Sunshine Coast Regional District

Request for Proposal

Number: 2313601

for

Climate Adaptation: Coastal Flooding Project

Issue Date:

November 3, 2023

Closing Date of

December 1, 2023 at 3:00 PM local time

CONTACT: All enquiries related to this Request for Proposal, including any requests for information and clarification, are to be submitted by November 17, 2023 and directed, in writing, to purchasing@scrd.ca, who will respond if time permits with a Q&A on BCBid by November 24, 2023 Information obtained from any other source is not official and should not be relied upon. Enquiries and any responses providing new information will be recorded and posted to BC Bid or otherwise distributed to prospective Proponents.

DELIVERY OF PROPOSALS: Proposals must be in English and must be submitted using one of the submission methods below, and must either **(1)** include a copy of this cover page that is signed by an authorized representative of the Proponent or **(2)** be submitted by using the e-bidding key on BC Bid (if applicable), in accordance with the requirements set out in the RFP.

BC Bid Electronic Submission: Proponents may submit an electronic proposal using BC Bid. Proposals must be submitted in accordance with the BC Bid requirements and e-bidding key requirements (found at https://www.bcbid.gov.bc.ca/). Only pre-authorized electronic bidders registered on the BC Bid system can submit an electronic proposal using the BC Bid system. Use of an e-bidding key is effective as a signature.

OR

Hard Copy Submission*:* Proponents must submit **ONE (1)** hard-copies and **ONE (1)** electronic copy on a USB Drive of the proposal. Proposals submitted by hard copy must be submitted by hand or courier to:

Sunshine Coast Regional District
1975 Field Road
Sechelt, BC V7Z 0A8

Regardless of submission method, proposals must be received before Closing Time to be considered.

CONFIRMATION OF PROPONENT'S INTENT TO BE BOUND:

The enclosed proposal is submitted in response to the referenced Request for Proposal, including any Addenda. By submitting a proposal the Proponent agrees to all of the terms and conditions of the RFP including the following:

a) The Proponent has carefully read and examined the entire Request for Proposal;
b) The Proponent has conducted such other investigations as were prudent and reasonable in preparing the proposal; and
c) The Proponent agrees to be bound by the statements and representations made in its proposal.

PROPONENT NAME (please print): ______________________________

NAME OF AUTHORIZED REPRESENTATIVE (please print):______________________________

SIGNATURE OF AUTHORIZED REPRESENTATIVE: ______________________________

DATE: ______________________________

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1. GENERAL TERMS & CONDITIONS

1.1 DEFINITIONS

Throughout this Request for Proposal, the following definitions apply:

"**Addenda**" means all additional information regarding this RFP, including amendments to the RFP;
"**BC Bid**" means the BC Bid website located at https://www.bcbid.gov.bc.ca/ ;
"**Closing Location**" includes the location or email address for submissions indicated on the cover page of this RFP, or BC Bid, as applicable;
"**Closing Time**" means the closing time and date for this RFP as set out on the cover page of this RFP;
"**Contract**" means the written agreement resulting from the RFP executed by the Regional District and the successful Proponent;
"**Contractor**" means the successful Proponent to the RFP who enters into a Contract with the Regional District;
"**Must**", or "**mandatory**" means a requirement that must be met in order for a proposal to receive consideration;
"**Proponent**" means a person or entity (excluding its parent, subsidiaries or other affiliates) with the legal capacity to contract, that submits a proposal in response to the RFP;
"**Proposal**" means a written response to the RFP that is submitted by a Proponent;
"**Request for Proposals**" or "**RFP**" means the solicitation described in this document, including any attached or referenced appendices, schedules or exhibits and as may be modified in writing from time to time by the Regional District by Addenda; and
"**Should**", "**may**" or "**weighted**" means a requirement having a significant degree of importance to the objectives of the Request for Proposals.
"SCRD", "Regional District", "Organization", "we", "us", and**"our"** mean Sunshine Coast Regional District.

1.2 FORM OF PROPOSAL

This Proposal must be completed in its entirety. Failure to properly complete this Proposal form may cause your Proposal to be rejected. The signing officer must initial all corrections. The Sunshine Coast Regional District (Regional District) reserves the right to permit a correction, clarification or amendment to the Proposal or to correct minor errors and irregularities.

1.3 SUBMISSION OF PROPOSAL

a) Proposals must be submitted before Closing Time to the Closing Location using one of the submission methods set out on the cover page of this RFP. Proposals must not be sent by fax. The Proponent is solely responsible for ensuring that, regardless of submission method selected, the Regional District receives a complete Proposal, including all attachments or enclosures, before the Closing Time.

b) For electronic submissions (BC Bid or email), the following applies:

(i) The Proponent is solely responsible for ensuring that the complete electronic Proposal, including all attachments, is received before Closing Time;

(ii) The Regional District limits the maximum size of any single email message to 20MB or less.

(iii) Proponents should endeavour to submit emailed proposal submissions in a single message and avoid sending multiple email submissions for the same opportunity. If an electronic submission exceeds the applicable maximum single message size, the Proponent may make multiple submissions (BC Bid upload or multiple emails for the same opportunity). Proponents should identify the order and number of emails making up the email proposal submission (e.g. "email 1 of 3, email 2 of 3…");

(iv) For email proposal submissions sent through multiple emails, the Regional District reserves the right to seek clarification or reject the proposal if the Regional District is unable to determine what documents constitute the complete proposal;

(v) Attachments must not be compressed or encrypted, must not contain viruses or malware, must not be corrupted, and must be able to be opened using commonly available software (e.g. Adobe Acrobat). Proponents submitting by electronic submission are solely responsible for ensuring that any emails or attachments are not corrupted. The Regional District has no obligation to attempt to remedy any message or attachment that is received corrupted or cannot be viewed. The Regional District may reject proposals that are compressed encrypted, cannot be opened or that contain viruses or malware or corrupted attachments.

c) For BC Bid e-submissions only pre-authorized e-bidders registered on BC Bid can submit electronic bids on BC Bid. BC Bid is a subscription service ($150 per year) and the registration process may take two business days to complete. If using this submission method, Proponents should refer to the BC Bid website or contact BC Bid Helpdesk at 250-387-7301 for more information. An electronic proposal submitted on BC Bid must be submitted using the e-bidding key of an authorized representative of the Proponent. Using the e-bidding key of a subcontractor is not acceptable.

d) For email proposal submissions, including any notices of amendment or withdrawal referred to in Section 1.6, the subject line of the email and any attachment should be clearly marked with the name of the Proponent, the RFP number and the project or program title.

e) The Regional District strongly encourages Proponents using electronic submissions to submit proposals with sufficient time to complete the upload and transmission of the complete proposal and any attachments before Closing Time.

f) The Proponent bears all risk associated with delivering its Proposal by electronic submission, including but not limited to delays in transmission between the Proponent's computer and the Regional District Electronic Mail System or BC Bid.

g) While the Regional District may allow for email proposal submissions, the Proponent acknowledges that email transmissions are inherently unreliable. The Proponent is solely responsible for ensuring that its complete email proposal submission and all attachments have been received before Closing Time. If the Regional District Electronic Mail System rejects an email proposal submission for any reason, and the Proponent does not successfully resubmit its proposal by the same or other permitted submission method before Closing Time, the Proponent will not be permitted to resubmit its proposal after Closing Time. The Proponent is strongly advised to contact the Regional District Contact immediately to arrange for an alternative submission method if:

(i) the Proponent's email proposal submission is rejected by the Regional District Electronic Mail System; or

(ii) the Proponent does not receive an automated response email from the Regional District confirming receipt of each and every message transmitted, within a half hour of transmission by the Proponent.

An alternate submission method may be made available, at the Regional District's discretion, immediately to arrange for an alternative submission method, and it is the Proponent's sole responsibility for ensuring that a complete proposal (and all attachments) submitted using an approved alternate submission method is received by the Regional District before the Closing Time. The Regional District makes no guarantee that an alternative submission method will be available or that the method available will ensure that a Proponent's proposal is received before Closing Time.

1.4 SIGNATURE REQUIRED

Proposals must be properly signed by an officer, employee or agent having authority to bind the Proponent by that signature.

1.5 CLARIFICATIONS, ADDENDA & MINOR IRREGULARITIES

If any Proponent finds any inconsistencies, errors or omissions in the proposal documents or requires information, clarification of any provision contained therein, they shall submit their query in writing or email, addressed as follows:

Purchasing Division
Sunshine Coast Regional District
1975 Field Road, Sechelt, BC V7Z 0A8
purchasing@scrd.ca

Any interpretation of, addition to, deletions from or any corrections to the proposal documents will be issued as written addendum by the Regional District.

All Addenda will be posted on BC Bid. It is the sole responsibility of the Proponent to check for Addenda on BC Bid. Proponents are strongly encouraged to subscribe to BC Bid's email notification service to receive notices of Addenda.

1.6 WITHDRAWAL OR REVISIONS

Proposals or revisions may be withdrawn by written notice provided such a notice of withdrawal is received prior to the closing date and time. Proposals withdrawn will be returned to the Proponent unopened. Revisions to the proposals already received shall be submitted only by electronic mail, or signed letter. The revision must state only the amount by which a figure is to be increased or decreased, or specific directions as to the exclusions or inclusion of particular words.

1.7 CONDUCT OF THE CONTRACT

Unless otherwise specified within this document, any queries regarding this Request for Proposal are to be directed to purchasing@scrd.ca. No other verbal or written instruction or information shall be relied upon by the Bidder, nor will they be binding upon the Regional District.

1.8 CONFLICT OF INTEREST/NO LOBBYING

(a) A Proponent may be disqualified if the Proponent's current or past corporate or other interests, or those of a proposed subcontractor, may, in the Regional District's opinion, give rise to an actual or potential conflict of interest in connection with the services described in the RFP. This includes, but is not limited to, involvement by a Proponent in the preparation of the RFP or a relationship with any employee, contractor or representative of the Regional District involved in preparation of the RFP, participating on the evaluation committee or in the administration of the Contract. If a Proponent is in doubt as to whether there might be a conflict of interest, the Proponent should consult with the Regional District Contact prior to submitting a proposal. By submitting a proposal, the Proponent represents that it is not aware of any circumstances that would give rise to a conflict of interest that is actual or potential, in respect of the RFP.

(b) A Proponent must not attempt to influence the outcome of the RFP process by engaging in lobbying activities. Any attempt by the Proponent to communicate, for this purpose directly or indirectly with any employee, contractor or representative of the Regional District, including members of the evaluation committee and any elected officials of the Regional District, or with the media, may result in disqualification of the Proponent.

1.9 CONTRACT

By submitting a proposal, the Proponent agrees that should its proposal be successful the Proponent will enter into a Contract with the Regional District on substantially the same terms and Conditions set out in www.scrd.ca/bid and such other terms and conditions to be finalized to the satisfaction of the Regional District, if applicable.

1.10 SUSTAINABLE PROCUREMENT

The Regional District adheres to its sustainable consideration factors. Proposals will be considered not only on the total cost of services, but Proposals that addresses the environment and social factors.

1.11 INVOICING AND PAYMENT

Unless otherwise agreed, the Regional District payment terms are Net 30 days following receipt of services or approved invoices, whichever is later. Original invoices are to be forwarded to the accounts payable department of the Regional District. The purchase order number assigned by the Regional District must be stated on the invoice otherwise payment may be delayed.

1.12 PRICING, CURRENCY AND TAXES

Offered prices are to be attached as a price schedule in Canadian dollars with taxes stated separately when applicable.

1.13 IRREVOCABLE OFFER

This Proposal must be irrevocable for 90 days from the Proposal closing date and time.

1.14 TIME IS OF THE ESSENCE

Time shall be of the essence in this contract.

1.15 ASSIGNMENT

The Proponent will not, without written consent of the Regional District, assign or transfer this contract or any part thereof.

1.16 OWNERSHIP OF DOCUMENTS & FREEDOM OF INFORMATION

All documents submitted in response to this Request for Proposal shall become the property of the Regional District and as such will be subject to the disclosure provisions of the *Freedom of Information and Protection of Privacy Act* and any requirement for disclosure of all or a part of a Proposal under that Act.

The requirement for confidentiality shall not apply to any Proposal that is incorporated into a Contract for the Work. Further, the Regional District may disclose the top scoring proponent's aggregate pricing to the Regional District Board at a public meeting, when making a recommendation for the award of the Contract.

For more information on the application of the Act, go to http://www.cio.gov.bc.ca/cio/priv_leg/index.page.

1.17 AWARD OF CONTRACT

The Purchasing Policy at the Regional District offers contracts to businesses through an open, fair and consistent competitive bidding process. This ensures that the Regional District will receive the best overall value for the goods and services it requires. The Regional District reserves the right to cancel, award all or part of the scope of work described in this document to a single Proponent or may split the award with multiple Proponents.

All awards are subject to Board approval that meets the needs as determined by the Board. The Regional District, in receipt of a submission from a Proponent, may in its sole discretion consider the Proponent to have accepted the terms and conditions herein, except those expressly excluded or changed by the Proponent in writing.

The RFP shall not be construed as an agreement to purchase goods or services. The lowest priced or any proposal will not necessarily be accepted. The RFP does not commit the Regional District in any way to award a contract and that no legal relationship or obligation regarding the procurement of any good or service will be created between Regional District and the proponent unless and until Regional District and the proponent execute a written agreement for the Deliverables

1.18 COST OF PROPOSAL

The Proponent acknowledges and agrees that the Regional District will not be responsible for any costs, expenses, losses, damage or liability incurred by the Proponent as a result of or arising out submitting a Proposal for the proposed contract or the Regional District's acceptance or non-acceptance of their proposal. Further, except as expressly and specifically permitted herein, no Proponent shall have any claim for any compensation of any kind whatsoever, as a result of participating in this RFP, and by submitting a proposal each Proponent shall be deemed to have agreed that it has no claim.

1.19 PROPONENT'S RESPONSIBILITY

It is the Proponent's responsibility to ensure that the terms of reference contained herein are fully understood and to obtain any further information required for this proposal call on its own initiative. The Regional District reserves the right to share, with all proponents, all questions and answers related to this bid call.

1.20 EVALUATIONS

Proposals will be evaluated in private, including proposals that were opened and read in public, if applicable. Proposals will be assessed in accordance with the evaluation criteria.

If only one Proposal is received, the Regional District reserves the right to open the Proposal in private or if the total bid price exceeds the estimated budget for the Contract, the Regional District may cancel and re-tender, accept, not accept and cancel or re-scope the Work seeking a better response, with or without any substantive changes being made to the solicitation documents. If more than one Proposal is received from the same Proponent, the last Proposal received, as determined by the Regional District, will be the only Proposal considered.

1.21 ACCEPTANCE OF TERMS

The submission of the Proposal constitutes the agreement of the Proponent that all of the terms and conditions of the RFP are accepted by the Proponent and incorporated in its Proposal, except those conditions and provisions which are expressly excluded and clearly stated as excluded by the Proponent's proposal.

1.22 MANDATORY REQUIREMENTS

Proposals not clearly demonstrating that they meet the mandatory requirements will receive no further consideration during the evaluation process.

1.23 INSURANCE & WCB

The Proponent shall obtain and continuously hold for the term of the contract, insurance coverage with the Regional District Listed as "Additional Insured" the minimum limits of not less than those stated below:

(a) Commercial General Liability – not less than $2,000,000 per occurrence
(b) Motor Vehicle Insurance, including Bodily Injury and Property Damage in an amount no less than $2,000,000 per accident from the Insurance Corporation of British Columbia on any licensed motor vehicles of any kind used to carry out the Work.
(c) Error & Omissions Insurance – not less than $5,000,000 per occurrence
(d) A provision requiring the Insurer to give the Owners a minimum of 30 days' notice of cancellation or lapsing or any material change in the insurance policy;

The Proponent must comply with all applicable laws and bylaws within the jurisdiction of the work. The Proponent must further comply with all conditions and safety regulations of the Workers' Compensation Act of British Columbia and must be in good standing during the tern of any contract entered into from this process.

1.24 COLLUSION

Except otherwise specified or as arising by reason of the provisions of these documents, no person, or corporation, other than the Proponent has or will have any interest or share in this proposal or in the proposal contract which may be completed in respect thereof. There is no collusion or arrangement between the Proponent and any other actual or prospective Proponent in connection with proposals submitted for this project and the Proponent has no knowledge of the context of other proposals and has no comparison of figures or agreement or arrangement, express or implied, with any other party in connection with the making of the proposal.

1.25 CONFLICT OF INTEREST

Proponents shall disclose in its Proposal any actual or potential conflict of interest and existing business relationship it may have with the Regional District, its elected or appointed officials or employees.

1.26 LIABILITY FOR ERRORS

While the Regional District has used considerable efforts to ensure an acute representation of information in these bid documents, the information contained is supplied solely as a guideline for Proponents. The information is not guaranteed or warranted to be accurate by the Regional District nor is it necessarily comprehensive or exhaustive.

1.27 TRADE AGREEMENTS

This RFP is covered by trade agreements between the Regional District and other jurisdictions, including the following:

a) Canadian Free Trade Agreement; and
b) New West Partnership Trade Agreement.

1.28 LAW

This contract and any resultant award shall be governed by and construed in accordance with the laws of the Province of British Columbia, which shall be deemed the proper law thereof.

1.29 REPRISAL CLAUSE

Tenders will not be accepted by the Regional District from any person, corporation, or other legal entity (the

"Party") if the Party, or any officer or director of a corporate Party, is, or has been within a period of two years prior to the tender closing date, engaged either directly or indirectly through another corporation or legal entity in a legal proceeding initiated in any court against the Regional District in relation to any contract with, or works or services provided to, the Regional District; and any such Party is not eligible to submit a tender.

1.30 FORCE MAJEURE (ACT OF GOD)

Neither party shall be liable for any failure of or delay in the performance of this Agreement for the period that such failure or delay is due to causes beyond its reasonable control including but not limited to acts of God, war, strikes or labour disputes, embargoes, government orders or any other force majeure event. The Regional District may terminate the Contract by notice if the event lasts for longer than 30 days.

1.31 CONFIDENTIAL INFORMATION OF PROPONENT

A proponent should identify any information in its proposal or any accompanying documentation supplied in confidence for which confidentiality is to be maintained by Regional District. The confidentiality of such information will be maintained by Regional District, except the total proposed value, which must be publicly released for all proposals, or otherwise required by the Freedom of Information and Protection of Privacy Act ("FOIPPA"), law or by order of a court or tribunal. Proponents are advised that their proposals will, as necessary, be disclosed, on a confidential basis, to advisers retained by Regional District to advise or assist with the RFP process, including the evaluation of proposals. If a proponent has any questions about the collection and use of personal information pursuant to this RFP, questions are to be submitted to the RFP Contact.

1.32 DISPUTE RESOLUTION

All unresolved disputes arising out of or in connection with this Proposal or in respect of any contractual relationship associated therewith or derived therewith shall be referred to and finally resolved by arbitration as prescribed by Mediate BC services pursuant to its rules, unless otherwise mutually agreed between the parties.

1.33 DEBRIEFING

At the conclusion of the RFP process, all Proponents will be notified. Proponents may request a debriefing meeting with the Regional District.

2. INTRODUCTION

2.1 Purpose

The primary purpose of the project is to develop flood risk mapping for priority areas of the Sunshine Coast. Additionally, the Regional District, member municipalities and Islands Trust are seeking specific and defensible Flood Construction Levels for different zones of the Sunshine Coast as well as initial adaptation recommendations.

The Regional District is aware that floodplain mapping for the entire coastline may not be possible. Mapping will not be required for the shíshálh Nation Government District lands, as they have recently completed coastal flood risk mapping and are outside the scope of this project.

3. SITUATION / OVERVIEW

3.1 Background

Coastal flooding from sea level rise and increased storm wave action were identified as climate risks of concern in the Sunshine Coast Climate Risk Assessment. At 509km of coastline, the Regional District has more coastline than most other regional districts. Several assets owned by local governments or provincial agencies are in low lying areas including community docks, utilities, and roads.

Flood maps are the basic tool needed to understand present-day and future flood hazards, informing appropriate planning and adaptation actions. The results of this project will enable the partners to update regulations, improve customer service of development applications, update Hazards Risk Vulnerability Assessments, and facilitate an internal and a community-wide discussion on climate adaptation to coastal flooding. Official Community Plan (OCP) OCP rewrites are also in the work plan and will benefit from this foundational work.

The project has been funded as part of the Union of BC Municipalities (UBCM) Disaster Risk Reduction – Climate Adaptation stream with an expected completion date of April 30, 2025.

3.2 Scope

The Regional District successfully received a Union of BC Municipalities grant under the Disaster Risk Reduction - Climate Adaptation stream in partnership with the District of Sechelt, the Town of Gibsons, and Islands Trust. The grant provides a maximum of $425,000 for consulting fees.

The purpose of the project is to develop the coastal flooding hazard mapping for the Lower Sunshine Coast and subsequent flood construction levels and mapping for developed and developable areas. The outcomes of this project will form the basis for further flood risk analysis and vulnerability assessment for the communities in this area.

The project will focus on the populated coastal areas of the lower Sunshine Coast. Of particular interest are areas with a single transportation corridor or with development pressures in low lying areas, examples include downtown Sechelt (49.471455, -123.752608), Highway 101 at Davis Bay (49.442779, -123.728631), Ocean Beach Esplanade Rd (49.390980, -123.557451), Vaucroft Dock and neighbourhood (49.506351, -123.995618).

The scope of work will include three components:

A. Coastal Flood Hazard Mapping.

Development of a better understanding of how coastal areas will be impacted by flooding. Flood maps that clearly delineate the extents and depths of floodwater for the defined scenarios. Climate change should be applied to the flood scenarios with a design year of 2100. **It is expected that the bulk of the Contractors efforts will focus on this area**. This work will include a review of previous work done to support the delineation of Coastal Hazards Development Permit Areas and related studies, including shíshálh Nation's Coastal Flood mapping work completed in 2022 for Tsukwum and Sechelt lands. This activity will inform future activity by the local governments' staff to develop risk assessments to built and natural assets.

Detailed activities include:

- Review of background documents in section 4.3
- An gap analysis of the data and identification of outstanding data.
- Identify boundaries of areas that will be mapped.
- Identify and include river-coast interface locations where river flows into coastal flooding zones occurs.
- Define appropriate Sea Level Rise (SLR) factors for the lower Sunshine Coast for years 2050, 2100 and 2200.
- Development of Digital Elevation Model (DEM) and coastal flood hazard map under different scenarios (outlined in section 3), including integration of latest science on impacts of climate change (e.g. IPCC AR6) and coastal hazard mapping without overriding the guidelines outlined in section 3.2.b).
- Develop a series of mapping products and GIS datasets at the regional, municipal / electoral areas, and island boundaries.
- Development of recommendations for go-forward approaches for developing and maintaining flood map data and for its use.
- Provision of a complete report for review.

B. Flood Construction Level development for various zones of the Sunshine Coast.

The Sunshine Coast is experiencing growth pressures and development that includes coastal areas and low lying areas. There is a need to better understand specific Flood Construction Levels for various zones of the Sunshine Coast on a more holistic basis to enable better levels of service and protect the public interest. This work will complement other work, such as the recently completed Regional Growth Strategy - Baseline Study and how the Sunshine Coast local governments mitigate risk.

Detailed activities include:

- Development of recommendations for the creation of geographic zones based on topographic and hydrologic factors – provided as a report.
- Consideration of development factors as related to the zones, including current development and current development opportunities.
- Recommendations for floodplain setbacks with consideration of coastal erosion and accretion.
- Calculation of updated flood construction levels for each zone, with detailed supporting rationale and mapping – provided as a report, map set and a GIS dataset
- The provision of public information regarding flood construction levels and the process used for their development – could include a workshop, brochure, etc.

C. Initial recommendations for adaptation and updating regulations in each jurisdiction.

There are several regulatory tools, including Official Community Plans, that are scheduled to be updated. The Contractor will develop high level recommendations based on the findings of the above activities and best practices to inform review processes that staff will undertake in the near future. Additionally, a Community Climate Action Plan is under development and will benefit from defensible maps and values to support community adaptation work. Detailed activities include:

- Development of recommendations based on best practices for updates to official community plan policy statements and maps.
- Development of recommendations based on best practices for amendments to any relevant regulatory bylaws.
- Development of recommendations based on best practices for the process of evaluation of variance applications.
- Development of high level recommendations for adaptation in high risk areas.
- Creation of implementation recommendations.

Final reports and mapping products should include executive summaries suitable for communication with lay public and non-expert staff and decision-makers.

3.3 Additional Work

The Contractor may be requested to expand the service area if additional funding is secured, the Contractor would perform the same services but in a different geographical location if the Regional District is able to source additional funding to expand the scope of study for the services. The Contractor would submit a proposal for the additional service area utilizing the unit prices provided in section 5.4.

4. CONTRACT

4.1 General Contract Terms and Conditions

Proponents should review carefully the terms and conditions set out in the General Service Contract, including the Schedules. The General Contract terms can be found at: Information about our General Service Terms and Conditions can be found at www.scrd.ca/bid.

