upstream channels and floodways, debris dams, culverts, sources of debris (channels and eroded banks) and related hydrologic features.
- Analysis should include an estimate of the 200-year return period peak flow and corresponding flood elevation. In addition, consideration shall be given to potential for overbank flooding due to blockages in the creek, such as at upstream road crossings, or areas where debris accumulates.

5.2.2 DPA 2A/D – Creek Corridor / Low Channel Confinement Guidelines

Within DPA 2A/D, the SCRD may require a report from an appropriately qualified Professional Engineer or Professional Geoscientist to address potential debris flow and debris flood creek hazard. If applicable, it is envisioned that the assessment by the qualified professional might include the following:

- An analysis of the creek system upland from the subject property may be required if there is foreseeable risk to development to identify flooding and/or debris flood/debris flow potential, including the potential effects on downstream properties.
- Debris flow and flood hazards may require considerations of channel and slope characteristics upstream from the subject property. Associated data may include stream and ravine bank profiles, bank stability assessment, and run out limits of debris within the creeks.
  a) Comprehensive developments (i.e., multi-lot subdivisions) near debris flow or debris flood creeks should require a detailed watershed level investigation of watercourse hazards including determination of frequency and magnitude of debris flow or debris flood potential, and development of a risk mitigation approach for the development that does not result in a transfer of risk.

b) Single-lot developments may not require a detailed watershed assessment; however, an appropriately qualified professional shall conduct an assessment to state that the site is safe for the use intended and identify any conditions are required to ensure the site will be safe, based on professional guidelines and practice (APEGBC, 2012).

5.2.3 DPA 2B – Ravines Guidelines

Within DPA 2B, the SCRD may require a report from an appropriately qualified Professional Engineer or Professional Geoscientist. If applicable, it is envisioned that the assessment by the qualified professional might include the following:

- A recommendation of required setbacks from the crests and/or toes of ravine or other steep slopes, and a demonstration of suitability for the proposed use.
- A field definition of the required setback from the top of a ravine or other steep slope.
- The report should indicate the required setback to top of bank and recommendations pertaining to construction design requirements for the above development activities, on-site storm water drainage management and other appropriate land use recommendations.
- For proposed development within ravine slope setbacks, it is envisioned that reporting requirements would be consistent with DPA 3 (Slope Hazards).

5.3 DPA 3: Slope Hazards

The SCRD may require a Development Permit on lands identified as being within DPA 3 for the following activities:

- Subdivision as defined in the Land Title Act and Strata Property Act;
- Building Permit; and
- Land alteration, which includes, but is not limited to the removal and deposition of soils and aggregates, paving, removal of trees and the installation of septic fields.

DPA 3 includes both open slope failures and rockfall hazard. If required by the SCRD, it is envisioned that applications for subdivision, Building Permit or land alteration would include a report from an appropriately qualified Professional Engineer or Professional Geoscientist that considers all relevant potential steep slope and rockfall hazards.

If applicable, the report may include the following:

- Slope profiles with documentation of the limits of slope instability shall be provided. Consideration should be given to the limits and types of instability and changes in stability that may be induced by forest clearing. The down-slope impact of forest clearing and land development also should be considered.
- A detailed stability assessment indicating foreseeable slope failure modes and limiting factors of safety, and stability during seismic events.
- An assessment of shallow groundwater conditions and the anticipated effects of septic systems, footing drains, etc., on local slope stability.

- A recommendation of required setbacks from the crests and/or toes of steep slopes, and a demonstration of suitability for the proposed use.
- A field definition of the required setback from the top of steep slope.
- Appropriate land-use recommendations such as restrictions on tree cutting, surface drainage, filling and excavation.
- If required, definition of the site-specific rockfall 'shadow' area, including an indication of the appropriate buffer zone and required protective works.

5.4 Possible Exemptions

The SCRD may choose to grant general exemptions in the following circumstances:

- For "Low Importance" structures, as defined in the BC Building Code: Buildings that represent a low direct or indirect hazard to human life in the event of failure, including: low human-occupancy buildings, where it can be shown that collapse is not likely to cause injury or other serious consequences, or minor storage buildings.
- Where the proposed construction involves a structural change, addition or renovation to existing conforming or lawfully non-conforming buildings or structures, provided that the footprint of the building or structure is not expanded, and provided that it does not involve any alteration of land.
- The planting of native trees, shrubs, or groundcovers for the purpose of enhancing the habitat values and/or soil stability within the development permit area.
- A subdivision where an existing registered covenant or proposed covenant with reference plan based on a qualified professional's review, relating to the protection of the environment or hazardous conditions outlined in the subject development permit area, is registered on title or its registration secured by a solicitor's undertaking.
- Immediate threats to life and property provided they are undertaken in accordance with the provincial Water Act and Wildlife Act and the Federal Fisheries Act, and are reported to the Regional District.
- Emergency procedures to prevent, control or reduce erosion, or other immediate threats to life and property provided they are undertaken in accordance with the provincial Water Act and Wildlife Act and the Federal Fisheries Act, and are reported to the Regional District.
- The removal of two trees over 20 centimetre diameter breast height or ten square metres of vegetated area of per calendar year per lot, provided there is replanting of four trees or re-vegetation of the same amount of clearing.

5.5 Report Submission

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Revision #	Date	Status	Revision	Author
B	December 15, 2014	Draft	For client review.	CD/EE
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