4.2 Service Requirements

The Contractor's responsibilities will include the following:

- Support the Regional District's work with EMBC and GeoBC to support integration of Value-Added Products, derived products, and methodology into the Provincial Data Repository and Web Mapping Platforms. This will include transferring knowledge to replicate the solutions created on proprietary mapping platforms managed by the consultant.
- Collaborate with GeoBC to ensure an integrated and collaborative approach is taken to collect, capture, analyze, visualize, and manage data and information based on consistent standards and data models.
- Meet all existing federal and provincial guidelines and adhere to the Engineers and Geoscientists BC (EGBC) Professional Practice Guidelines, including (but not limited to): Federal Flood Mapping Guideline Series, FLNRORD's Specifications for Airborne LiDAR for the Province of British Columbia (2020), FLNRORD's Coastal Floodplain Mapping – Guidelines and Specifications (2011), EGBC's Professional Practice Guidelines – Floodplain Mapping in BC (2017), EGBC's Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC (2018), The BC Floodplain Mapping and Geomatics Guidelines (pending in 2022), Provincial Flood Hazard Area Land Use Management Guidelines, Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC, Flood Mapping in BC: APEGBC Professional Practice Guidelines V1.0, Coastal Flood Risk Assessment Guidelines.

- Provision of regular project meetings with project steering committee comprised of representatives of Regional District, Town of Gibsons, District of Sechelt, and Islands Trust.
- Draft reports for review by the project steering committee.
- Final reports and presentations to Regional District's Board of Directors as well as Town of Gibsons Council, District of Sechelt Council, and Islands Trust. The Contractor will be expected to provide the presentation up to four (4) times.
- Determine appropriate 2100 and 2200 SLR for the lower Sunshine Coast
- Develop six (6) flood scenarios for the study area (scenarios subject to change based on recommendations from the Contractor):

	Existing Condition	5% AEP	0.5% AEP
2100 SLR	Scenario 1	Scenario 2	Scenario 3
2200 SLR	Scenario 4	Scenario 5	Scenario 6

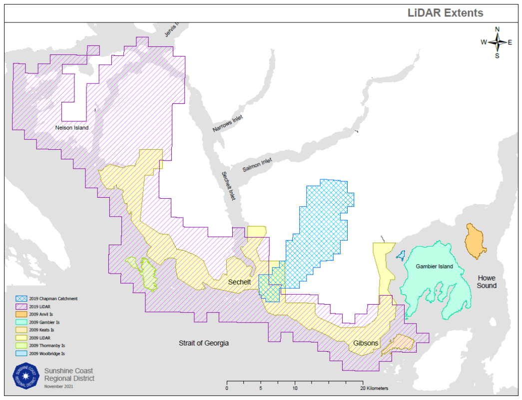
- With the project team, select the appropriate design scenario for designated flood level for future flood planning and FCL.
- Develop flood hazard mapping for the selected scenario for the study area.
- Develop FCL mapping for the study area and recommendations for building setbacks.
- Initial risk maps overlaying flood hazard scenario with critical infrastructure and ecological values.
- Digital data used to support development of maps; flood extents and major contours are expected to be provided as polygons/polylines in addition to data used to develop maps if methods involve use of raster datasets. All digital data is to be supported with appropriate metadata and transferred to the Regional District for future reference.
- A technical report outlining modelling and mapping methods (draft and final). This must be developed with consideration of the appropriate Provincial and Federal guidelines. Draft and final reporting is expected. The final report will be accompanied by a signed and sealed Flood Mapping Assurance Statement.
- A summary report suitable for lay readers (draft and final)
- The Regional District upon request from the Province of British Columbia, TOG, DOS and Island trust will provide all documents, any spatial data products and images t were developed under this agreement to the corporations for reproduction, distribution, or for use in their data base. The Consultant will provide any relevant data or support.

4.3 Related Documents

The local governments have data available to support the development of flood mapping that will be provided following the project kick-off meeting between Contractor and project steering committee. The intent of this project is to build on these and not to replicate or repeat effort. The project should consider, but not be limited to the following list:

- LiDAR for the following areas of the Coast, as outlined in the image below with the following specifications.
    - **2019 Chapman Catchment & SCRD LiDAR.** Acquisition Date: April, 2019. Source: National Disaster Mitigation Program (NDMP) – GeoBC. LiDAR = 12 points per m2 **Vertical Datum:** Canadian Geodetic Vertical Datum of 2013
    - **2009 LiDAR Islands Trust (Anvil, Gambier, Keats, Thormanby, Woolbridge Islands).** Acquistion Date: unknown date in 2009. Source: Islands Trust

- **2009 LiDAR SCRD.** Acquisition Date: September 12, 2009. Source: McElhanney. LiDAR: 1 point per 2 square meter resolution, providing a DEM area of better than 0.25 m. The LiDAR was acquired in conjunction with color imagery flown at a photo scale of 1:8,000 with 15cm map control. The coordinate system is UTM NAD83 and CGVD 28 Ht2 is the vertical datum.



- Regional District's Coastal Flood Development Permit Area background report by KWL (2013). See Appendix 1.
- Town of Gibsons Managing Natural Assets to Increase Coastal Resilience project (2021). (p.30)
- District of Sechelt's Shoreline Development Permit Area supporting reports.
- Islands Trust has an existing Development Permit Area for Shoreline Protection for Brigade Bay (Gambier Island).
- shíshálh Nation coastal flood mapping (2022).
- Each local government has a collection of individual Development Permit Approval files that contain site specific Flood Construction Levels.

5. REQUIREMENTS

In order for a proposal to be considered, a Proponent must clearly demonstrate that they meet the mandatory requirements set out in Section 7.1 (Mandatory Criteria) of the RFP.

This section includes "Response Guidelines" which are intended to assist Proponents in the development of their proposals in respect of the weighted criteria set out in Section 7.2 of the RFP. The Response Guidelines are not intended to be comprehensive. Proponents should use their own judgement in determining what information to provide to demonstrate that the Proponent meets or exceeds the Regional District's expectations.

Please address each of the following items in your proposal in the order presented. Proponents may find it helpful to use the individual Response Guidelines as headings for proposal responses.

5.1 Capabilities

5.1.1 Relevant Experience

The project will rely on the use of multi-disciplinary Qualified Professionals to define the methods and will meet or exceed standards in Provincial and Federal guidelines with the latest scientific knowledge. Proponents should outline team members expertise, experience, and capabilities in completing similar projects. The project team **must** include a Professional Engineer with a minimum of five years experience in coastal engineering. Teams should provide examples of recent projects of similar magnitude and complexity.

5.1.2 References

Proponents need to provide a minimum of 3 references (i.e. names and contact information) of individuals who can verify the quality of work provided specific to the relevant experience of the Proponent and of any subcontractors named in the proposal. References from the Proponent's own organization or from named subcontractors are not acceptable.

The Regional District reserves the right to seek additional references independent of those supplied by the Proponent, including internal references in relation to the Proponent's and any subcontractor's performance under any past or current contracts with the Regional District or other verifications as are deemed necessary by it to verify the information contained in the proposal and to confirm the suitability of the Proponent.

5.2 Sustainable Social Procurement

A factor in the Regional District evaluation process is sustainable social procurement and the evaluation of proposals will take this into consideration.

As part of any submission the Proponent is encouraged to identify how they may contribute to the following key social, employment and economical goals, but not limited to the following:

a) Contribute to a stronger local economy by:
   - promoting a Living Wage
   - Using fair employment practices;
   - Increase training and apprenticeship opportunities;

b) Local expertise knowledge by:
   a. Being locally owned;
   b. Utilization of local subcontractors;

c) Environmental Cost of Ownership;
d) Energy efficient products;
e) Minimal or environmental friendly use of packing materials; and
f) Reducing hazardous materials (toxics and ozone depleting substances).

5.3 Approach

Proponents should describe project management approaches to successfully complete the project and should discuss on how the Proponent will keep projects on time and on budget to support this timeline.

Proponents need to outline in their methodology used to prioritize areas on the Sunshine Coast that will be covered and provide an estimate of the areas covered in the proposal, as we are aware that the entire coastline may not be possible. The Proponent also need to include details on how existing data and tools will be leveraged to maximize the amount of the coast and value to the Regional District.

Proponents are encouraged and should describe any innovative ideas that may be used to support communications, especially with consideration of the implementation of flood mitigation policies.

5.4 Price

Proponents need to submit a fee proposal that sets out the separate costs of each deliverable described (coastal flood hazard mapping, flood construction levels for zones, initial recommendations on adaptation and updating regulations) as well as an all-inclusive cost for all the projects; the proposal should include a breakdown of the fix prices including time, travel, hourly billable rates and material costs; the breakdown of fees will be the fees used for additional work.

Prices quoted will be deemed to be:

- in Canadian dollars;
- inclusive of duty, FOB destination, and delivery charges where applicable; and
- exclusive of any applicable taxes.

6. PROPOSAL FORMAT

Proponents should ensure that they fully respond to all requirements in the RFP in order to receive full consideration during evaluation. It is expected that the Proponent will use their experience and expertise to review the scope and recommend any additions, deletions or changes to best achieve the goals of this project.

The following format, sequence, and instructions should be followed in order to provide consistency in Proponent response and ensure each proposal receives full consideration. All pages should be consecutively numbered.

a) Signed cover page (see section 7.1 Mandatory Criteria).
b) Table of contents including page numbers.
c) A short (one or two page) summary of the key features of the proposal.
d) The body of the proposal, including pricing, i.e. the “Proponent Response”.
e) Appendices, appropriately tabbed and referenced.
f) Identification of Proponent (legal name)
g) Identification of Proponent contact (if different from the authorized representative) and contact information.

7. EVALUATION

Evaluation of proposals will be by a committee formed by the Regional District and may include other employees and contractors.

The Regional District’s intent is to enter into a Contract with the Proponent who has met all mandatory criteria and minimum scores (if any) and who has the highest overall ranking.

Proposals will be assessed in accordance with the entire requirement of the RFP, including mandatory and weighted criteria.

The Regional District reserves the right to be the sole judge of a qualified proponent.

The Evaluation Committee may, at its discretion, request clarifications or additional information from a Proponent with respect to any Proposal, and the Evaluation Committee may make such requests to only selected Proponents. The Evaluation Committee may consider such clarification or additional information in evaluating a Proposal.

7.1 Mandatory Criteria

Proposals not clearly demonstrating that they meet the following mandatory criteria will be excluded from further consideration during the evaluation process.

Mandatory Criteria
The proposal must be received at the Closing Location before the Closing Time.
The proposal must be in English.
The proposal must be submitted using one of the submission methods set out on the cover page of the RFP
The proposal must either (1) include a copy of the cover page that is signed by an authorized representative of the Proponent, this is also required for email submissions or (2) be submitted by using the e-bidding key on BC Bid (if applicable), in accordance with the requirements set out in the RFP

Mandatory Criteria
The project team must include a Professional Engineer with a minimum of five years experience in coastal engineering.

7.2 Weighted Criteria

Proposals meeting all of the mandatory criteria will be further assessed against the following weighted criteria.

Weighted Criteria	Weight (%)
Proponent and team member experience	35
Methodology & Approach	30
Sustainable Social Procurement	5
Price	30
TOTAL	**100**

7.3 Price Evaluation

The lowest priced Proposal will receive full points for pricing. All other prices will be scored using the following formula: lowest priced proposal/price of this proposal* total points available for price.

Appendix 1 Coastal Flood Development Permit Area Background Reports

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Geotechnical Hazards Report: Halfmoon Bay

Final Report
May 2013
KWL Project No. 724.024-300

Prepared for:

Sunshine Coast Regional District

Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of the Sunshine Coast Regional District for the Geotechnical Hazards Report: Halfmoon Bay. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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Revision History

Revision #	Date	Status	Revision	Author
0	Feb 22, 2013	Draft	Draft Hazard Screen (submitted to SCRD).	CED/DTM
1	March 26, 2013	Final Draft	Following review meeting .	CED/DTM
2	May 15, 2013	Final	Client Review	CED/DTM

Contents

Figures

Tables

Section 1

Introduction

1. Introduction

1.1 Background

The OCP area of Halfmoon Bay is located on the Sunshine Coast, approximately 15 km northwest of Sechelt. The Sunshine Coast Highway (Highway 101) is the main route that bisects the community of Halfmoon Bay. The OCP area is bounded by the Strait of Georgia to the west with Sechelt Inlet flanking the eastern boundary.

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 to the east are sources of potential landslide activity that may affect lower slopes;
- Creeks support 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 hazard.

The area encompassing the OCP of Halfmoon Bay has increased substantially with the last OCP revision.

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 Halfmoon Bay, Elphinstone and West Howe sound based on the RFP closed in July, 2012.

The work scope was to assess and recommend revisions to the existing Development Permit Area (DPA) included in the Official Community Plans pertaining to the areas of for Halfmoon Bay, Elphinstone and West Howe Sound. The study provides the SCRD with technical guidance on possible amendments to existing DPAs. Each OCP area is discussed in separate reports. The report herein pertains to Halfmoon Bay.

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, BC Building Code, the Riparian Areas Regulation, and the SCRD Risk Assessment and Liability Policy); and
- Propose DPA areas 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:

- David Matsubara, M.Eng., P.Eng., KWL (Project Manager);
- Mike Currie, M.Eng., P.Eng., KWL (Senior Technical Review);
- Chad Davey, M.Sc., KWL (Fluvial Geomorphologist); and
- Pierre Friele, M.Sc., P.Geo., PG (WA), Cordilleran Geoscience (Senior Geoscientist).

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Section 2

Data Sources

2. Data Sources

2.1 Background Reports

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

- "Reconnaissance Study of Geotechnical Hazards Halfmoon Bay Official Community Plan" (Thurber, 1990);
- Halfmoon Bay Official Community Plan (SCRD, 2009);
- "Hazard Risk and Vulnerability Analysis for the Sunshine Coast Regional District" (EmergeX Planning, 2005);
- "Halfmoon Creek, Trout Lake, and Milne Creek Watershed Assessments" (Summit Environmental Consultants, 1997); and
- Surface geology maps for Sunshine Coast.

Brief summaries of selected reports are provided below:

Thurber (1990)

This report summarized a reconnaissance geotechnical hazard evaluation for the Halfmoon Bay OCP. The work largely focused upon the Redrooffs Escarpment where active shoreline erosion and landslide hazards exist adjacent to residential development. Recommendations by Thurber include a shoreline setback, a tree-cutting bylaw along watercourses and a prohibition of soil removal and waste dumping. Thurber also recommended that more detailed geotechnical and hydrological studies be conducted along the Redrooffs escarpment should residential development continue in expand in this area.

EmergeX Planning (2005)

EmergX Planning conducted a general hazard 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 Air Photographs

Hard copy air photographs were obtained from the SCRD and UBC's airphoto library and reviewed (Table 2-1).

Table 2-1: Summary of Air Photographs Reviewed

Date	Roll/Photo Number	Scale
2003	30BCC03039 #006-010	~1:15,000
1997/09/22	FFC VCR9700 L-11 #284-285	1:30,000
1994	30BCB94079 #1-266	~1:10,000
1990	30BCB90014 #122-124/130-135/184-187	~1:10,000
1980	30BC80060 #192-197/247-250	~1:30,000
1950	BC1230 #95-101	~1:40,000

In general, the relatively small size of the creeks in combination with the forest canopy cover prevented detailed observations of the channels. Thus, airphotos 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;
- general confinement noted for the creeks except in select locations.

2.3 GIS Analysis

GIS data were obtained from the SCRD including:

- Topographic data:
  - 1 m contours and LiDAR (x, y, z) (partial coverage of OCP area, from ocean to above highway);
  - 20 m contours (full coverage of OCP area);
- Creeks and rivers;
- Geology, surficial geology and soils data;
- Administrative data:
  - OCP Boundary (old and revised);
  - Parcels;
  - Existing DPA areas;
- Roads; and
- Orthophotos (2009).

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

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Section 3

Hazard Analysis

3. Hazard Analysis

3.1 Background

Topography

The Halfmoon Bay OCP mainly consists of gently sloping bedrock hummocks, rising from sea-level to elevations of 220 m along eastern OCP boundary. A feature unique to the area is a bedrock plateau along the southern boundary (commonly referred to as the Redrooffs Escarpment). The Redrooffs area is of concern due to landslide activity and shoreline erosion occurring adjacent to residential development. Development is typically on gently sloping terrain (less than 30% slopes). Steeper slopes occur in small, scattered areas in the following locations:

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

Climate and hydrology

The study area lies within the Coastal Douglas-fir (CDF) biogeoclimatic zone (Meidinger and Pojar, 1991). The CDF is limited to a small part of southeastern Vancouver Island, several islands in the Strait of Georgia, and a narrow strip of the Sunshine Coast. It is confined to elevations mostly below 150 m.

The CDF lies in the rainshadow of the Vancouver Island and Olympic mountains. It has warm, dry summers and mild, wet winters. Based on long-term weather stations, the mean annual temperature ranges from 9.2 to 10.5 °C, and the absolute minimum temperature ranges from -21.1 to -11.7°C. Mean annual precipitation varies from 647 to 1263 mm; very little (5% or so) falls as snow from November to April. In most winters the snow melts within a week of falling. It is substantially drier than the neighbouring Coastal Western Hemlock areas.

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 Figures 3.3 through 3.6 (Sheets 1 through 4).

3.3 Coastal Zone Hazards

Coastal hazards include flooding from a combination of regular tidal processes (e.g. surge, waves, etc), but also could occur from rare seismically included 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 are indicating 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.

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.

Tidal Condition

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

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

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 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

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 be greater 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), resulting in a 500-year return period value of 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 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 setback a minimum of 15 m 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, 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).

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

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.

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

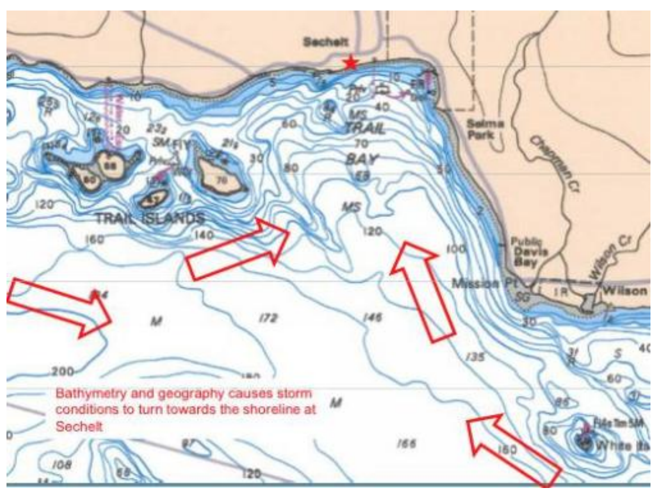
A recent cursory study was conducted for Trail Bay in Sechelt for the purposes of planning a long-term approach for the sea wall and shoreline area.

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 3-1.

Table 3-1: Summary of 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.



[2] Elevation referenced to Canadian Geodetic Vertical Datum.

In Trail Bay, the seawall at 4.0 to 4.5 m elevation is overtopped annually. Raising the seawall to about 5.5 m CGD 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. Typical coastal water level values for the near term quickly reach 5.5. 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. This additional metre provides a planning elevation for assessment of 7.15 m CGD or more simply 8 m.

The 8 m CGD planning area ensures that any sites below this elevation are assessed by a qualified professional to address flood hazards, but does not preclude development.

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 Halfmoon Bay OCP 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 1-2 m.

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 3 times horizontal setback is applied to 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 approach outlined in the provincial guidelines (Ausenco Sandwell, 2011).

In some isolated areas, due to shoreline and slope geometry, this setback may extend beyond the shoreline property. These areas have been shown on the maps for clarity, but these areas are not included in the DPA area at present.

3.4 Creek Hazards

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 5-10 m/s. These events leave sheets of poorly sorted debris ranging from sand to cobbles or small boulders. The peak discharge (flow rate) of debris floods and flows is commonly 2 to 5 times higher than that of 200 year return period water floods (Jakob and Jordan, 2001).

These types of events would be expected to initiate higher in the 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 flood and debris flow 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.

The watercourses in Halfmoon Bay are not typically incised channels but are contained between bedrock hummocks, where potential hazards are somewhat restricted to the immediate creek or river corridor. Areas without good confinement are usually 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.

Defining the Dominant Creek Hazard

GIS data were used to assess the creeks draining through the Halfmoon Bay OCP for debris flow or debris flood potential. It has been shown that the Melton Ratio[3] can successfully discriminate between

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

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 Figures 3-1 and 3-2, and summarized in Table 3-2.

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

Creek Name (from Northwest to Southeast)	Process Category (Ocean Outlet)	Process Category (Tributary Junction or at Upper Limit of Existing Development)
Wood Bay Creek	Flood	N/A[1]
Secret Cove Creek	Flood/debris flood (near class boundary) [1]	N/A[1]
Rollison Creek	Debris Flood	N/A[1]
Homesite Creek	Flood	Flood
Rawlston Creek	Flood	N/A[1]
Halfmoon Bay Creek	Flood	Flood
Milne (Kitchen) Creek	Flood	N/A[1]
Kitchen Creek	Flood	N/A[1]
Kenyon Creek	Flood	N/A[1]
Colvin Creek	Flood	N/A[1]
Wakefield Creek	N/A[2]	Flood

Notes:
1. Very little or no drainage area upstream of existing development according to mapping.
2. Drainage area within existing development is outside Halfmoon OCP boundaries.

As indicated by the results of the screening summary, Rollison Creek and, to a lesser extent, Secret Cove Creek may be subject to debris floods. Note, the smaller streams were not previously mapped in the stream feature class; however, they were identified in the topographic analysis. These potential creeks will field truthed and may be removed from the analysis for the final mapping product.

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.

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), we have followed RAR definitions, including:

- **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.

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.

Creek-Road Crossings

The majority of the major crossings in the OCP are reported to be Ministry of Transportation and Infrastructure assets, and 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 the current study; 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, the Ministry of Transportation and Infrastructure (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. Figures 3-1 and 3-2), extra allowance should be provided for sediment.

Where debris flows are anticipated (e.g. Figures 3-1 and 3-2), analysis of the debris flow recurrence interval should be conducted, and findings should inform the design, before it is finalized.

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, we have not recommended DPAs based on slope categories alone, without additional consideration of hazard mechanism.

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.

Areas of moderately steep (50-70%) and steep (>70%) terrain are not typically found in the Halfmoon Bay area. However, a few isolated areas of rocky, steep terrain in the OCP of Halfmoon Bay have the potential for landslides, these include: rock bluffs along Kitchen Creek, near Wood Bay Ridge Road and Birch Way. 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 we have applied travel angles to predict areas within the Halfmoon Bay OCP 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) debris flows 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 result was compared to the method proposed by Horel (2007) and found to be conservative.

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 Halfmoon Bay 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.

3.6 Fieldwork

A field visit of the Halfmoon Bay OCP was conducted in late February 2013. The following observations were made:

- The Secret Cove Creek culvert at the Highway 101 clear of debris at the upstream end; however the downstream end is submerged in water due to a backwater condition from beaver dam activity. This could cause sediment deposition to occur in the downstream portion of the culvert, which may eventually lead to a blockage.
- Homesite Creek Culvert at Highway 101 is clear of debris. A small section of channel immediately upstream of the culvert appears to be a small floodplain area.
- An area of low channel confinement on Homesite Creek (1km upstream of Highway 101 crossing) identified during the hazard screening was visited. Low channel confinement was observed within a ravine (Photo 3.1).
- An ocean front slope down gradient of Welcome Wynd road was visited. Although exposed to wave action, this granitic bluff appears to be quite stable with little evidence of recent erosion (i.e. absence of large blocks or colluvium deposits at base) (Photo 3.2).

- The Halfmoon Bay Creek culvert at Highway 101 is clear of debris. It appears that a larger alluvial fan feature existed in the vicinity of the Highway 101 crossing. The construction of Highway 101 and Redrooffs Road however, has cut off Halfmoon Bay Creek from the alluvial fan and restricted the creek channel a smaller area of low channel confinement downstream of the highway crossing (Photo 3.3).
- Kitchen Creek culvert at Fishermans Road has some sediment accumulation at the downstream end (Photo 3.4). It appears that during high tidal events a backwater is created upstream of Fishermans Road and floods a small area adjacent to Cooper Green Park (Photo 3.5). Some minor bank erosion, likely the result of the backwater events, was observed adjacent to Fishermans Road culvert along the upstream side (Photo 3.6). It also appears that live staking of vegetation was used to mitigate this erosion (Photo 3.6).
- A few large blocks were observed upslope from the Redrooffs Road at Kitchen Creek. These blocks appear to have fallen from a small 3 m high rock bluff upslope (Photo 3.7).
- Upstream of the Redrooffs Road, Kitchen Creek fairly stable and contained in a small gully. A rock bluff on the north side of Kitchen Creek has evidence of recent small rock slides and block failure (Photo 3.8).
- The Redrooffs bluffs were field investigated along the Sargeants Bay area and further west along the shoreline. A small unnamed creek was observed along the most southeast point of the Redrooffs bluffs. Slope movement and active erosion was observed at several locations along the south-facing bluff. The bluff appears to consist of a glacial till dominated by silt with some gravel/cobbles (Photos 3.9). It is assumed that wave attack during high tides is the dominant erosional process here.
- The Colvin Creek culvert at Redrooffs Road (near Kenyon Road intersection) is damaged on the downstream end. The damage to the culver is causing sediment to deposit within the culvert. It is recommended that this culvert be repaired to prevent further sediment deposition and possible blockage (Photo 3.10).
- A steep rock bluff identified in the hazard screening near Birch Way was visited. The high degree of recent residential development was not anticipated prior to visiting this area. Thus, permission to access the cliffs toe by crossing residential property was not sought and a more detailed investigation was not conducted. However, some large blocks were observed near the road (Leaning Tree North Road), suggesting that past, isolated failure of the cliff had occurred. A more detailed investigation is recommended once permission to access properties along the cliffs toe is granted.

Photo 3.1: Area of low channel confinement along Homesite Creek.

Photo 3.2: Granitic bluff along Welcome Wynd Road.

Photo 3.3: Area of low channel confinement at Halfmoon Bay Creek.

Photo 3.4: Sediment accumulation within the Kitchen Creek culvert at Fishermans Road.

Photo 3.5: Small floodplain area at Kitchen Creek near Cooper Green Park.

Photo 3.6: Bank erosion along Fishermans Road at Kitchen Creek.

Photo 3.7: Large blocks associated with a small bluff upslope near Kitchen Creek at Redrooffs Road.

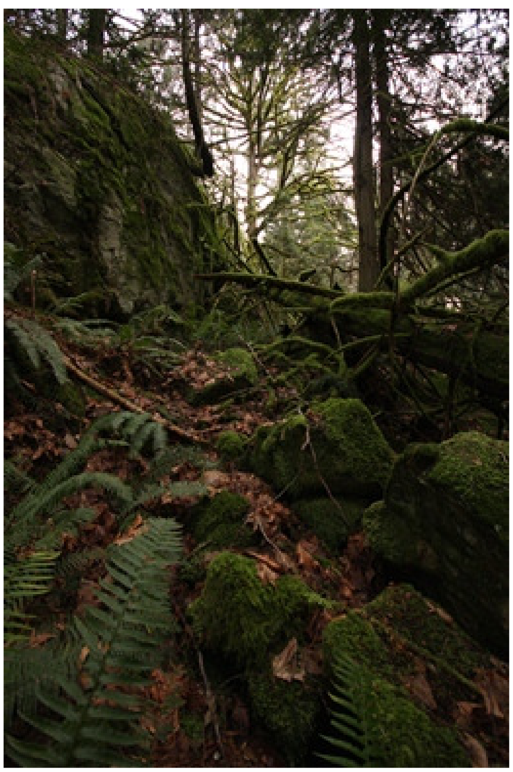


Photo 3.8: Small rock slide evident on north side of Kitchen Creek.

Photo 3.9: Recent erosion scar along Redrooffs bluff.

Photo 3.10: Observed sediment accumulation and damage to the Colvin Creek culvert along Redrooffs road.

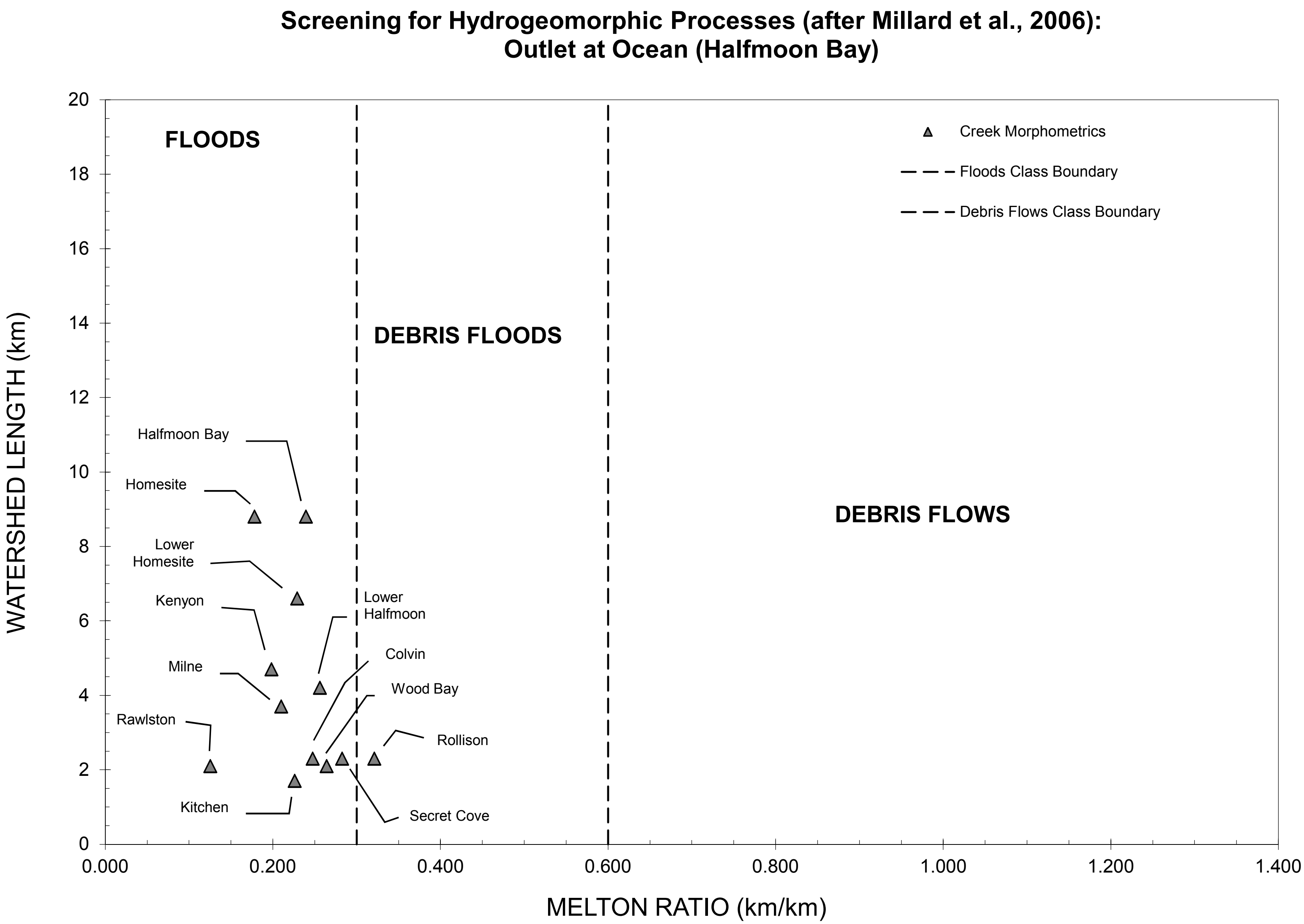


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Figure 3-1

Screening for Hydrogeomorphic Processes (after Millard et al., 2006): Outlet At Tributary Junctions or At Upper Limit of Existing Development (Halfmoon Bay)

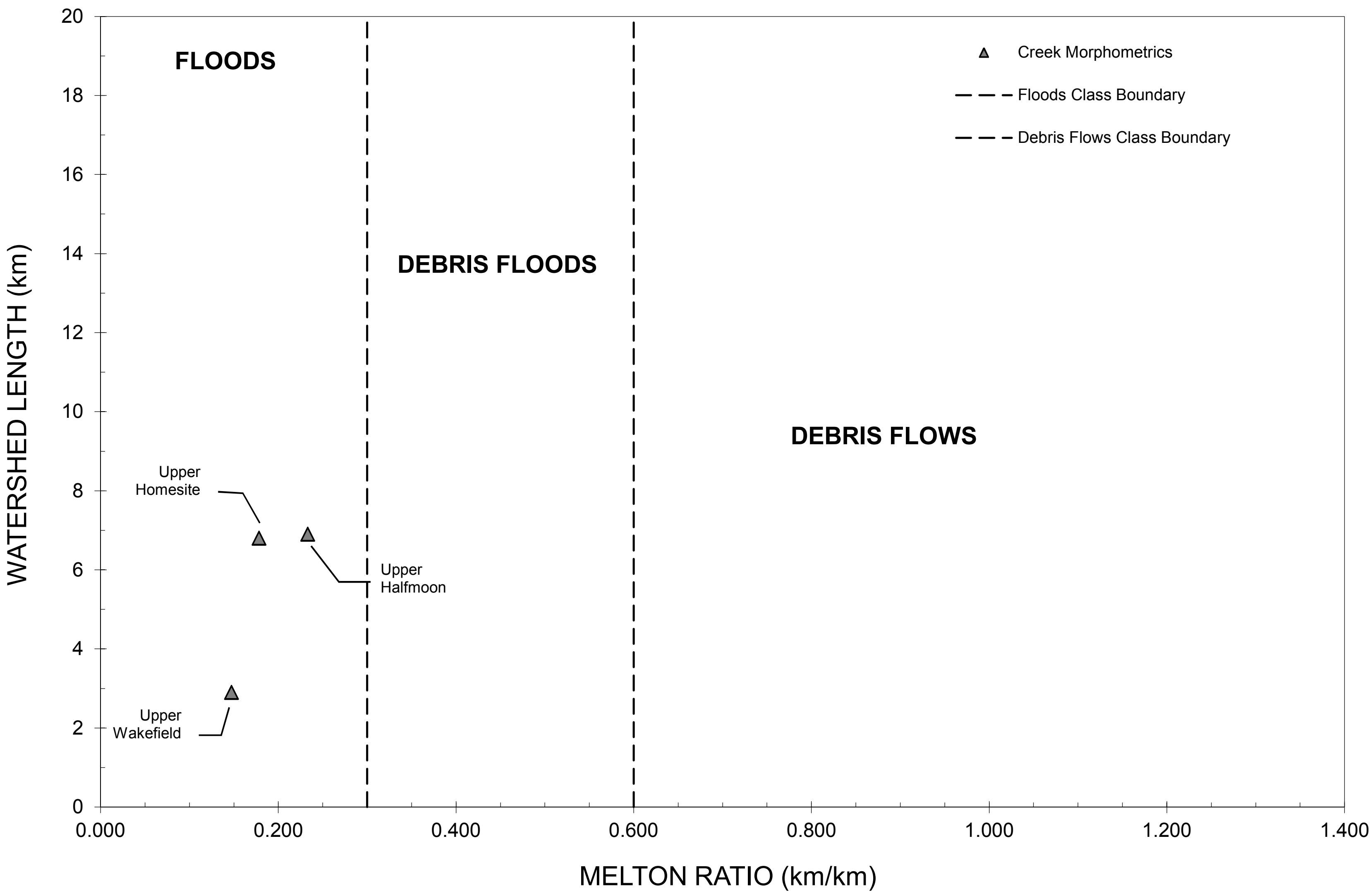

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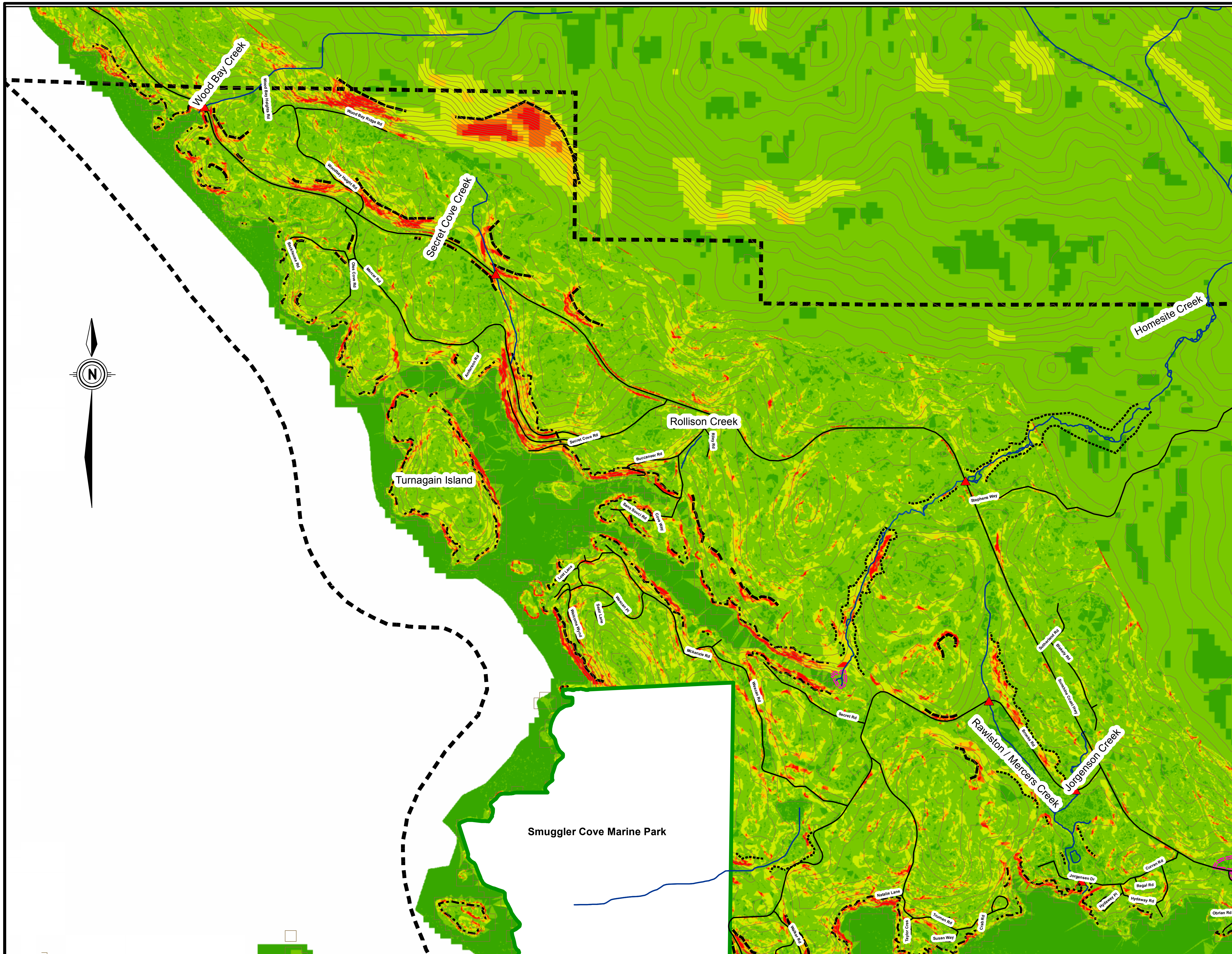
Figure 3-2



Geotechnical Hazards Report:
Halfmoon Bay
Sunshine Coast Regional District

Legend

- Ravine Crest
- Creek-Road Crossings
- Roads
- Creeks/Rivers
- Provincial Park Boundary
- 10 m Contours
- Oceanfront Slope Crest
- Open Slope Failure Initiation Line
- Low Channel Confinement (Fan)
- Halfmoon Bay OCP Boundary
- 0 - 5
- 5 - 30
- 30 - 50
- 50 - 60
- 60 - 70
- >70

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Project No.	Date
724-024	May 2013

Halfmoon Bay Hazards Screen (Sheet 1)

Figure 3-3

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Author: CDavey

Geotechnical Hazards Report:
Halfmoon Bay
Sunshine Coast Regional District

Legend

- Ravine Crest
- Creek-Road Crossings
- Roads
- Creeks/Rivers
- Provincial Park Boundary
- 10 m Contours
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- Open Slope Failure Initiation Line
- Low Channel Confinement (Fan)
- Halfmoon Bay OCP Boundary
- 0 - 5
- 5 - 30
- 30 - 50
- 50 - 60
- 60 - 70
- >70

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Project No.	Date
724-024	May 2013

Halfmoon Bay Hazards Screen (Sheet 2)

Figure 3-4

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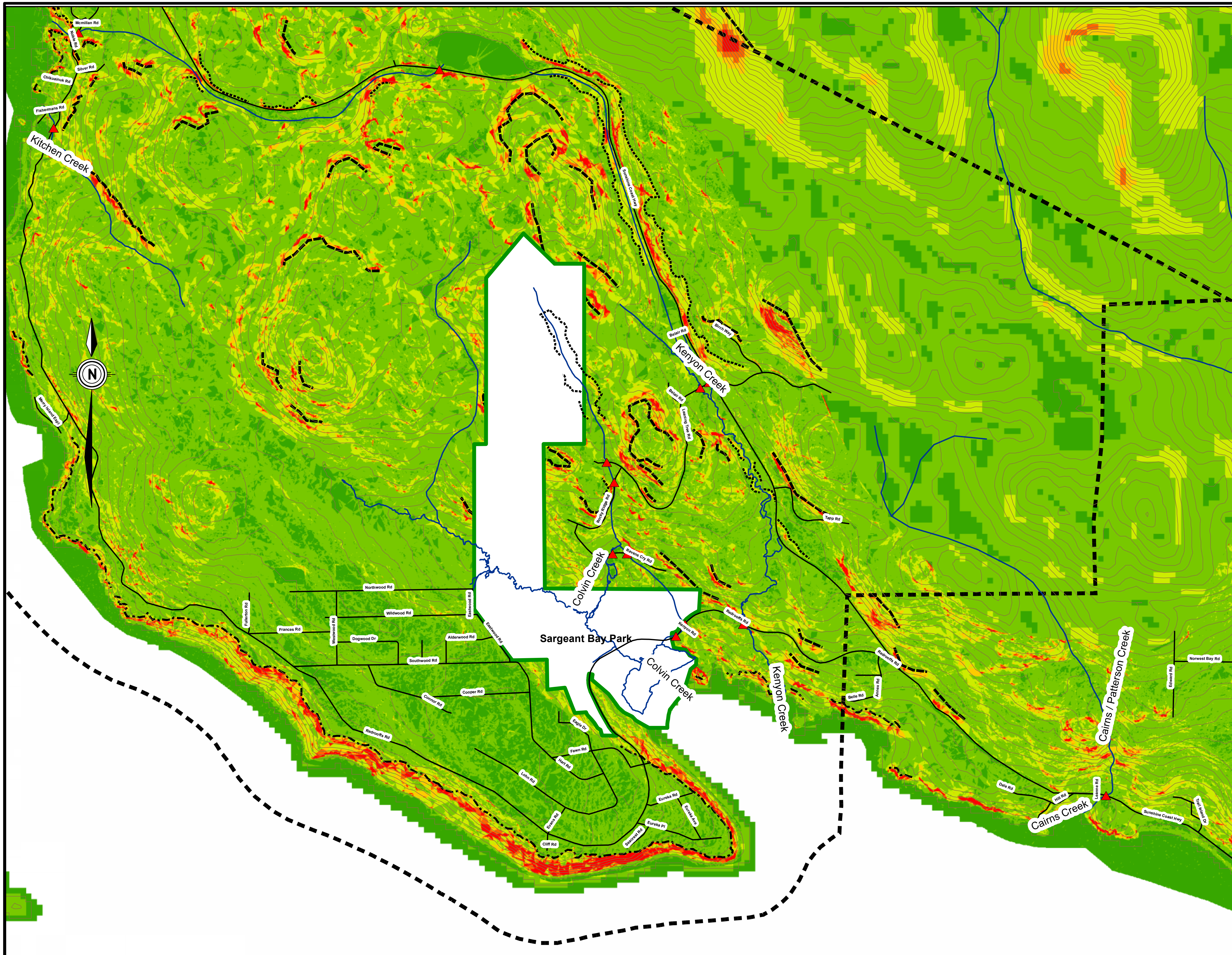
Author: CDavey

Geotechnical Hazards Report:
Halfmoon Bay
Sunshine Coast Regional District



Legend

- Ravine Crest
- Creek-Road Crossings
- Roads
- Creeks/Rivers
- Provincial Park Boundary
- 10 m Contours
- Oceanfront Slope Crest
- Open Slope Failure Initiation Line
- Low Channel Confinement (Fan)
- Halfmoon Bay OCP Boundary
- 0 - 5
- 5 - 30
- 30 - 50
- 50 - 60
- 60 - 70
- >70

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Project No.	Date
724-024	May 2013

Halfmoon Bay Hazards Screen (Sheet 3)

Figure 3-5

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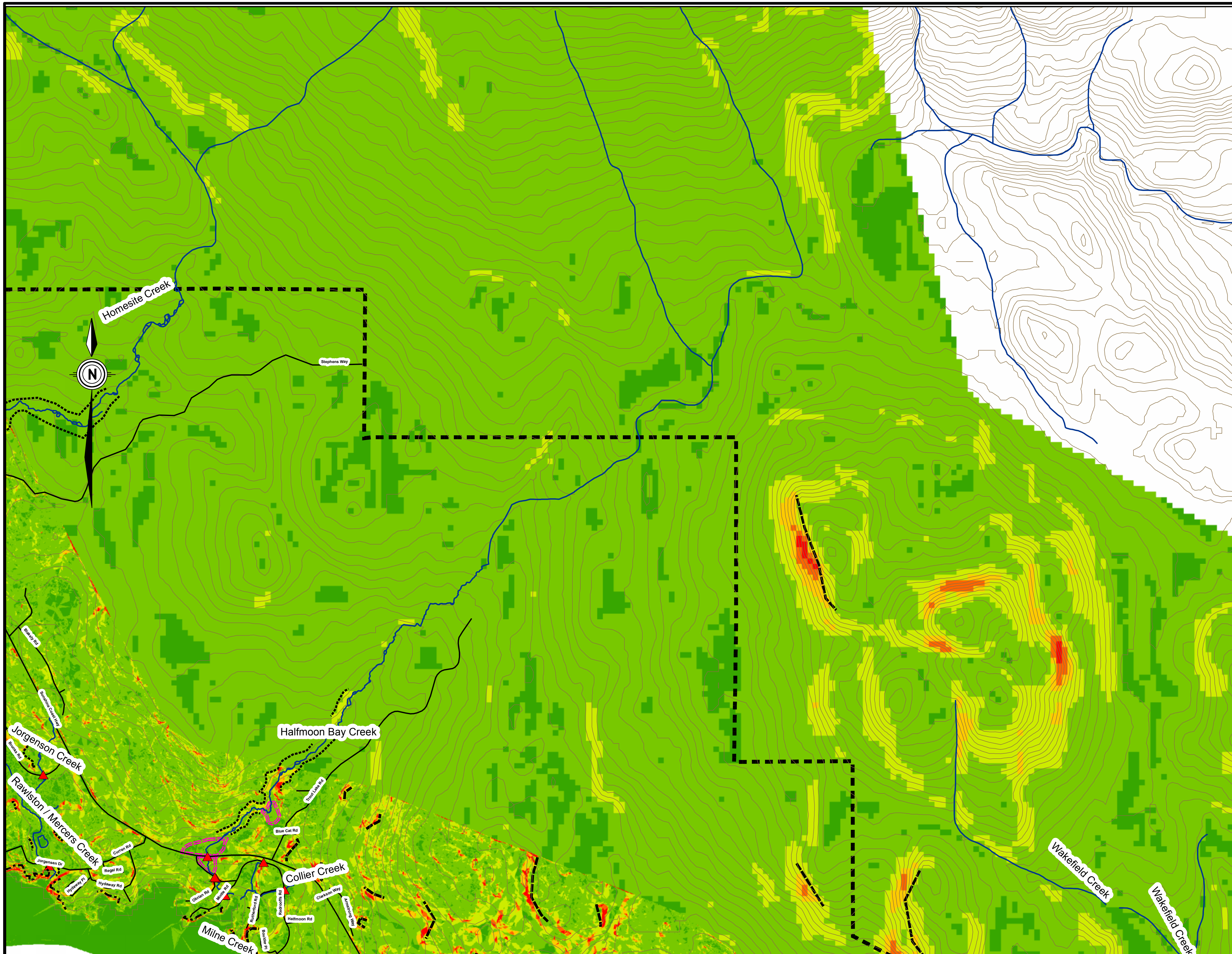

Geotechnical Hazards Report:
Halfmoon Bay
Sunshine Coast Regional District

Legend

- Ravine Crest
- Creek-Road Crossings
- Roads
- Creeks/Rivers
- Provincial Park Boundary
- 10 m Contours
- Oceanfront Slope Crest
- Open Slope Failure Initiation Line
- Low Channel Confinement (Fan)
- Halfmoon Bay OCP Boundary
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- 30 - 50
- 50 - 60
- 60 - 70
- >70

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Project No.	Date
724-024	May 2013

Halfmoon Bay Hazards Screen (Sheet 4)

Figure 3-6

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Section 4

Proposed DPA Framework

4. Proposed DPA Framework

4.1 Overview

The following sections outline the proposed development permit area (DPA) framework for hazardous areas in the Halfmoon Bay 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.
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.

Uncertainty

The goal of the DPA boundary delineation is to apply a uniform screening criterion 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 site specific surveys may be used 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.

DPA 1A: Coastal Flooding

The DPA extends from the coastal DPA boundary to 8 m CGD[4]. Within the DPA, development applications would require a coastal flood hazard assessment to define the coastal flood components, namely wave runup, wave setup, and possibly wind setup by a qualified professional, or siting development above 8 m CGD.

DPA 1B: Coastal Slopes

The recently released Guidelines report addresses the need to provide setbacks under conditions of a rising sea level (Ausenco Sandwell, 2011). 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 3 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.

In certain instances (Redrooffs area), the geometry of steep/tall bluffs caused the setback determination on the landward-side boundary to extend beyond the first row of lot parcels and included road ways and lot parcels further upslope. In these cases, the landward-side DPA boundary was limited to the upslope boundary of the lot parcels nearest the ocean bluff, and the remainder of the setback was delineated separately. The DPA setback was truncated, given that slope failure consequences for properties across the road are remote, and more a function of increased progressive erosion due to sea level rise. Also from a practical approach, all slope stability and protective measures would be addressed by the waterfront property and not inland properties. The full setback area was shown to communicate the potential future slope risks and extents.

[4] Elevation referenced to Canadian Geodetic Vertical Datum.

Within the DPA, landslide risk assessment will be required 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).

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.

Riparian, flood, debris flood and debris flow hazard assessments will be required within DPA 2A.

DPA 2B: Ravines

Ravine areas were defined using the crest lines mapped in the GIS. Based on consideration of stable angles of repose and the typical terrain seen in the on the Sunshine Coast; however, Halfmoon Bay typically has broader and shallower ravines than the areas to the south and east. The following approach has been adopted:

- A 30 m setback from ravine crests defines the area that falls within DPA 2B. A 15 m setback line is also indicated.
- A <u>minimum</u> 15 m setback from ravine crest is required for all development.
- <u>For ravines that are deeper than 15 m</u>, the setback from ravine crest will be 30 m. An engineering report from an appropriately qualified professional will 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 they fall into.

DPA 2B will require a landslide assessment for ravine sidewalls.

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, which is not captured in DPA 2A.

Flood and erosion hazard assessment will be required within DPA 2C.

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 air photographs and contour mapping have been used to identify potential areas of low channel confinement, which are included in DPA 2D.

Flood and erosion, and channel avulsion hazard assessment will be required within DPA 2D.

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 shall meet general MOTI criteria outlined in Section 3.

Any culverts on major road crossing have been identified on the mapping, a requirement to review those crossings for development permit applications in close proximity (e.g. 300 m) and should be implemented as a Development Approval Information Area - General Condition in the OCP.

4.4 DPA 3: Slope Hazards

Three sub-categories of slope hazards are identified that are applicable to the Halfmoon Bay OCP area: open slope failures, rockfall hazards and seisimic-initated slope hazards. Open slope failures and rock fall hazard sub-categories are delineated under 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.

Open Slope Failures

Potential for open slope failures in the Halfmoon Bay OCP were identified where there are areas of moderately steep and steep terrain. Areas of high, steep terrain within the Halfmoon Bay OCP are not common, although small, isolated rock bluffs (< 10 m in height) are found throughout the electoral area. Potential landslide impact areas were only 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). Open slope crests where initiation of a landslide may occur (bluffs higher than 10 m) are delineated in the DPA maps.

Landslide risk assessments will be required within DPA 3.

Rockfall

Within the 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.

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

Seismic-Initiated Slope Hazards

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

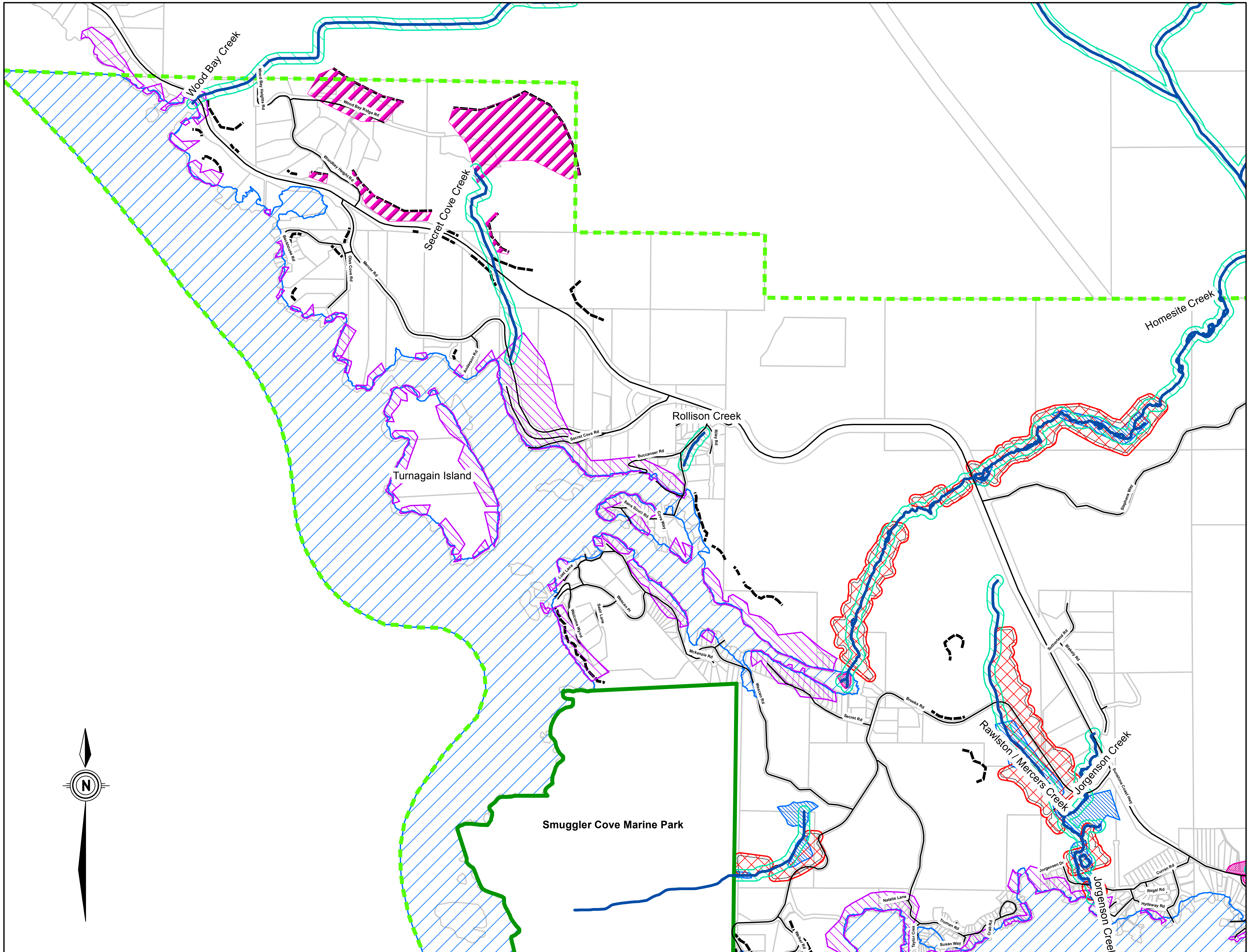
No map-based screening tool is currently available to identify seismic slope hazard areas and therefore is not a Development Permit area, and should be implemented as a Development Approval Information Area - General Condition in the OCP.

4.5 Proposed Revised DPAs for Halfmoon Bay OCP

Proposed revised DPA's are presented in Figures 4-1 through 4-4.

Based upon our field assessment, it was evident that a few hazards identified during the screening process warranted adjustment to the DPA boundaries that were initially developed using the protocols employed in the sections above. They include:

- Ravine crests along the upper section of Kenyon Creek and Milne Creek (adjacent to Highway 101) appear to be the result of blasting activity during the construction of the highway and not the result of fluvial erosional processes. As a result, the crest lines are mapped but these features are included in the DPA.
- The screening process identified slope related hazards within Smuggler Cove Marine Park and Sargeant bay Park. Any hazard identified within the park boundaries have been removed from the maps presented here.



Geotechnical Hazards Report:
Halfmoon Bay
Sunshine Coast Regional District

Legend

- DPA Zone 1A: Coastal Flooding
- DPA Zone 1B: Coastal Slopes
- DPA Zone 2A: Creek/River Corridor
- DPA Zone 2B: Ravines (30m)
- DPA Zone 2B: Ravines (15m)
- DPA Zone 2C: Floodplain
- DPA Zone 2D: Low Channel Confinement (Fan)
- DPA Zone 3: Slope Hazards
- Creeks/Rivers
- Roads
- Halfmoon Bay OCP Boundary
- Provincial Park Boundary
- HMB Parcels

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Project No.	Date
724-024	May 2013

Halfmoon Bay
Proposed DPAs (Sheet 1)

Figure 4-1

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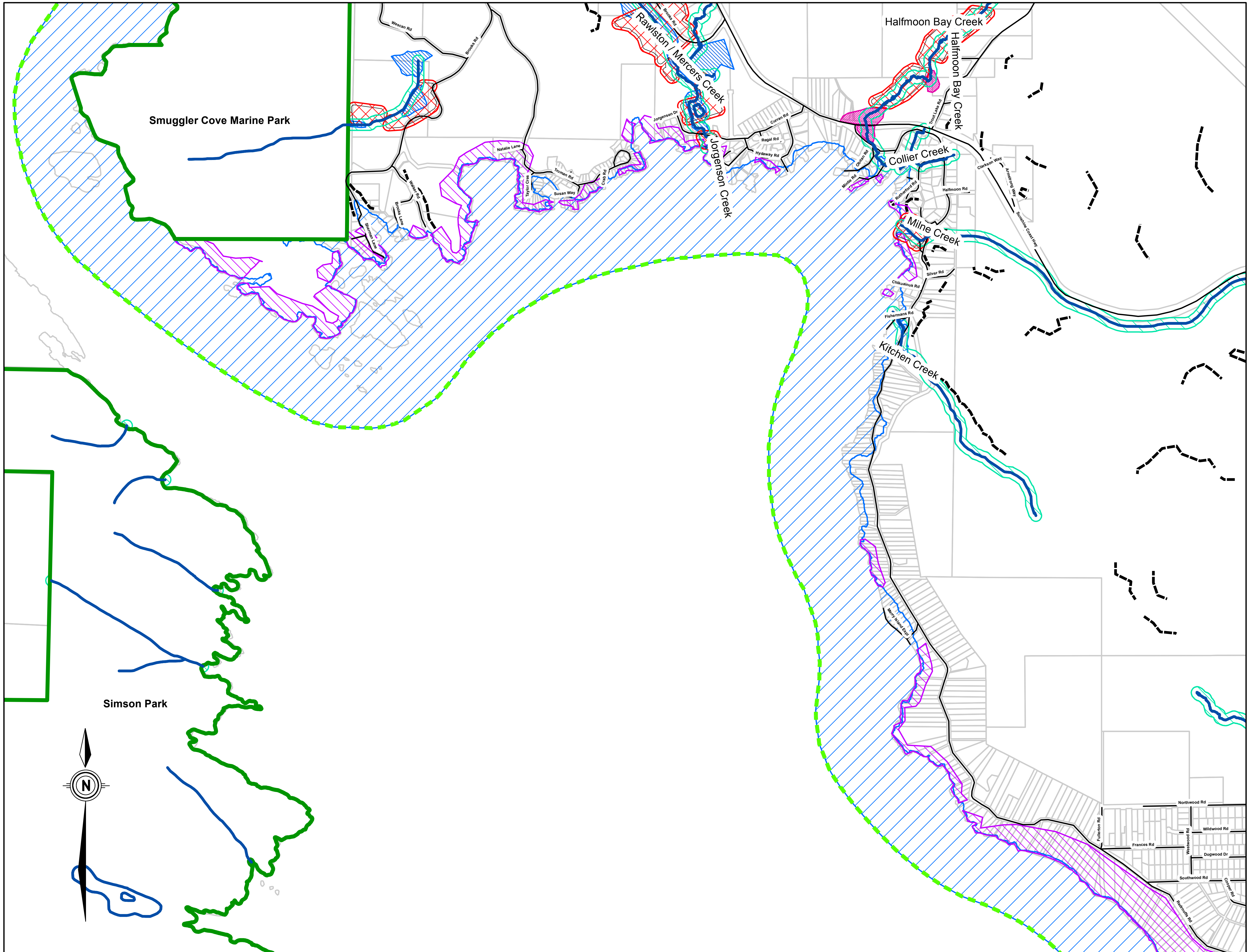
Author: CDavey

Geotechnical Hazards Report: Halfmoon Bay Sunshine Coast Regional District



Legend

- DPA Zone 1A: Coastal Flooding
- DPA Zone 1B: Coastal Slopes
- DPA Zone 2A: Creek/River Corridor
- DPA Zone 2B: Ravines (30m)
- DPA Zone 2B: Ravines (15m)
- DPA Zone 2C: Floodplain
- DPA Zone 2D: Low Channel Confinement (Fan)
- DPA Zone 3: Slope Hazards
- Creeks/Rivers
- Roads
- Halfmoon Bay OCP Boundary
- Provincial Park Boundary
- HMB Parcels

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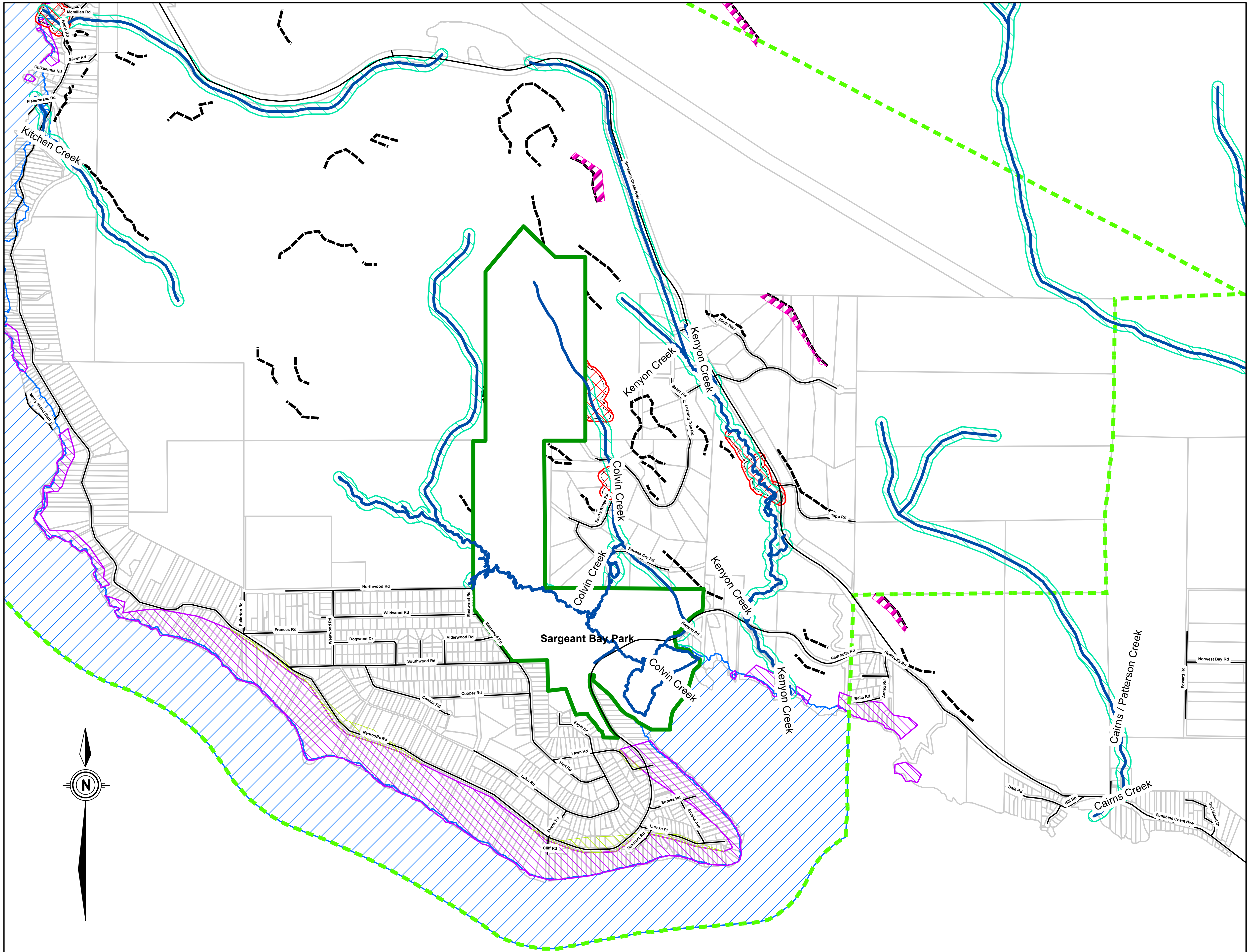
Project No.	Date
724-024	May 2013

Halfmoon Bay Proposed DPAs (Sheet 2)

Figure 4-2

Path: O:\0700-0799\724-024\430-GIS\MXD-Wk-CED-Main\724024_Wk_CED_DPA.mxd Date Saved: 16/04/2013 11:58:06 AM
Author: CDavey



Geotechnical Hazards Report:
Halfmoon Bay
Sunshine Coast Regional District

Legend

- DPA Zone 1A: Coastal Flooding
- DPA Zone 1B: Coastal Slopes
- DPA Zone 1B: Coastal Slopes (caution zone)
- DPA Zone 2A: Creek/River Corridor
- DPA Zone 2B: Ravines (30m)
- DPA Zone 2B: Ravines (15m)
- DPA Zone 2C: Floodplain
- DPA Zone 2D: Low Channel Confinement (Fan)
- DPA Zone 3: Slope Hazards
- Creeks/Rivers
- Roads
- Halfmoon Bay OCP Boundary
- Provincial Park Boundary
- HMB Parcels

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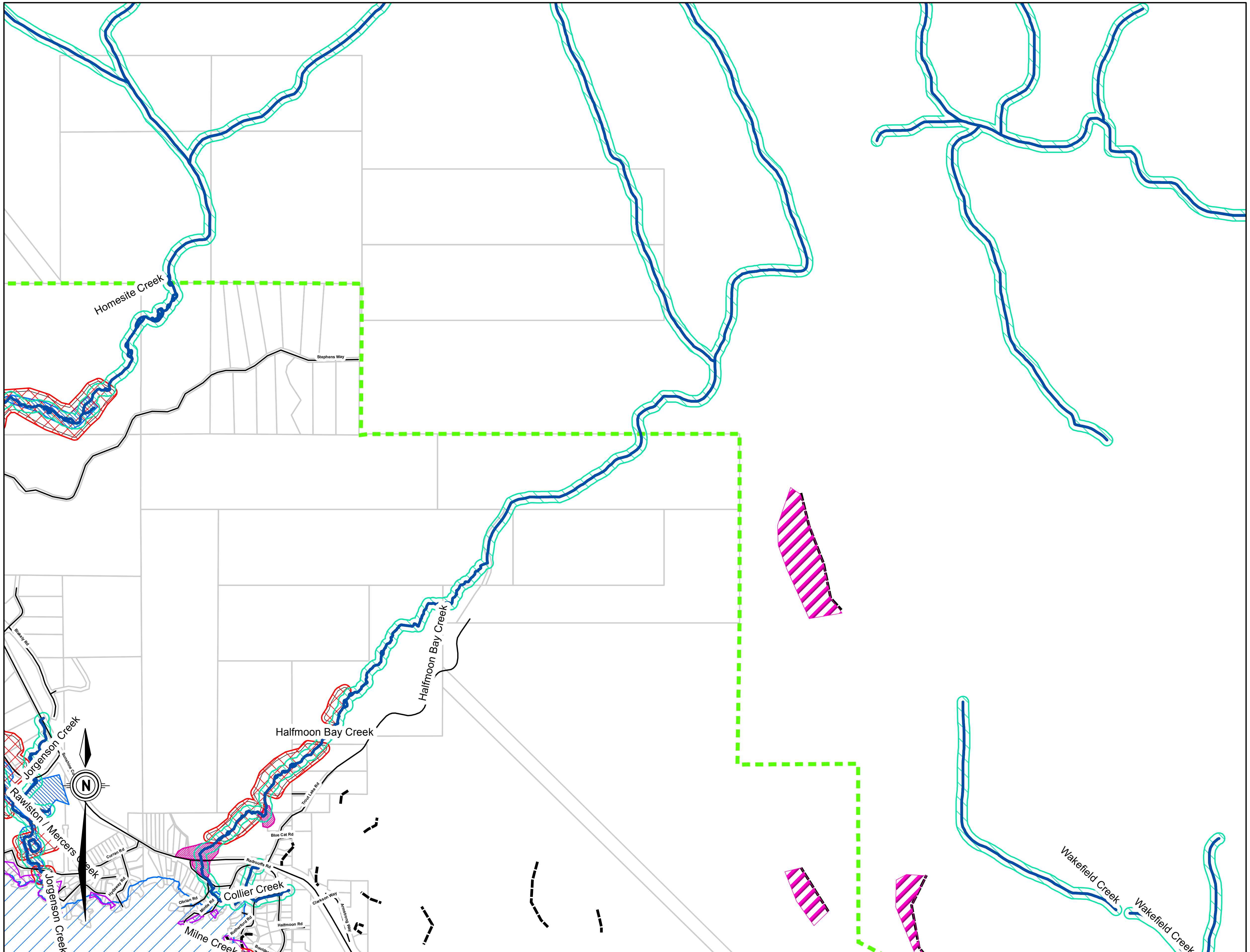
Project No.	Date
724-024	May 2013

Halfmoon Bay
Proposed DPAs (Sheet 3)

Figure 4-3

Path: O:\0700-0799\724-024\430-GIS\MXD-Wk-CED-Main\724024_Wk_CED_DPA.mxd Date Saved: 16/04/2013 11:58:06 AM
Author: CDavey



Geotechnical Hazards Report:
Halfmoon Bay
Sunshine Coast Regional District

Legend

- DPA Zone 1A: Coastal Flooding
- DPA Zone 1B: Coastal Slopes
- DPA Zone 2A: Creek/River Corridor
- DPA Zone 2B: Ravines (30m)
- DPA Zone 2B: Ravines (15m)
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- DPA Zone 2D: Low Channel Confinement (Fan)
- DPA Zone 3: Slope Hazards
- Creeks/Rivers
- Roads
- Halfmoon Bay OCP Boundary
- Provincial Park Boundary
- HMB Parcels

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Project No.	Date
724-024	May 2013

Halfmoon Bay
Proposed DPAs (Sheet 4)

Figure 4-4

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Author: CDavey

Section 5

Guidelines for Development

5. Guidelines for Development

5.1 DPA 1: Ocean Hazards

A Development Permit on lands identified as being within DPA 1 is required 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.

Different hazards have been identified within the general category of "ocean hazards": applications for subdivision, building permit or land alteration shall include a report from an appropriately qualified Professional Engineer or Professional Geoscientist that considers all relevant potential ocean hazards.

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.

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

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 by qualified professional
Freeboard	Nominal allowance	0.6 m
Flood Construction Level = Sum of all components.		

A regional study may be appropriate for the Sunshine Coast to 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.

DPA 1B – Coastal Slopes Guidelines

If applicable, the report shall include the following:

- Surveyed slope profiles with documentation of the limits of slope instability. Consideration shall 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 shall also 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 recommendation for any mitigative works for slope stability or erosion.
- 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 (Ausenco Sandwell, 2011b).
- 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

A Development Permit on lands identified as being within DPA 2 is required 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 2A/C/D – Creek Corridor / Floodplain / Low Channel Confinement Guidelines

- A review of the property by an appropriately qualified Professional Engineer or Professional Geoscientist shall be required as part of a development permit review process. The report shall include an 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.

- Flooding and associated creek processes are subject to assessment 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 shall consider upstream channels and floodways, debris dams, culverts, sources of debris (channels and eroded banks) and related hydrologic features.
- Analysis shall 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.

DPA 2B – Ravines Guidelines

- 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.
- Development within ravine slope setbacks will be subject to the reporting requirements for DPA 3.
- A field definition of the required setback from the top of a ravine or other steep slope.
- The report shall 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.

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

- Where identified as a possible mechanism (Table 3-2), potential debris flow and debris flood creeks shall be assessed by an appropriately qualified professional. 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) around debris flow or debris flood creeks shall 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).

5.3 DPA 3: Slope Hazards

A Development Permit on lands identified as being within DPA 3 is required 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.

Both open slope failures and rockfall hazards fall within this DPA. Applications for subdivision, building permit or land alteration shall 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 shall include the following:

- Slope profiles with documentation of the limits of slope instability shall be provided. Consideration shall 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 shall also 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 rock fall shadow area, including an indication of the appropriate buffer zone and required protective works.

5.4 Exemptions

The following general exemptions may be granted 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.
- 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 2 trees over 20 centimetre diameter breast height or 10 square metres of vegetated area of per calendar year per lot, provided there is replanting of 4 trees or re-vegetation of the same amount of clearing.

5.5 Report Submission

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.

____

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Fluvial Geomorphologist

Reviewed by:

____

David Matsubara, M.Eng., P.Eng.
Senior Technical Review

References

Association of Professional Engineers and Geoscientists, BC. 2012. Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC. 40 pp + appendices.

Ausenco Sandwell. 2011a. Climate Change Adaption Guildeines for Sea Dikes and Coastal Flood Hazard Use – Sea Dikes Guidelines. Report prepared for Ministry of the Environment. 19 pp + appendices

Ausenco Sandwell. 2011b. Climate Change Adaption Guildeines for Sea Dikes and Coastal Flood Hazard Use – Guidelines for Management of Coastal Flood Hazard Land Use. Report prepared for Ministry of the Environment. 23 pp + appendices

Ausenco Sandwell. 2011c. Climate Change Adaption Guildeines for Sea Dikes and Coastal Flood Hazard Use – Draft Policy Discussion Paper. Report prepared for Ministry of the Environment. 45 pp + appendices

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Meidinger, D. and Pojar, J. 1991. Ecosystems of British Columbia. Report prepared by the BC Ministry of Forests. 330 pp. + appendices.

Millard, T.H., D.J. Wilford and M.E. Oden. 2006. Coastal fan destabilization and forest management. Res. Sec., Coast For. Reg., BC Min. For., Nanaimo, BC. Technical Report TR-034/2006.

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Geotechnical Hazards Report: Elphinstone

Final Report
May 2013
KWL Project No. 724.024-300

Prepared for:

Sunshine Coast Regional District

Statement of Limitations

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Revision History

Revision #	Date	Status	Revision	Author
0	Feb 22, 2013	Draft	Draft Hazard Screen (submitted to SCRD).	CED/DTM
1	March 26, 2013	Final Draft	Following review meeting .	CED/DTM
2	May 15, 2013	Final	Client Review	CED/DTM

Contents

Figures

Tables

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Section 1

Introduction

1. Introduction

1.1 Background

The OCP area of Elphinstone is located on the Sunshine Coast, approximately 15 km east of Sechelt. The Sunshine Coast Highway (Highway 101) is the main route through the community of Elphinstone. The OCP area is bounded by the town of Gibsons to the east, the Elphinstone Mountains to the north and the OCP of Roberts Creek to the west.

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 to the east are sources of potential landslide activity that may affect lower slopes;
- Creeks support 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 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 Halfmoon Bay, Elphinstone and West Howe sound based on the RFP closed in July, 2012.

The work scope was to assess and recommend revisions to the existing Development Permit Area (DPA) included in the Official Community Plans pertaining to the areas of for Halfmoon Bay, Elphinstone and West Howe Sound. The study provides the SCRD with technical guidance on possible amendments to existing DPAs. Each OCP area is discussed in separate reports. The report herein pertains to Elphinstone.

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, BC Building Code, the Riparian Areas Regulation, and the SCRD Risk Assessment and Liability Policy); and

- Propose DPA areas 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:

- David Matsubara, M.Eng., P.Eng., KWL (Project Manager);
- Mike Currie, M.Eng., P.Eng., KWL (Senior Technical Review);
- Chad Davey, M.Sc., KWL (Fluvial Geomorphologist); and

- Pierre Friele, M.Sc., P.Geo., PG (WA), Cordilleran Geoscience (Senior Geoscientist).

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Section 2

Data Sources

2. Data Sources

2.1 Background Reports

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

- "Reconnaissance Study of Geotechnical Hazards Elphinstone and West Howe Sound Official Community Plans" (Thurber, 1990);
- Elphinstone Official Community Plan (SCRD, 2011);
- "Hazard Risk and Vulnerability Analysis for the Sunshine Coast Regional District" (EmergeX Planning, 2005);
- Surface geology maps for Sunshine Coast.

Brief summaries of selected reports are provided below:

Thurber (1990)

This report summarized a reconnaissance geotechnical hazard evaluation for the Elphinstone and West Howe Sound OCP's. The work touched upon several areas of concern, including: Upper Chaster Creek (debris flows), upper steep slopes in the OCP (landslides), lower Chaster Creek and ravine (flooding, soil creep), Ocean Beach Esplanade (wave erosion), and a lagoon near Second Street and Chaster Creek (flooding during high tide). Recommendations by Thurber is to inform residents living along the Coastal slopes between Pine and Oak street that these bluffs are geomorphically active and to avoid dumping fill or debris on these slopes to prevent slope movement acceleration.

EmergeX Planning (2005)

EmergX Planning conducted a general hazard 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 Air Photographs

Hard copy air photographs were obtained from the SCRD and UBC's airphoto library and reviewed (Table 2-1).

Table 2-1: Summary of Air Photographs Reviewed

Date	Roll/Photo Number	Scale
1998	30BCB98007 #218-247	~1:10,000
1994	30BCC94145 #1-147	~1:10,000
1990	30BCb90045 #38-40	~1:10,000
1972	BC5492 #217,218	~1:40,000

In general, the relatively small size of the creeks in combination with the forest canopy cover prevented detailed observations of the channels. Thus, airphotos 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;
- general confinement noted for the creeks except in select locations.

2.3 GIS Analysis

GIS data were obtained from the SCRD including:

- Topographic data:
  - 1 m contours and LiDAR (x, y, z) (partial coverage of OCP area, from ocean to above highway);
  - 20 m contours (full coverage of OCP area);
- Creeks and rivers;
- Geology, surficial geology and soils data;
- Administrative data:
  - OCP Boundary (old and revised);
  - Parcels;
  - Existing DPA areas;
- Roads; and
- Orthophotos (2009).

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

Section 3

Hazard Analysis

3. Hazard Analysis

3.1 Background

Topography

The Elphinstone OCP area is generally concave in vertical profile, rising from sea-level (Georgia Strait) to elevations of 1,200 m at the divide (Elphinstone Mountains). Development is typically 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.

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 occur as a result of rain or rain-on-snow runoff events from September through March.

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 Figures 3.3 through 3.6 (Sheets 1 through 4).

3.3 Coastal Zone Hazards

Coastal hazards include flooding from a combination of regular tidal processes (e.g. surge, waves, etc), but also could occur from rare seismically included 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 are indicating 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.

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.

Tidal Condition

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 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

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

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

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 be greater 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), resulting in a 500-year return period value of 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 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 setback a minimum of 15 m 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).

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

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

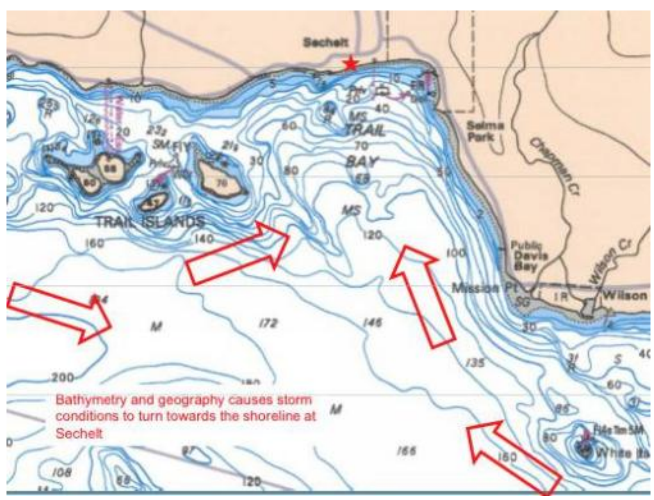
A recent cursory study was conducted for Trail Bay in Sechelt for the purposes of planning a long-term approach for the sea wall and shoreline area.

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 **Error! Reference source not found.**.

Table 3-1: Summary of 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. Typical coastal water level values for the near term quickly reach 5.5 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. This additional metre provides a planning elevation for assessment of 7.15 m CGD or more simply 8 m.

The 8 m CGD planning area, ensures that any sites below this elevation are assessed by a qualified professional to address flood hazards, but does not preclude development.

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 Elphinstone OCP 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 1-2 m.

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 3 times horizontal setback is applied to 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 approach outlined in the provincial guidelines (Ausenco Sandwell, 2011).

In some isolated areas, due to shoreline and slope geometry, this setback may extend beyond the shoreline property. These areas have been shown on the maps for clarity, but these areas are not included in the DPA area at present.

3.4 Creek Hazards

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 5-10 m/s. These events leave sheets of poorly sorted debris ranging from sand to cobbles or small boulders. The peak discharge (flow rate) of debris floods and flows is commonly 2 to 5 times higher than that of 200 year return period water floods (Jakob and Jordan, 2001).

These types of events would be expected to initiate higher in the 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 flood and debris flow 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 Elphinstone watercourses are confined within incised channels and ravines, and potential hazards are restricted to the immediate creek or river corridor. Areas without good confinement are usually 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.

Defining the Dominant Creek Hazard

GIS data were used to assess the creeks draining through the Elphinstone OCP 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.

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

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 Figures 3-1 and 3-2, and summarized in Table 3-2.

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)
Chaster Creek	Debris flood	Debris flood/ Debris flow
Cornwallis Creek	Debris flow	Debris flow
Smales Creek	Debris flood	Debris flow
Walker Creek	Debris flow	Debris flow
Seaward Creek	Flood	N/A[1]
Unnamed Creek #1	Debris flood	N/A[1]
Unnamed Creek #2	Debris flood	N/A[1]
Unnamed Creek #3	Flood	N/A[1]
Unnamed Creek #4	Debris flood	N/A[1]
Unnamed Creek #5	Debris flood	N/A[1]

Notes:
1. Very little or no drainage area upstream of existing development according to mapping.
2. Drainage area within existing development is outside Elphinstone OCP boundaries.

As indicated by the results of the screening summary Chaster, Cornwallis, Smales, and Walker Creeks, including many of their upper tributaries, 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.

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), we have followed RAR definitions, including:

- **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.

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.

Creek-Road Crossings

The majority of the major crossings in the OCP are reported to be Ministry of Transportation and Infrastructure assets, and 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 the current study; 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, the Ministry of Transportation and Infrastructure (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. Figures 3-1 and 3-2), extra allowance should be provided for sediment.

Where debris flows are anticipated (e.g. Figures 3-1 and 3-2), analysis of the debris flow recurrence interval should be conducted, and findings should inform the design, before it is finalized.

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, we have not recommended DPAs based on slope categories alone, without additional consideration of hazard mechanism.

Open Slope Failures and Associated Hazard Area

In the terrain typical of the Elphinstone OCP, open slope landslides are generally shallow slides, in which weaker organic or weathered overburden soils fail over more competent glacially-compressed soils or rock.

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 at higher elevations along the north and east boundary of the Elphinstone OCP. 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 we have applied travel angles to predict areas within the Elphinstone OCP 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) debris flows 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 result was compared to the method proposed by Horel (2007) and found to be conservative.

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 Elphinstone 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.

3.6 Fieldwork

A field visit of the Elphinstone OCP was conducted in late February 2013. The following observations were made:

- A large alluvial fan in the upper Walker Creek watershed was identified during the hazard screening. Upon field inspection, it appears that this fan may no longer be active and Walker Creek has become incised within this fan. However, a more detailed investigation is needed to confirm this finding. Thus, this fan feature will remain delineated as an area of low channel confinement. Photo 3.1 shows an exposed section of this alluvial fan.
- It was also observed that upper Walker Creek has been diverted and does not flow beneath Reed Road. It encounters Reed Road and abruptly flows east into the most western branch of Chaster Creek, near Jensen Road. The diverted Walker Creek enters Chaster Creek immediately upstream of the Reed Road crossing. This stream crossing appears to be an old wooden bridge that is partially clogged with sediment (Photo 3.2).
- The Chaster Creek culvert at Russell Road is damaged and partially filled with sediment (Photo 3.3).
- The low channel confinement area at Chaster Creek (along Russell Road) identified in the hazard screen could not be confirmed with certainty in the field due to limited access because of the private properties in the area.
- The lower section of Chaster Creek contains a small floodplain along the west bank both upstream and downstream of the stream crossing at Ocean Beach Esplanade (Photo 3.4).

- It appears that a high tidal event that coincides with a high flow event in Chaster Creek could cause backwater flooding along Ocean Beach Esplanade at the Chaster Creek bridge.
- Erosion, by way of, wave attack, is active along Ocean Beach Esplanade (Photo 3.5). Riprap protection has been placed along the road embankment, however, it appears to be in need of repair as waves have undermined the protection (Photo 3.6)
- The culvert along Cornwallis Creek beneath West Reed Road is clear of debris and sediment but has sagged slightly and may need replacement in the near future. There appears to a collapsed wooden bridge beneath gravel backfill approximately 50 m upstream of the stream crossing at West Reed Road (Photo 3.7).
- The Cornwallis Creek culvert beneath Highway 101 is partially blocked by debris on the upstream side (Photo 3.8). There are also numerous withdrawal pipes and holding tanks (assumed to be unpermitted) along Cornwallis Creek between West Reed Road and downstream of Highway 101 (Photo 3.9).
- Smales Creek appears to have been diverted at Highway 101 where it flows west along the highway (Photo 3.10) and into Unnamed Creek #1 upstream of the Seaview Cemetery.
- A potential open slope and rock fall hazard was investigate along Glower Point Road at the southeast boundary of the Elphinstone OCP. Several, small rock slide deposits were observed, particularly along the east facing slope (Photo 3.11). The steepness of the area and the presence of open rock faces suggest further rockfall and small rockslide activity could occur in the future.

Photo 3.1: Exposed section of the Walker Creek relict alluvial fan.

Photo 3.2: Reed Road stream crossing at west Chaster tributary appears to be an old wooden bridge that is partially clogged with sediment.

Photo 3.3: Damaged culvert along Chaster Creek at Russell Road.

Photo 3.4: Small floodplain is present along the east bank of lower Chaster Creek upstream of Ocean Beach Esplanade.

Photo 3.5: Active erosion along Ocean Beach Esplanade embankment.

Photo 3.6: Riprap boulder protection along Ocean Beach Esplanade that is starting to become undermined.

Photo 3.7: Partially collapsed crossing upstream of West Reed Road along Cornwallis Creek.

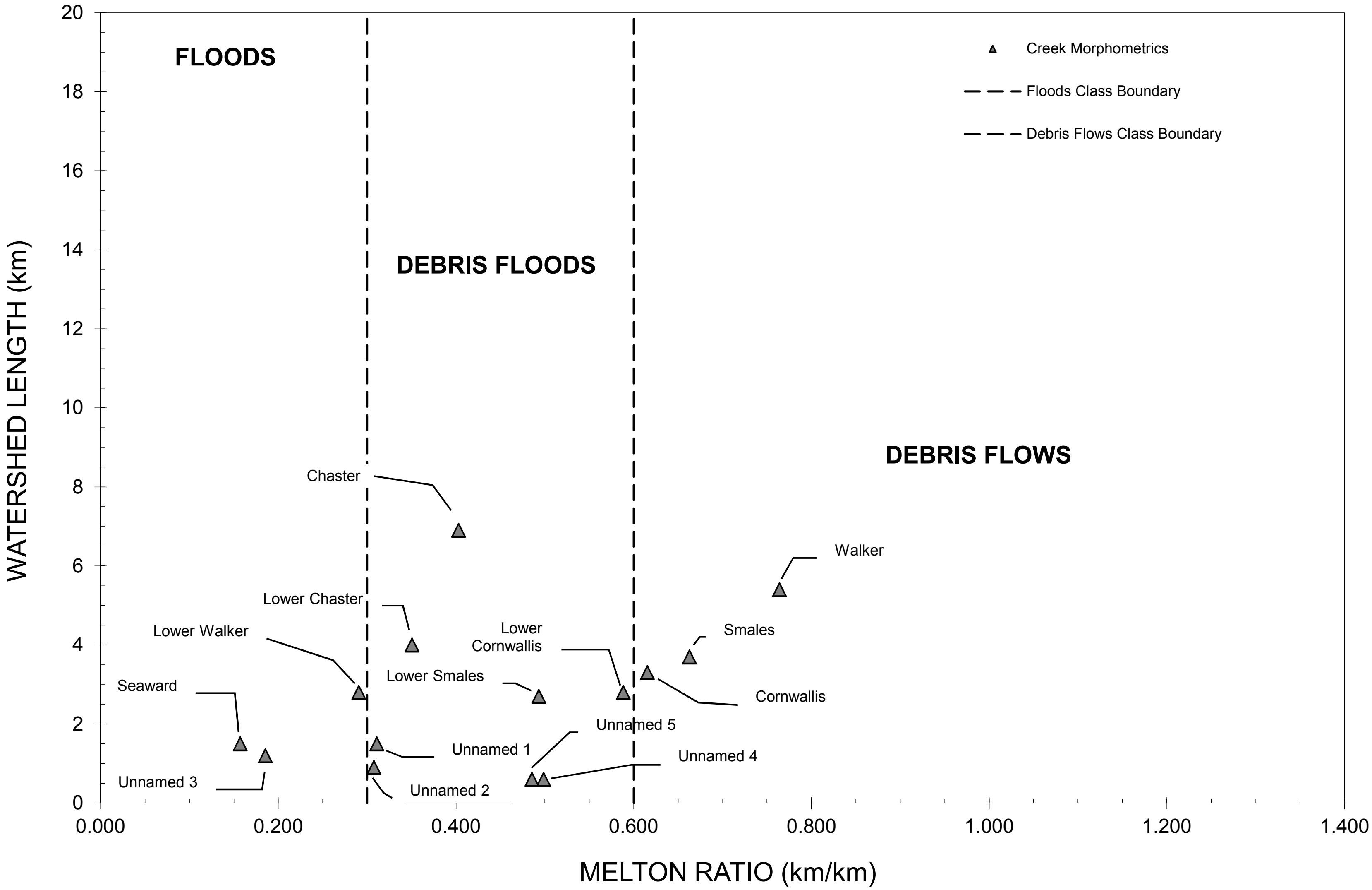
Photo 3.8: Culvert at Highway 101 along Cornwallis Creek is partially blocked by debris.

Photo 3.9: Many water withdrawal structures were noted on Cornwallis Creek both upstream and downstream of Highway 101.

Photo 3.10: Smales Creek appears to have been diverted along Highway 101 and into Unnamed Creek #1.

Photo 3.11: One example of several, small rock slide deposits observed along the east facing slope near Gower Point Road.

Screening for Hydrogeomorphic Processes (after Millard et al., 2006): Outlet at Ocean (Elphinestone)



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Consulting Engineers

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Figure 3-1

Screening for Hydrogeomorphic Processes (after Millard et al., 2006): Outlet At Tributary Junctions or At Upper Limit of Existing Development (Elphinstone)

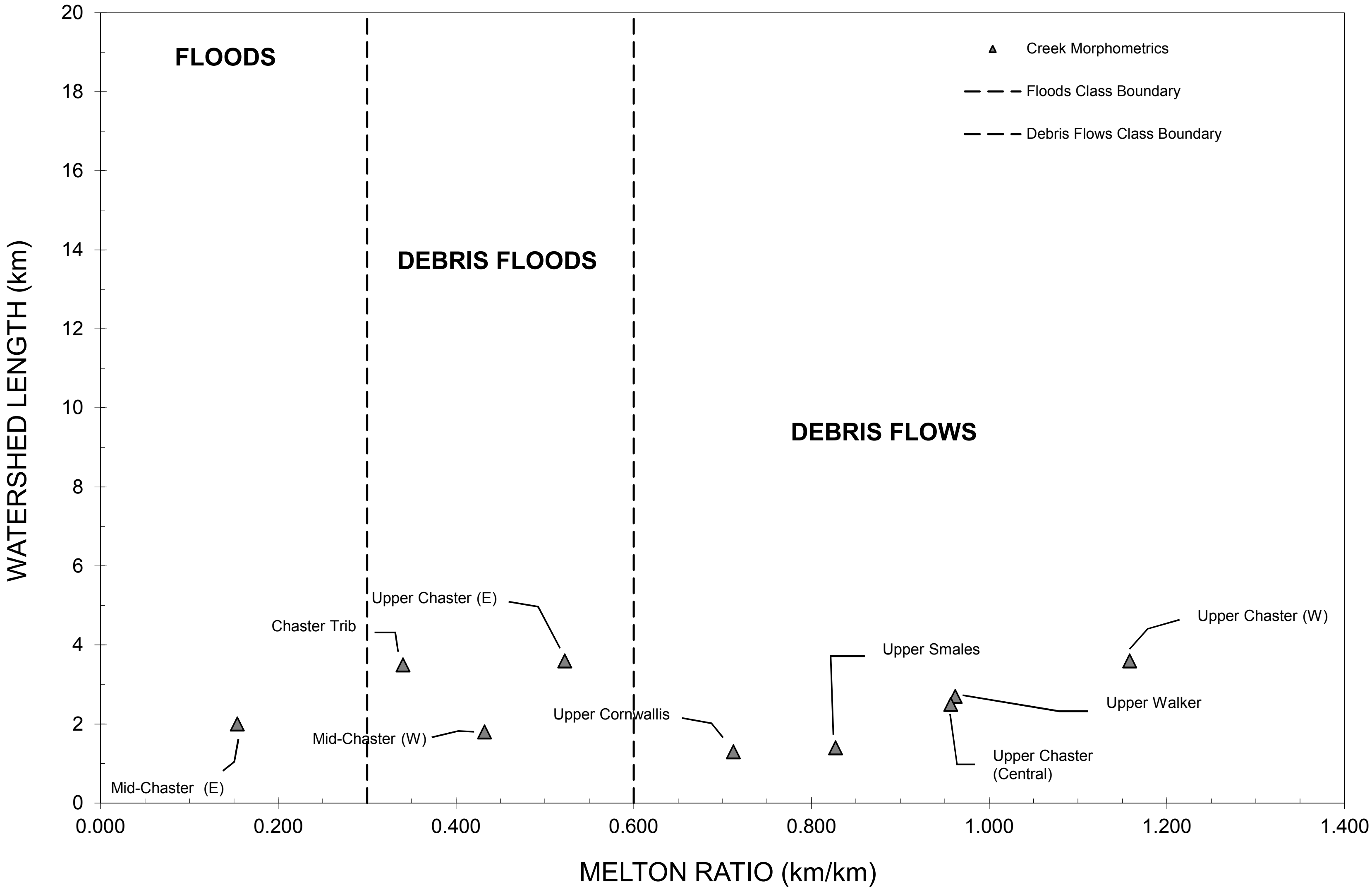

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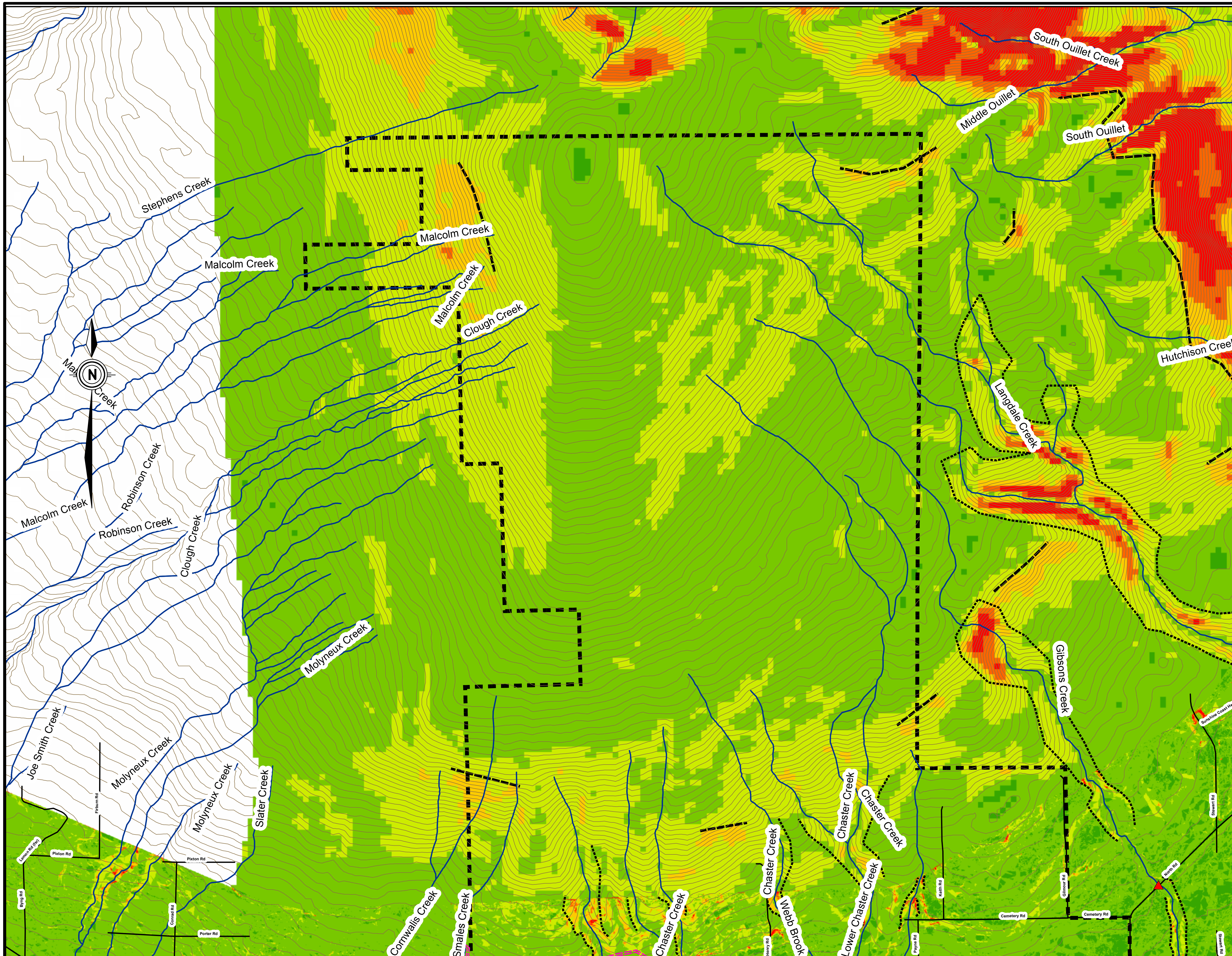
Figure 3-2

Geotechnical Hazards Report:
Elphinstone
Sunshine Coast Regional District



Legend

- Ravine Crest
- Creek-Road Crossings
- Roads
- Creeks/Rivers
- 10 m Contours
- Oceanfront Slope Crest
- Open Slope Failure Initiation Line
- Low Channel Confinement (Fan)
- Elphinstone OCP Boundary
- 0 - 5
- 5 - 30
- 30 - 50
- 50 - 60
- 60 - 70
- >70

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consulting engineers

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Project No.	Date
724-024	May 2013

Elphinstone Hazards Screen (Sheet 1)

Figure 3-3

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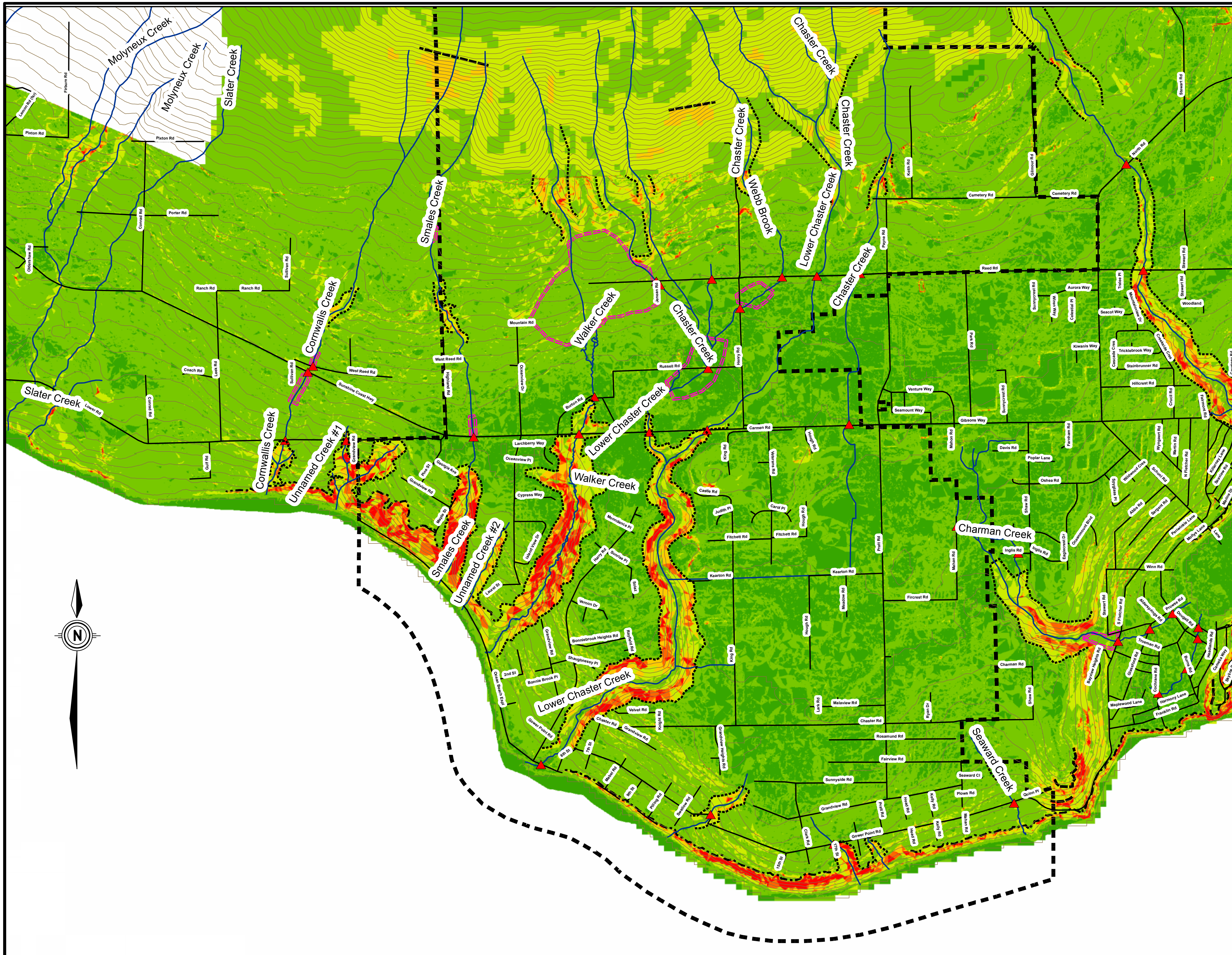
Author: CDavey



Geotechnical Hazards Report:
Elphinstone
Sunshine Coast Regional District

Legend

- Ravine Crest
- Creek-Road Crossings
- Roads
- Creeks/Rivers
- 10 m Contours
- Oceanfront Slope Crest
- Open Slope Failure Initiation Line
- Low Channel Confinement (Fan)
- Elphinstone OCP Boundary
- 0 - 5
- 5 - 30
- 30 - 50
- 50 - 60
- 60 - 70
- >70

KERR WOOD LEIDAL
consulting engineers

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Project No.	Date
724-024	May 2013

Elphinstone Hazards Screen (Sheet 2)

Figure 3-4

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Author: CDavey

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consulting engineers

Section 4

Proposed DPA Framework

4. Proposed DPA Framework

4.1 Overview

The following sections outline the proposed development permit area (DPA) framework for hazardous areas in the Elphinstone 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.

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.

Uncertainty

The goal of the DPA boundary delineation is to apply a uniform screening criterion 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 site specific surveys may be used 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.

DPA 1A: Coastal Flooding

The DPA extends from the coastal DPA boundary to 8 m CGD[4]. Within the DPA, development applications would require a coastal flood hazard assessment to define the coastal flood components, namely wave runup, wave setup, and possibly wind setup by a qualified professional, or siting development above 8 m CGD.

DPA 1B: Coastal Slopes

The recently released Guidelines report addresses 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 3 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.

One area of Elphinstone, along the western edge of Ocean Beach Esplanade, includes large a DPA for coastal slope erosion. This is due to the steep existing slope geometry and distance required for the 3(H):1(V) to daylight to the bench above. This DPA encompasses a large number of small lots; however, very few roads have been developed to access the mid-slope lots. Development of this area will likely be technically challenging and any engineering investigations should be carefully considered.

Within the DPA, landslide risk assessment will be required to determine building setbacks and foundation design.

---

[4] Elevation referenced to Canadian Geodetic Vertical Datum.

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).

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.

Riparian, flood, debris flood and debris flow hazard assessments will be required within DPA 2A.

DPA 2B: Ravines

Ravine areas were defined using the crest lines mapped in the GIS. Based on consideration of stable angles of repose and the typical terrain seen in the Elphinstone OCP area, the following approach has been adopted:

- A 30 m setback from ravine crests defines the area that falls within DPA 2B. A 15 m setback line is also indicated.
- A minimum 15 m setback from ravine crest is required for all development.
- For ravines that are deeper than 15 m, the setback from ravine crest will be 30 m. An engineering report from an appropriately qualified professional will 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 they fall into.

DPA 2B will require a landslide assessment for ravine sidewalls.

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, which is not captured in DPA 2A.

Flood and erosion hazard assessment will be required within DPA 2C.

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 air photographs and contour mapping have been used to identify potential areas of low channel confinement, which are included in DPA 2D.

Flood and erosion, and channel avulsion hazard assessment will be required within DPA 2D.

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 shall meet general MOTI criteria outlined in Section 3.

Any culverts on major road crossing have been identified on the mapping, a requirement to review those crossings for development permit applications in close proximity (e.g. 300 m) and should be implemented as a Development Approval Information Area - General Condition in the OCP.

4.4 DPA 3: Slope Hazards

Three sub-categories of slope hazards are identified that are applicable to the Elphinstone OCP area: open slope failures, rockfall hazards and seisimic-initated slope hazards. Open slope failures and rock fall hazard sub-categories are delineated under 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.

Open Slope Failures

Potential for open slope failures in the Elphinstone OCP were identified where there are areas of moderately steep and steep terrain. Potential landslide impact areas were only 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). Open slope crests where initiation of a landslide may occur (bluffs higher than 10 m) are delineated in the DPA maps.

Landslide risk assessments will be required within DPA 3.

Rockfall

Within the 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 present a low hazard and have not been specifically mapped.

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

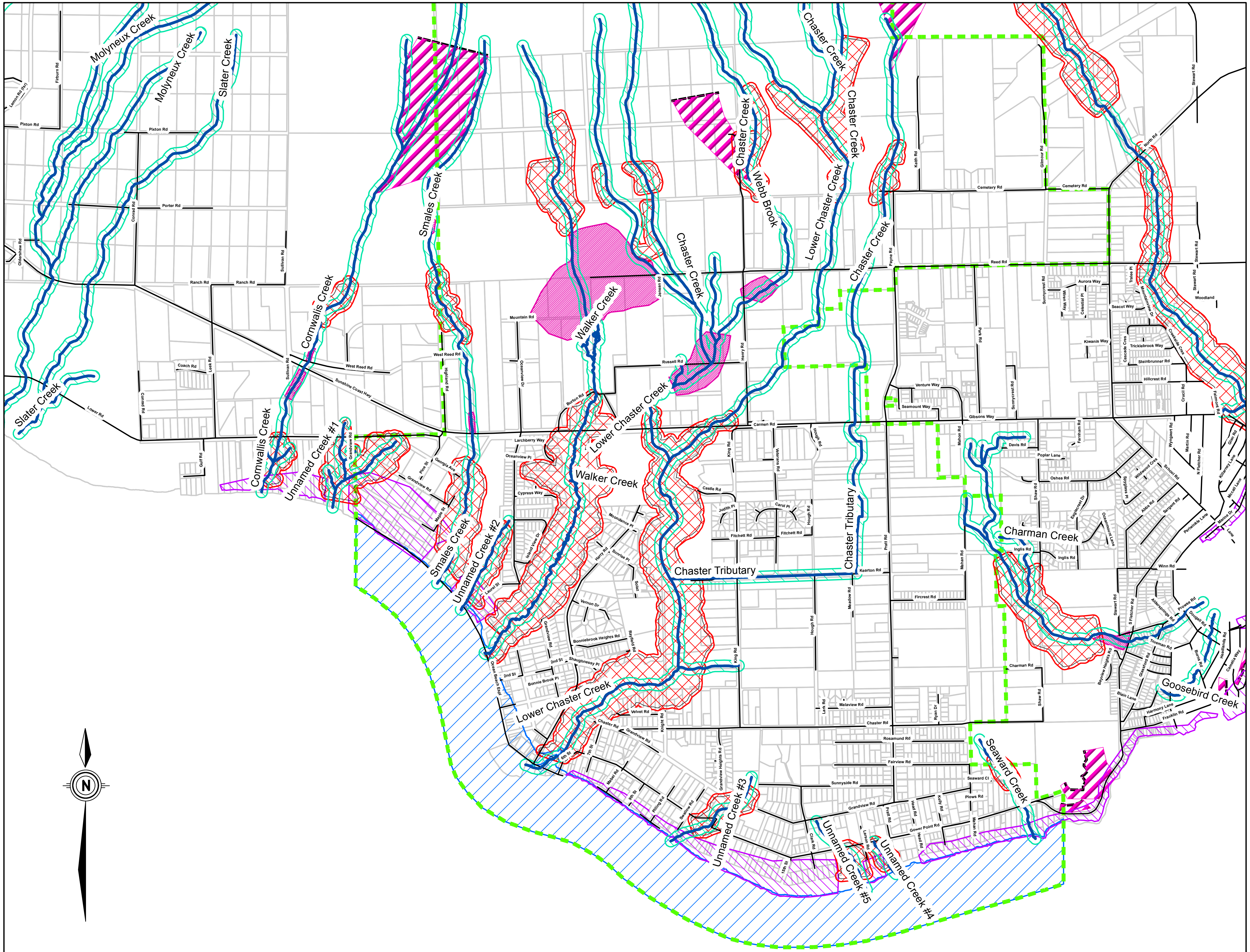
Seismic-Initiated Slope Hazards

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

No map-based screening tool is currently available to identify seismic slope hazard areas and therefore is not a Development Permit area, and should be implemented as a Development Approval Information Area - General Condition in the OCP.

4.5 Proposed Revised DPAs for Elphinstone OCP

Proposed revised DPA zones are presented in Figures 4-1 and 4-2.



Geotechnical Hazards Report:
Elphinstone
Sunshine Coast Regional District

Legend

- DPA Zone 1A: Coastal Flooding
- DPA Zone 1B: Coastal Slopes
- DPA Zone 2A: Creek/River Corridor
- DPA Zone 2B: Ravines (30m)
- DPA Zone 2B: Ravines (15m)
- DPA Zone 2C: Floodplain
- DPA Zone 2D: Low Channel Confinement (Fan)
- DPA Zone 3: Slope Hazards
- Creeks/Rivers
- Roads
- Elphinstone OCP Boundary
- Elphinestone Parcels

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Project No.	Date
724-024	May 2013

Elphinstone Proposed DPAs (Sheet 2)

Figure 4-2

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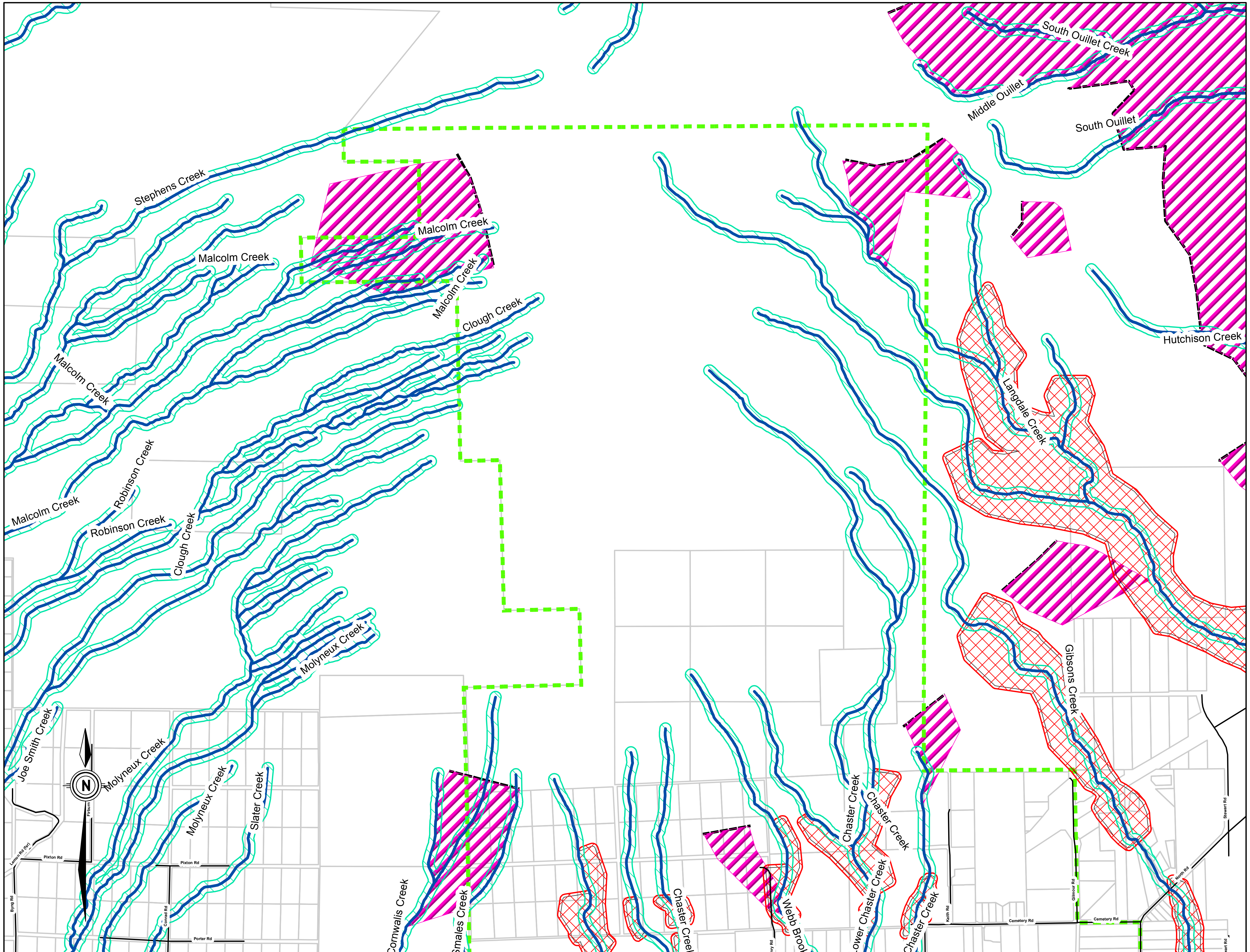
Author: CDavey

Geotechnical Hazards Report:
Elphinstone
Sunshine Coast Regional District



Legend

- DPA Zone 1A: Coastal Flooding
- DPA Zone 1B: Coastal Slopes
- DPA Zone 2A: Creek/River Corridor
- DPA Zone 2B: Ravines (30m)
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Project No.	Date
724-024	May 2013

Elphinstone Proposed DPAs (Sheet 1)

Figure 4-1

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Author: CDavey

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Section 5

Guidelines for Development

5. Guidelines for Development

5.1 DPA 1: Ocean Hazards

A Development Permit on lands identified as being within DPA 1 is required 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.

Different hazards have been identified within the general category of "ocean hazards": applications for subdivision, building permit or land alteration shall include a report from an appropriately qualified Professional Engineer or Professional Geoscientist that considers all relevant potential ocean hazards.

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.

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.		

A regional study may be appropriate for the Sunshine Coast to 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.

DPA 1B – Coastal Slopes Guidelines

If applicable, the report shall include the following:

- Surveyed slope profiles with documentation of the limits of slope instability. Consideration shall 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 shall also 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

A Development Permit on lands identified as being within DPA 2 is required 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 2A/C/D – Creek Corridor / Floodplain / Low Channel Confinement Guidelines

- A review of the property by an appropriately qualified Professional Engineer or Professional Geoscientist shall be required as part of a development permit review process. The report shall include an 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.
- Flooding and associated creek processes are subject to assessment 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 shall consider upstream channels and floodways, debris dams, culverts, sources of debris (channels and eroded banks) and related hydrologic features.

- Analysis shall 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.

DPA 2B – Ravines Guidelines

- 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.
- Development within ravine slope setbacks will be subject to the reporting requirements for DPA 3.
- A field definition of the required setback from the top of a ravine or other steep slope.
- The report shall 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.

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

- Where identified as a possible mechanism (Table 3-2), potential debris flow and debris flood creeks shall be assessed by an appropriately qualified professional. 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) around debris flow or debris flood creeks shall 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).

5.3 DPA 3: Slope Hazards

A Development Permit on lands identified as being within DPA 3 is required 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.

Both open slope failures and rockfall hazards fall within this DPA. Applications for subdivision, building permit or land alteration shall 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 shall include the following:

- Slope profiles with documentation of the limits of slope instability shall be provided. Consideration shall 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 shall also 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 rock fall shadow area, including an indication of the appropriate buffer zone and required protective works.

5.4 Exemptions

The following general exemptions may be granted 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.
- 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 2 trees over 20 centimetre diameter breast height or 10 square metres of vegetated area of per calendar year per lot, provided there is replanting of 4 trees or re-vegetation of the same amount of clearing.

5.5 Report Submission

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KERR WOOD LEIDAL ASSOCIATES LTD.

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Fluvial Geomorphologist

Reviewed by:

David Matsubara, M.Eng., P.Eng.
Senior Technical Review

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Geotechnical Hazards Report: Roberts Creek

Final Report
May 2013
KWL Project No. 724.022-300

Prepared for:

Sunshine Coast Regional District

Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of the Sunshine Coast Regional District for the Geotechnical Hazards Report: Roberts Creek. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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Revision History

Revision #	Date	Status	Revision	Author
0	Apr. 14, 2011	Draft	Draft (submitted to SCRD).	EE/DTM
1	August 2012	For Review	Final	EE/DTM
2	May 2013	Final	Final	EE/DTM

Contents

Figures

Tables

Section 1

Introduction

1. Introduction

1.1 Background

The OCP area of Roberts Creek is located on the Sunshine Coast, between the towns of Gibsons and Sechelt. The towns are linked by the Sunshine Coast Highway (Highway 101), which provides access to the urbanized strip between the towns that comprises the Roberts Creek community. The OCP area is bounded by the Strait of Georgia to the south and mountainous terrain to the north (Mount Elphinstone).

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 to the east are sources of potential landslide activity that may affect lower slopes;
- Creeks support 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 hazard.

The Roberts Creek OCP area has more than doubled since the last OCP revision in 1992. The new Roberts Creek OCP boundary incorporates more mountainous terrain north of existing development in and around Highway 101. This report revises and updates the OCP in light of boundary changes, the availability of new technologies for mapping terrain and storing information; improved information about geologic hazards; and new professional guidelines concerning residential development and landslide risk.

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 Roberts Creek, based on the RFP closed in November, 2010.

The work scope was to assess and recommend revisions to the existing Development Permit Area (DPA) included in the Official Community Plan area of Roberts Creek. 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, BC Building Code, the Riparian Areas Regulation, and the SCRD Risk Assessment and Liability Policy); and

- Propose DPA areas 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:

- David Matsubara, M.Eng., P.Eng., KWL (Project Manager);
- Mike Currie, M.Eng., P.Eng., KWL (Senior Technical Review);
- Erica Ellis, M.Sc., P.Geo., KWL (Fluvial Geomorphologist); and
- Pierre Friele, M.Sc., P.Geo., PG (WA), Cordilleran Geoscience (Senior Geoscientist).

At SCRD, David Rafael served as the key project liaison, with input from Mark McMullen, Andrew Allen and Steven Olmstead at review meetings. Trevor Fawcett provided GIS information.

Section 2

Data Sources

2. Data Sources

2.1 Background Reports

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

- "Reconnaissance Study of Geotechnical Hazards Roberts Creek Official Community Plan" (Thurber, 1992);
- Integrated Stormwater Management Planning reports (Delcan, 2008 and 2009);
- "Clough Creek Project" (Ministry of Environment, 1984);
- Roberts Creek Official Community Plan (SCRD, 1994); and
- Multiple engineering reports for DPA permit applications in Roberts Creek.

Brief summaries of selected reports are provided below:

Ministry of Environment (1984)

This report characterized a debris flow event that occurred in November 1983 on Clough Creek, as well as the creek restoration work that was carried out following the event. The debris flow event was likely triggered by intense precipitation, in combination with land disturbance arising from forestry activities. About 4,500 m3 of material was estimated to have been deposited during the event, including logs, mud and gravel. The event was considered to be unusual in that it had a low gradient in both the initiation and transport zone, as well as a relatively long distance of travel. It was noted that the material transported was finer than typically expected.

Thurber (1992)

This report summarized a reconnaissance geotechnical hazard evaluation for the Roberts Creek OCP. Part of the work involved locating and correctly identifying the existing drainage network in the OCP. A number of bylaws were recommended including a shoreline setback, a tree-cutting bylaw along watercourses and a prohibition of soil removal and waste dumping. Thirteen DPAs were recommended, corresponding to identified hazard zones either along the shoreline or along various watercourses and ravines.

Delcan (2006 and 2009)

Delcan conducted an Integrated Stormwater Management assessment for East Roberts Creek, which covered the area from approximately Stephens Creek eastward. Existing drainage issues were noted and mitigation measures developed to address selected higher priority sites. As part of the project, Intensity-Duration-Frequency rainfall curves were developed for the Roberts Creek area, and were used to estimate return period peak flows for catchments in East Roberts Creek using the Rational Method. Increases in peak flows were also estimated for future development conditions.

2.2 Air Photographs

Hard copy air photographs were obtained from the SCRD and reviewed (**Error! Not a valid bookmark self-reference.**). Although 1990 air photographs were also available, on the basis of the review of the

1998 photo review it was judged that there would be little additional value in a detailed review of the 1990 photos.

Table 2-1: Summary of Air Photographs Reviewed

Date	Roll/Photo Number	Scale
1998	30BCB98008 #207-211/223-229/239-247	1:15,000
1998	30BCB98007 #221-227/241-247	1:15,000

In general, the relatively small size of the creeks in combination with the forest canopy cover prevented detailed observations of the channels. The following observations were made from the 1998 photos:

- Evidence of a recent landslide on an oceanfront slope;
- Steep terrain indicating a potential start zone for slope failures;
- A forestry cut-block with multiple road-related landslide scars; and
- General confinement noted for the creeks except in select locations.

2.3 GIS Analysis

GIS data were obtained from the SCRD including:

- Topographic data:
  - 1 m contours and LiDAR (x, y, z) (partial coverage of OCP area, from ocean to above highway);
  - 20 m contours (full coverage of OCP area);
- Creeks and rivers;
- Geology, surficial geology and soils data;
- Administrative data:
  - OCP Boundary (old and revised);
  - Parcels;
  - Existing DPA areas;
- Roads; and
- Orthophotos (2009).

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

GIS analysis was used to screen for possible geohazards, and one day of fieldwork was carried out to “ground-truth” the results of the desktop hazard screen. The desktop hazard screen and fieldwork are described below.

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Section 3

Hazard Analysis

3. Hazard Analysis

3.1 Background

Topography

The Roberts Creek OCP area is generally concave in vertical profile, rising from sea-level to elevations of 1,100 m along the divide between Georgia Strait and Howe Sound. Development is typically on gently sloping terrain (less than 30% slopes). Steeper slopes occur in small, scattered areas in the following locations:

- associated with local rock outcrops;
- along the mountain front at the eastern boundary of the OCP;
- along creek ravines; and
- along the coastal bluffs.

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 occur as a result of rain or rain-on-snow runoff events from September through March.

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 Figures 3.3 through 3.7 (Sheets 1 through 5).

3.3 Coastal Zone Hazards

Coastal hazards include flooding from a combination of regular tidal processes (e.g. surge, waves, etc), but also could occur from rare seismically included 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 are indicating 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.

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.

Tidal Condition

Tidal fluctuations occur daily, and the magnitude of high tides varies 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

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 be greater 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), resulting in a 500-year return period value of 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 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 setback a minimum of 15 m 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).

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

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.

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 0.6 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

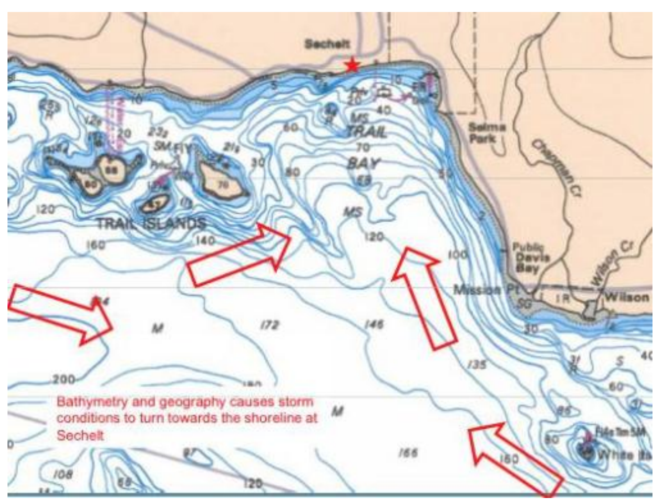
A recent cursory study was conducted for Trail Bay in Sechelt for the purposes of planning a long-term approach for the sea wall and shoreline area.

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 **Error! Reference source not found.**.

Table 3-1: Summary of 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

[2] Elevation referenced to Canadian Geodetic Vertical Datum.

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. 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. This additional metre provides a planning elevation for assessment of 7.15 m CGD or more simply 8 m.

The 8 m CGD planning area ensures that any sites below this elevation are assessed by a qualified professional to address flood hazards, but does not preclude development.

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 Roberts Creek OCP 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 1-2 m.

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 3 times horizontal setback is applied to 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 approach outlined in the provincial guidelines (Ausenco Sandwell, 2011).

In some isolated areas, due to shoreline and slope geometry, this setback may extend beyond the shoreline property. These areas have been shown on the maps for clarity, but these areas are not included in the DPA area at present.

3.4 Creek Hazards

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 5-10 m/s. These events leave sheets of poorly sorted debris ranging from sand to cobbles or small boulders. The peak discharge (flow rate) of debris floods and flows is commonly 2 to 5 times higher than that of 200 year return period water floods (Jakob and Jordan, 2001).

These types of events would be expected to initiate higher in the 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 flood and debris flow 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 Roberts Creek watercourses are confined within incised channels and ravines, and potential hazards are restricted to the immediate creek or river corridor. Areas without good confinement are usually 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.

Defining the Dominant Creek Hazard

GIS data were used to assess the creeks draining through the Roberts Creek OCP 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

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

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 Figures 3-1 and 3-2, and summarized in Table 3-2.

The 1983 Clough Creek debris flow travelled 5.9 km, with the bulk of the debris depositing just upstream of Highway 101. It passed into the developed area, but did not reach the ocean.

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

Creek Name (from West to East)	Process Category (Tributary Junction or at Upper Limit of Existing Development)	Process Category (Ocean Outlet)
Irgens Creek	Debris Flood	Debris Flood
Chapman Creek	Debris Flood [1]	Debris Flood [1]
Wilson Creek	Flood: Wilson NW Flood / Debris Flood: Wilson SE (near class boundary) Debris Flood: Wilson Mid	Flood
Moscrop Creek	N/A[2]	Flood
Flume Creek	Flood: Flume (W) Debris Flood: Flume (E)	Flood
Roberts Creek	Debris Flood: Roberts Mid SE Debris Flow: Roberts SE	Flood
Stephens Creek	Debris Flood/Flow (near class boundary)	Debris Flow
Malcolm Creek	Debris Flood	Debris Flood
Robinson Creek	Debris Flood	Debris Flood
Clough Creek	Debris Flow	Debris Flow
Unknown Creek #3	N/A[2]	Flood
Joe Smith Creek	Debris Flow	Debris Flow
Molyneux Creek	Debris Flood: Molyneux (SE) Debris Flow: Molyneux Mid & NW	Debris Flood
Slater Creek	Debris Flood	Debris Flood
Cornwallis Creek	Debris Flood	Debris Flow
Unknown Creek #1	N/A[2]	Flood
Smales Creek	Debris Flood/Flow (near class boundary)	Debris Flood/Flow (near class boundary)

Notes:
1. Based on recent KWL flood hazard assessment of Chapman Creek (KWL, 2010).
2. Very little or no drainage area upstream of existing development according to mapping.

As indicated by the results of the screening summary, many of the creeks draining through the Roberts Creek OCP may be subject to debris floods or possibly 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 may provide a basis for future detailed investigation.

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), we have followed RAR definitions, including:

- **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.

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.

Creek-Road Crossings

The majority of the major crossings in the OCP are reported to be Ministry of Transportation and Infrastructure assets, and 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 the current study; 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, the Ministry of Transportation and Infrastructure (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. Figures 3-1 and 3-2), extra allowance should be provided for sediment.

Where debris flows are anticipated (e.g. Figures 3-1 and 3-2), analysis of the debris flow recurrence interval should be conducted, and findings should inform the design, before it is finalized.

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, we have not recommended DPAs based on slope categories alone, without additional consideration of hazard mechanism.

Open Slope Failures and Associated Hazard Area

In the terrain typical of the Roberts Creek OCP, open slope landslides are generally shallow slides, in which weaker organic or weathered overburden soils fail over more competent glacially-compressed soils or rock.

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 at higher elevations along the east boundary of the Roberts Creek OCP and along the high valley sides bounding Chapman Creek. These areas are identified as potential landslide initiation areas. Logging on these slopes was identified as contributing to the landslide that affected Clough Creek in 1983. Several small open slope landslide scars were identified on these slopes on the 1998 air photographs.

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 we have applied travel angles to predict areas within the Roberts Creek OCP 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) debris flows 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 result was compared to the method proposed by Horel (2007) and found to be conservative.

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.

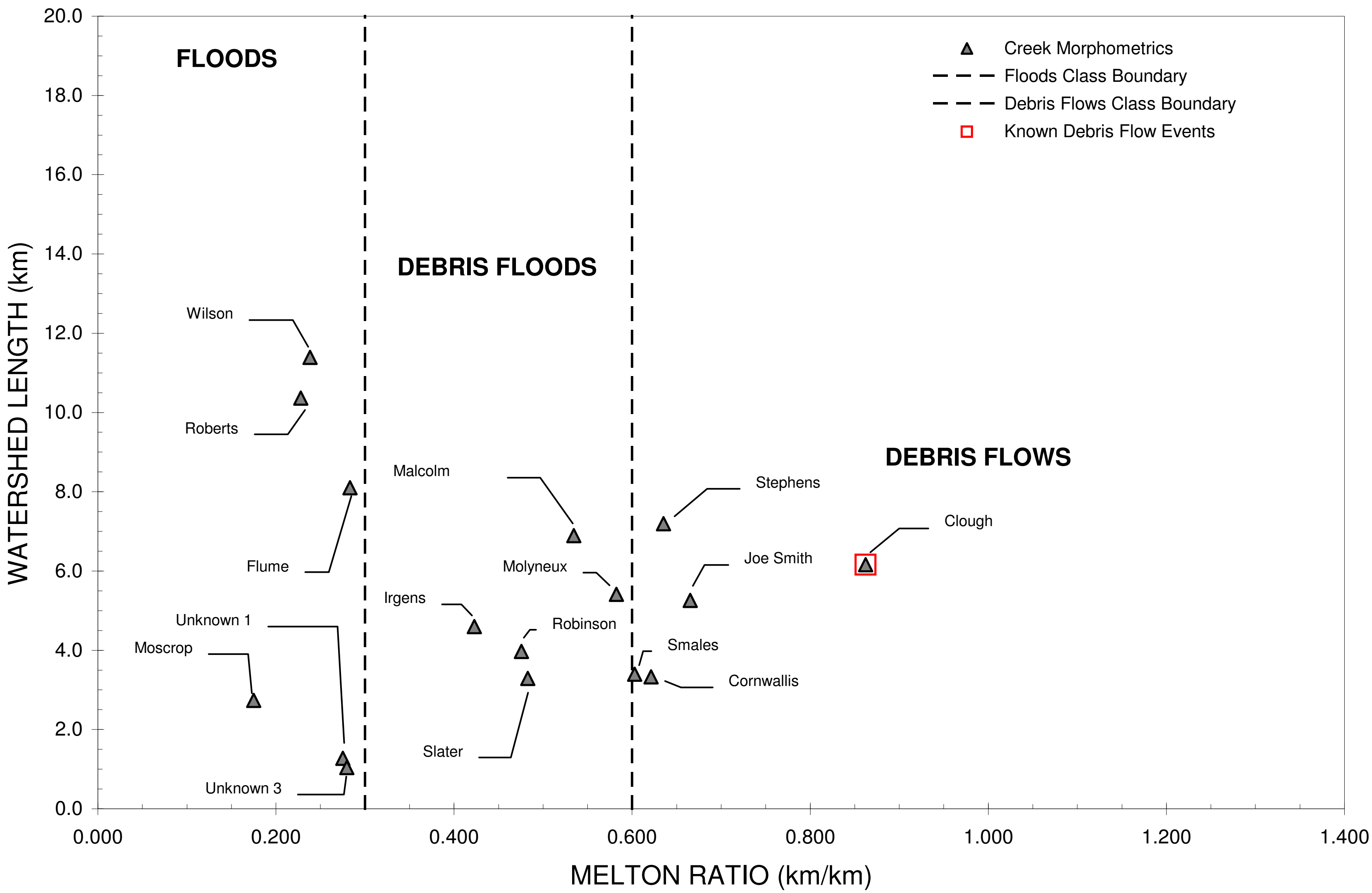
A suitable hazard screen would consist of a seismic slope hazard map. A seismic slope hazard map has been created for Greater Victoria (McQuarrie and Bean, 2000), and is being developed by the National Research Council of Canada (NRCAN) for the District of North Vancouver.

In the interim until such a screening map is produced for the Roberts Creek 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.

3.6 Fieldwork

Fieldwork was carried out on March 9, 2011, to perform limited ground-truthing of the hazards identified in the desktop assessment. Initial fieldwork found the LiDAR mapping to have been a very good tool at identifying steep terrain features, even at small scales. Alluvial fans and areas of low confinement were not as easy to identify based on the mapping data, and ground-truthing found that these features are very low gradient, and development has often obscured topography. Field investigations also found that the shoreline materials varied greatly, and that addressing bedrock shorelines versus soil shorelines with separate DPA measures would not be practical.

Screening for Hydrogeomorphic Processes (after Millard et al., 2006): Outlet at Ocean



KERR WOOD LEIDAL ASSOCIATES LTD.

Consulting Engineers

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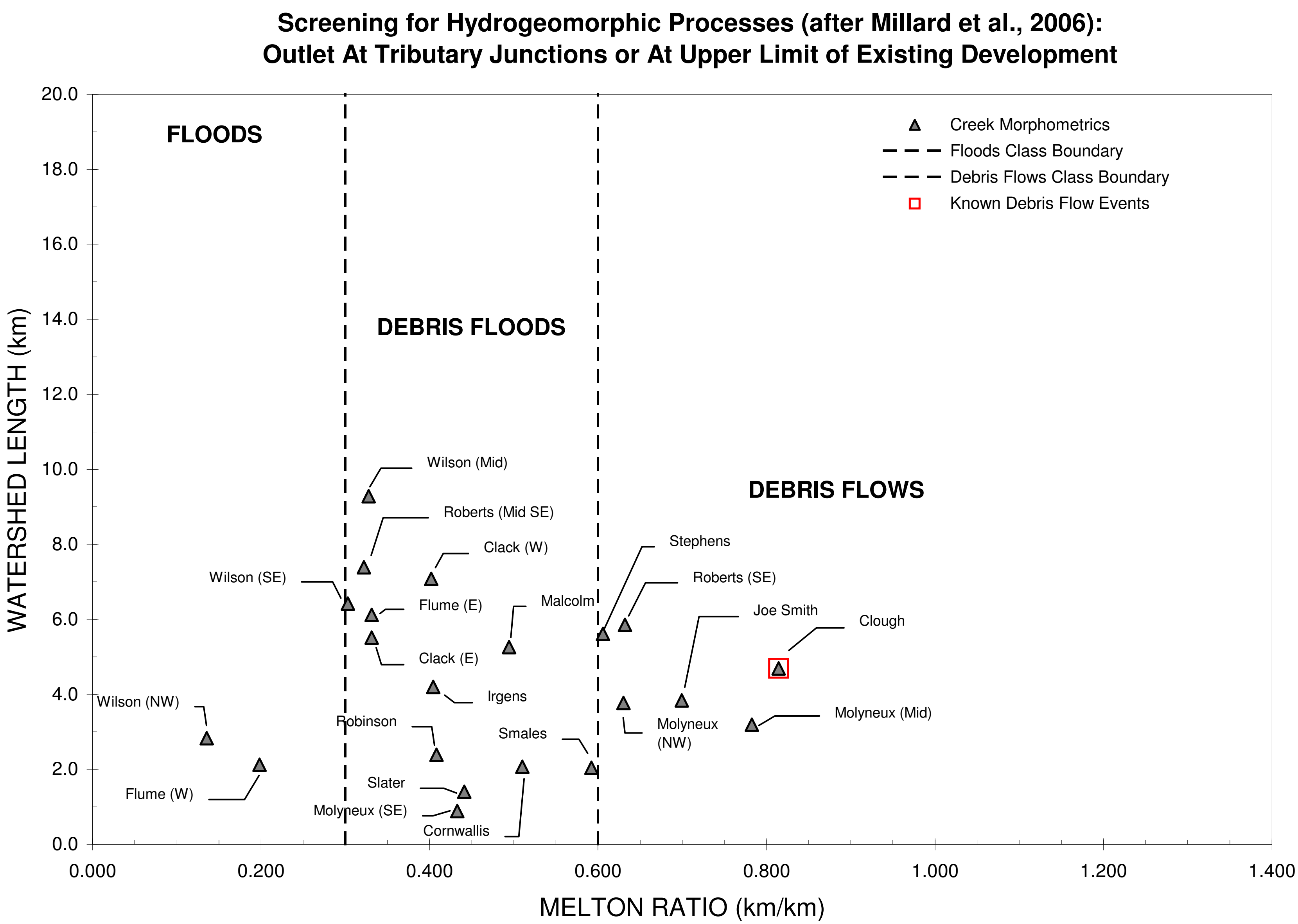
Figure 3-1



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Consulting Engineers

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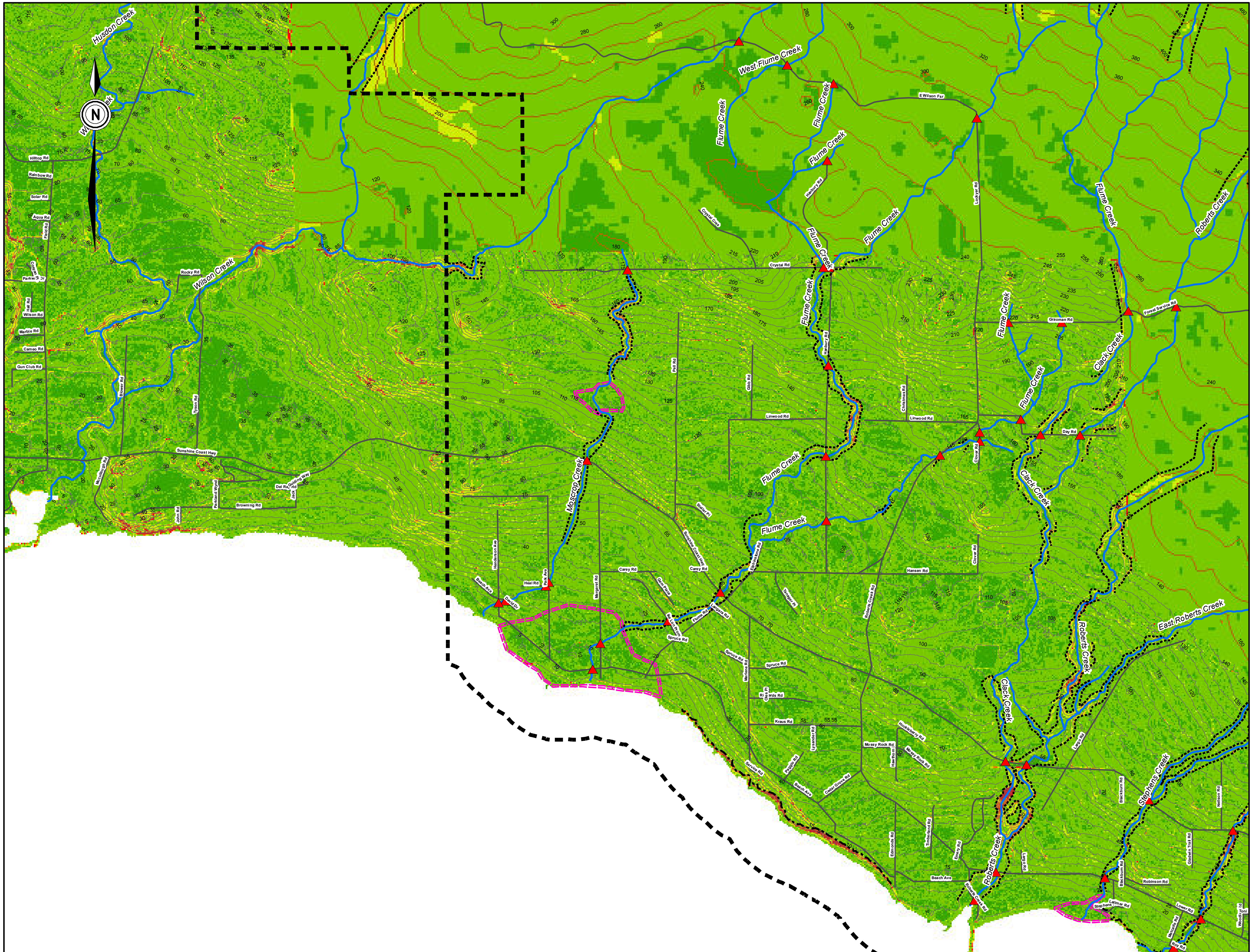
Figure 3-2



Geotechnical Hazards Report:
Roberts Creek
Sunshine Coast Regional District

Legend

- OCP Boundary
- Creek-Road Crossings
- Ravine Crest
- Oceanfront Slope Crest
- Open Slope Failure Initiation Line
- Creeks / Rivers
- Low Channel Confinement (Fan)
- 5 m Contours
- 20 m Contours

Terrain Slope (%)

- 0 - 5
- 5 - 30
- 30 - 50
- 50 - 60
- 60 - 70
- >70

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Project No.	Date
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Roberts Creek Hazard Screen (Sheet 1)

Figure 3-3

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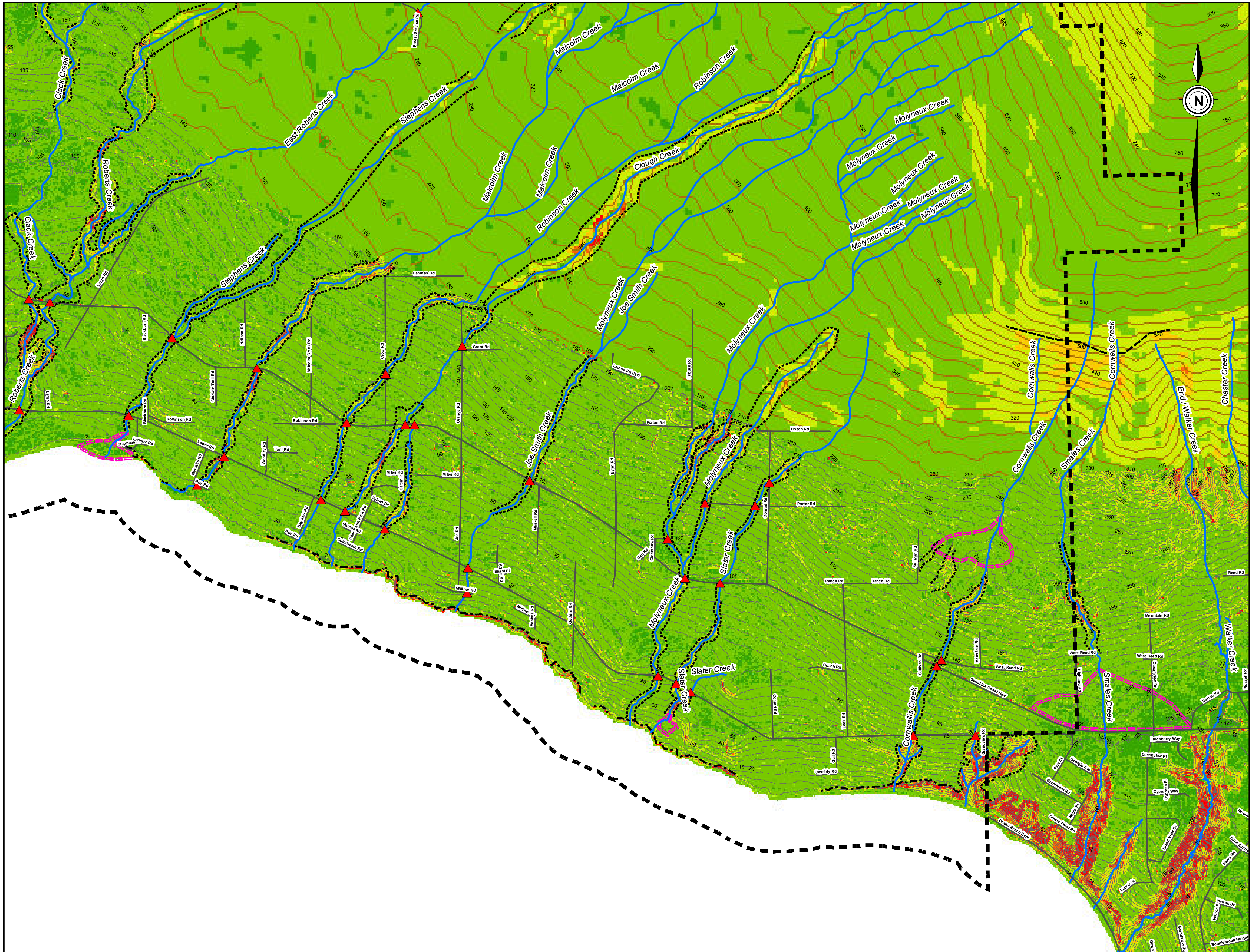

**Geotechnical Hazards Report:
Roberts Creek
Sunshine Coast Regional District**

Legend

- OCP Boundary
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Terrain Slope (%)

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- 5 - 30
- 30 - 50
- 50 - 60
- 60 - 70
- >70

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Project No.	Date
724-022	May 2012

Roberts Creek
Hazard Screen (Sheet 2)

Figure 3-4

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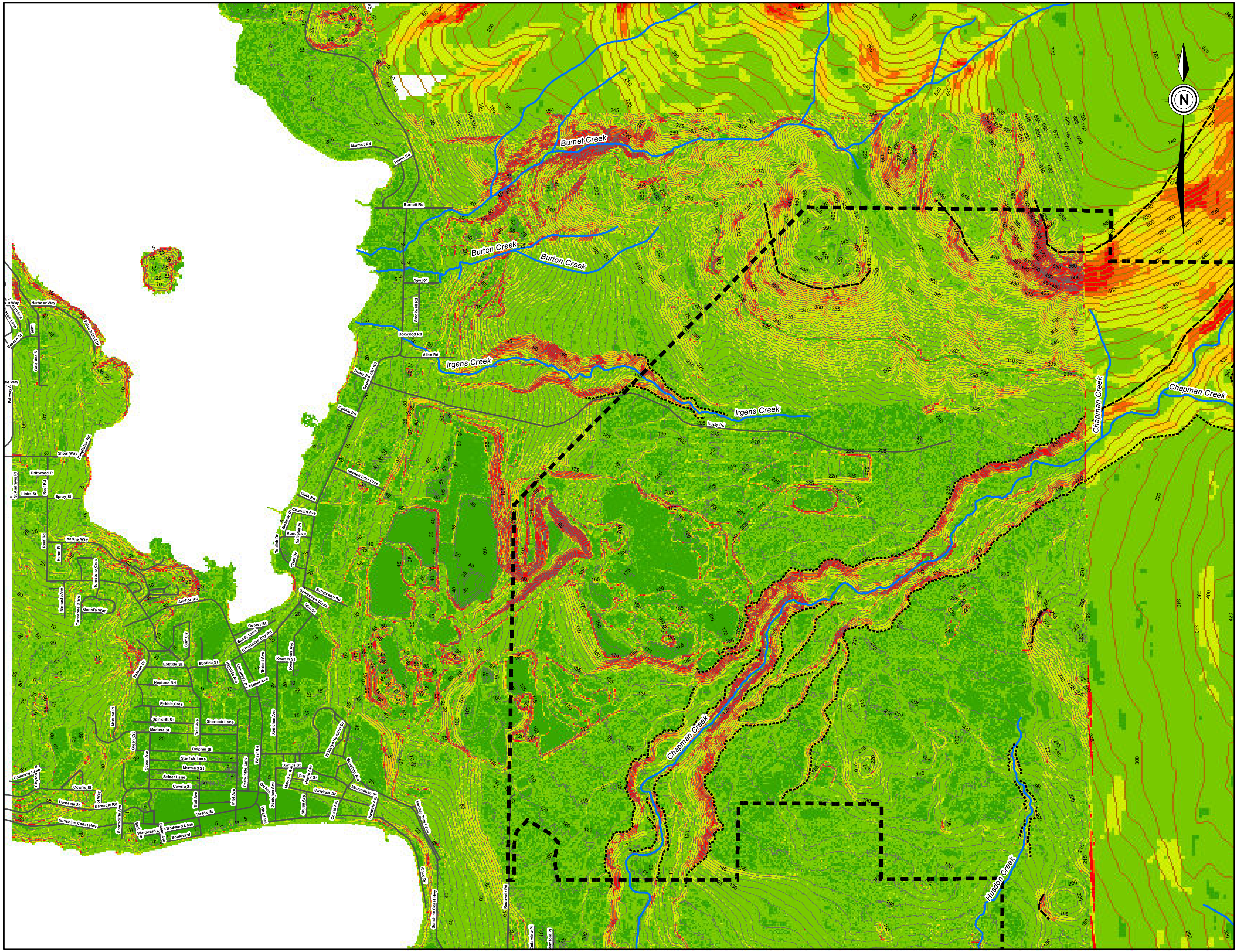

Geotechnical Hazards Report:
Roberts Creek
Sunshine Coast Regional District

Legend

- OCP Boundary
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- Ravine Crest
- Oceanfront Slope Crest
- Open Slope Failure Initiation Line
- Creeks / Rivers
- Low Channel Confinement (Fan)
- 5 m Contours
- 20 m Contours

Terrain Slope (%)

- 0 - 5
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- 60 - 70
- >70

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Project No.	Date
724-022	May 2012

Roberts Creek Hazard Screen (Sheet 3)

Figure 3-5

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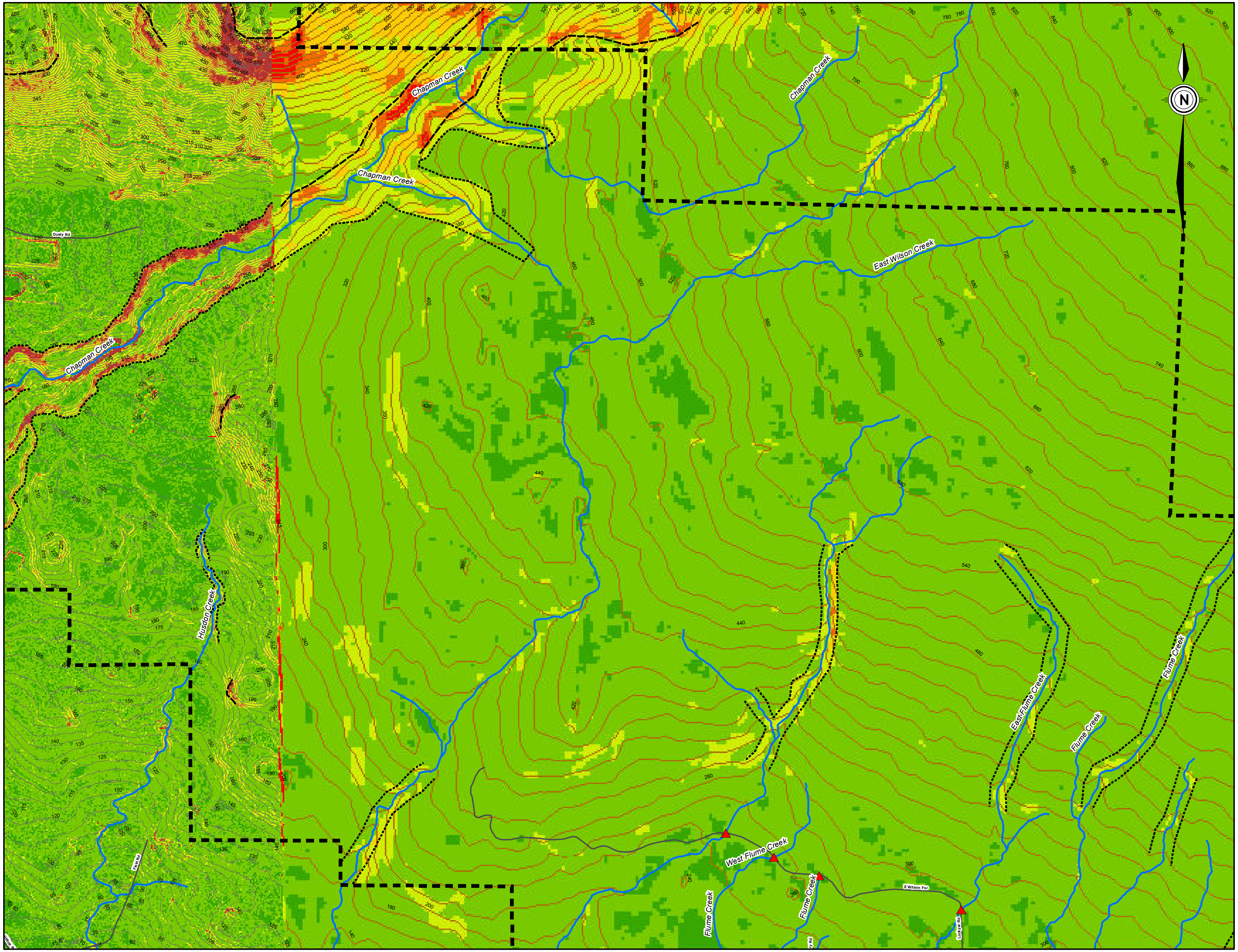

Geotechnical Hazards Report:
Roberts Creek
Sunshine Coast Regional District

Legend

- OCP Boundary
- Creek-Road Crossings
- Ravine Crest
- Oceanfront Slope Crest
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- Creeks / Rivers
- Low Channel Confinement (Fan)
- 5 m Contours
- 20 m Contours

Terrain Slope (%)

- 0 - 5
- 5 - 30
- 30 - 50
- 50 - 60
- 60 - 70
- >70

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Project No.	Date
724-022	May 2012

Roberts Creek Hazard Screen (Sheet 4)

Figure 3-6

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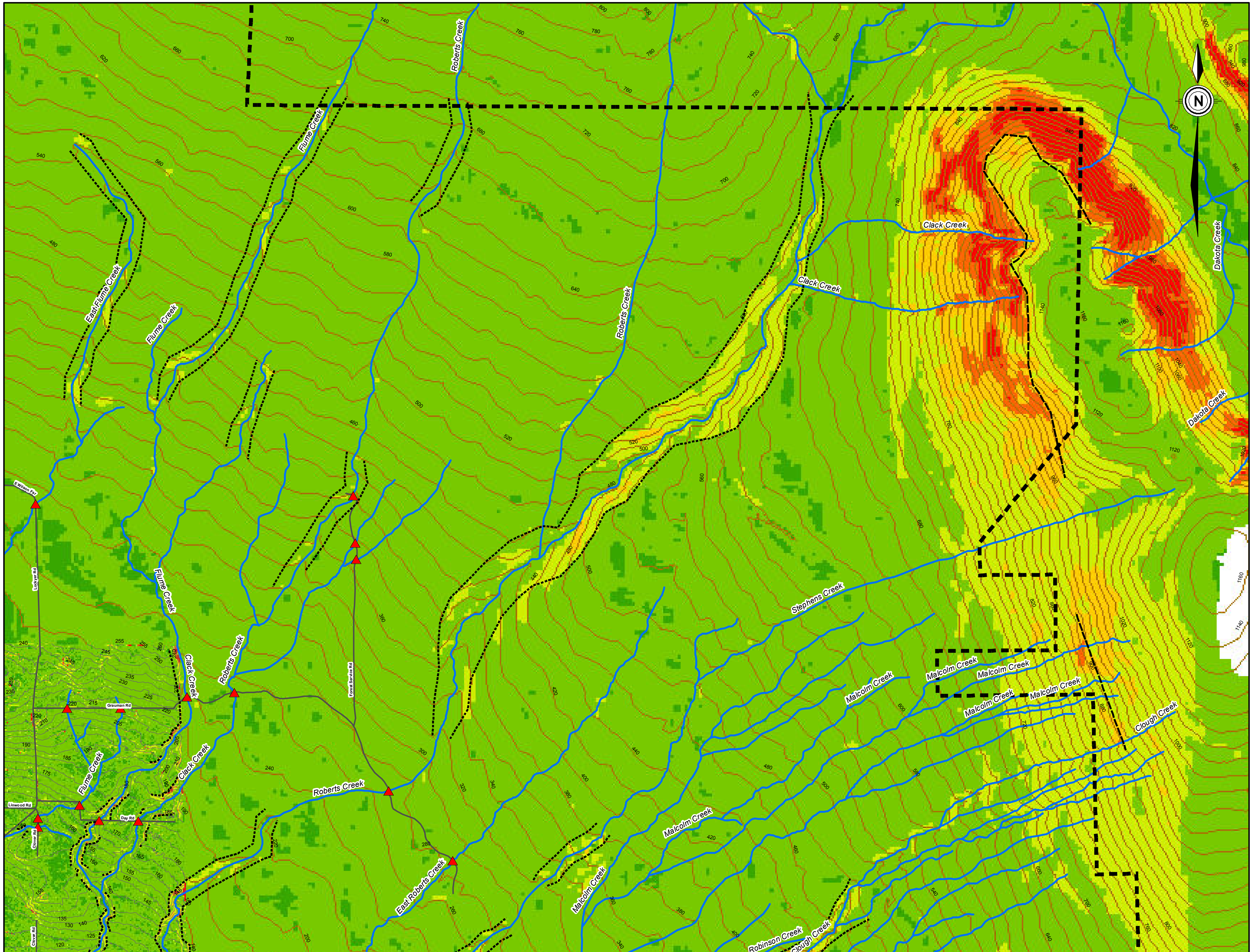
Author: EEllis

Geotechnical Hazards Report:
Roberts Creek
Sunshine Coast Regional District



Legend

- OCP Boundary
- Creek-Road Crossings
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- Low Channel Confinement (Fan)
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- 20 m Contours

Terrain Slope (%)

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Project No.	Date
724-022	May 2012

Roberts Creek Hazard Screen (Sheet 5)

Figure 3-7

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Section 4

Proposed DPA Framework

4. Proposed DPA Framework

4.1 Overview

The following sections outline the proposed development permit area (DPA) framework for hazardous areas in the Roberts Creek 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.
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.

Uncertainty

The goal of the DPA boundary delineation is to apply a uniform screening criterion 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 site specific surveys may be used 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.

DPA 1A: Coastal Flooding

The DPA extends from the coastal DPA boundary to 8 m CGD[4]. Within the DPA, development applications would require a coastal flood hazard assessment to define the coastal flood components, namely wave runup, wave setup, and possibly wind setup by a qualified professional, or siting development above 8 m CGD.

DPA 1B: Coastal Slopes

The recently released Guidelines report addresses 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 3 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.

Within the DPA, landslide risk assessment will be required to determine building setbacks and foundation design.

[4] Elevation referenced to Canadian Geodetic Vertical Datum

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).

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.

Riparian, flood, debris flood and debris flow hazard assessments will be required within DPA 2A.

DPA 2B: Ravines

Ravine areas were defined using the crest lines mapped in the GIS. Based on consideration of stable angles of repose and the typical terrain seen in the Roberts Creek OCP area, the following approach has been adopted:

- A 30 m setback from ravine crests defines the area that falls within DPA 2B. A 15 m setback line is also indicated.
- A <u>minimum</u> 15 m setback from ravine crest is required for all development.
- <u>For ravines that are deeper than 15 m</u>, the setback from ravine crest will be 30 m. An engineering report from an appropriately qualified professional will 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 they fall into.

DPA 2B will require a landslide assessment for ravine sidewalls.

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, which is not captured in DPA 2A.

Limited floodplain areas are present within the Roberts Creek OCP, all adjacent to Chapman Creek. Floodplain limits have been estimated using available LiDAR and 1:50,000 topographic data. In areas where only 1:50,000 scale data is available, a more conservative definition of the floodplain has been adopted, based on judgement.

Flood and erosion hazard assessment will be required within DPA 2C.

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 air photographs and contour mapping have been used to identify potential areas of low channel confinement, which are included in DPA 2D.

Flood and erosion, and channel avulsion hazard assessment will be required within DPA 2D.

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 shall meet general MOTI criteria outlined in Section 3.

Any culverts on major road crossing have been identified on the mapping, a requirement to review those crossings for development permit applications in close proximity (e.g. 300 m) and should be implemented as a Development Approval Information Area - General Condition in the OCP.

4.4 DPA 3: Slope Hazards

Three sub-categories of slope hazards are identified that are applicable to the Roberts Creek OCP area: open slope failures, rockfall hazards and seismic-initiated slope hazards. Open slope failures and rock fall hazard sub-categories are delineated under 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.

Open Slope Failures

Potential for open slope failures in the Roberts Creek OCP were identified where there are areas of moderately steep and steep terrain. Potential landslide impact areas were only 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). Open slope crests where initiation of a landslide may occur (bluffs higher than 10 m) are delineated in the DPA maps.

Landslide risk assessments will be required within DPA 3.

Rockfall

Within the 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 present a low hazard and have not been specifically mapped.

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

Seismic-Initiated Slope Hazards

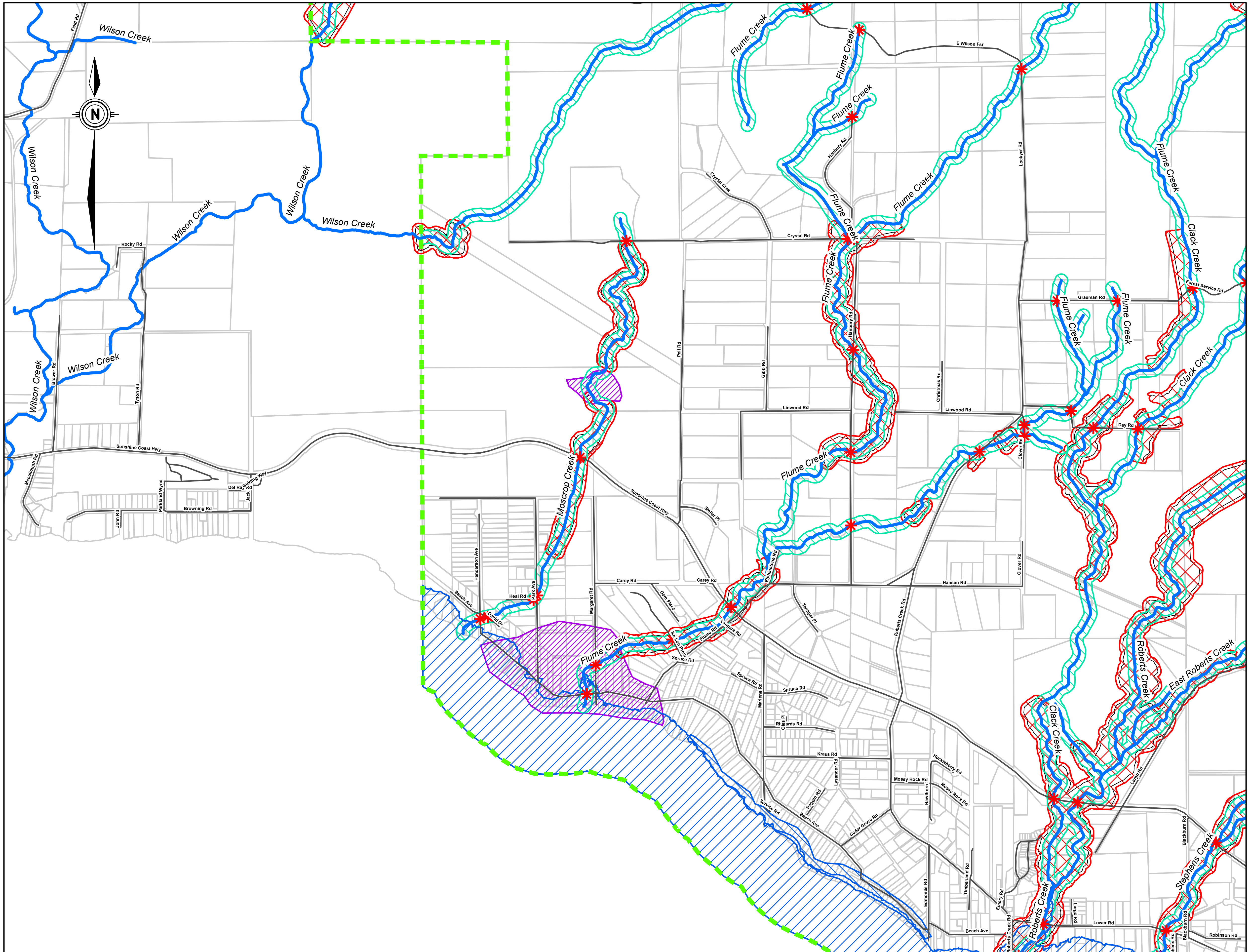
Seismic-initiated slope hazards need to be considered under the current guidelines for assessment of slope hazards developed by the Association of Professional Engineers and Geoscientists BC (2008).

No map-based screening tool is currently available to identify seismic slope hazard areas and therefore is not a Development Permit area, and should be implemented as a Development Approval Information Area - General Condition in the OCP.

4.5 Proposed Revised DPAs for Roberts Creek OCP

Proposed revised DPA's are presented in Figures 4-1 through 4-5.

Geotechnical Hazards Report:
Roberts Creek
Sunshine Coast Regional District



Legend

- OCP Boundary
- Creeks / Rivers
- DPA Zone 1A: Coastal Flooding
- DPA Zone 1B: Coastal Slopes
- DPA Zone2A: Creek/River Corridor
- DPA Zone 2B: Ravines
- Ravines: 15 m crest setback line
- DPA Zone 2C: Floodplain
- DPA Zone 2D: Low Channel Confinement
- DPA Zone 2E: Road Crossings
- DPA Zone 3: Slope Hazards
- Parcels

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Project No.	Date
724-022	May 2013

Roberts Creek Proposed DPAs (Sheet 1)

Figure 4-1

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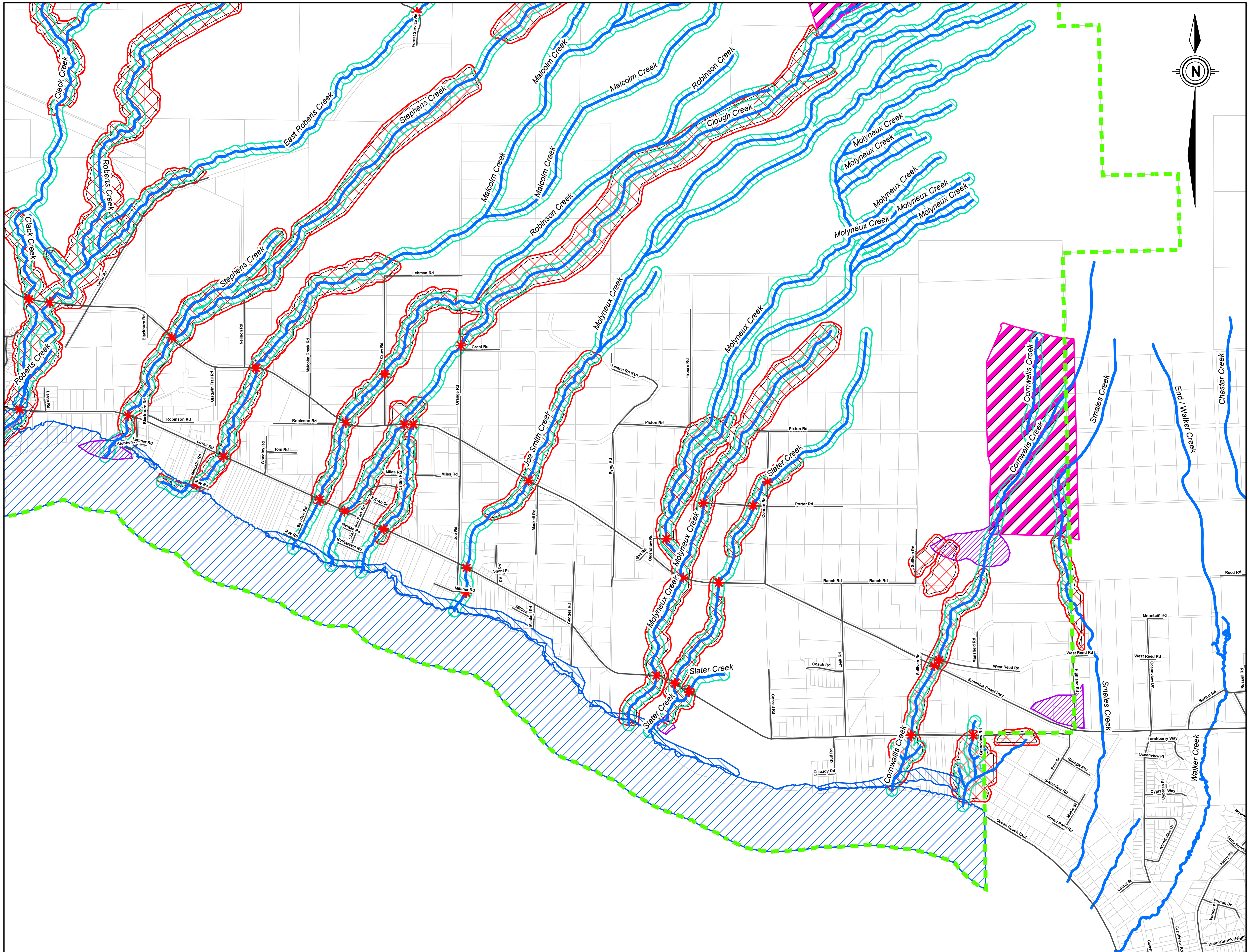

Geotechnical Hazards Report:
Roberts Creek
Sunshine Coast Regional District

Legend

- **OCP Boundary**
- **Creeks / Rivers**
- DPA Zone 1A: Coastal Flooding
- DPA Zone 1B: Coastal Slopes
- DPA Zone2A: Creek/River Corridor
- DPA Zone 2B: Ravines
- Ravines: 15 m crest setback line
- DPA Zone 2C: Floodplain
- DPA Zone 2D: Low Channel Confinement
- DPA 2E: Creek-Road Crossings
- DPA Zone 3: Slope Hazards
- Parcels

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Project No.	Date
724-022	May 2013

Roberts Creek
Proposed DPAs (Sheet 2)

Figure 4-2

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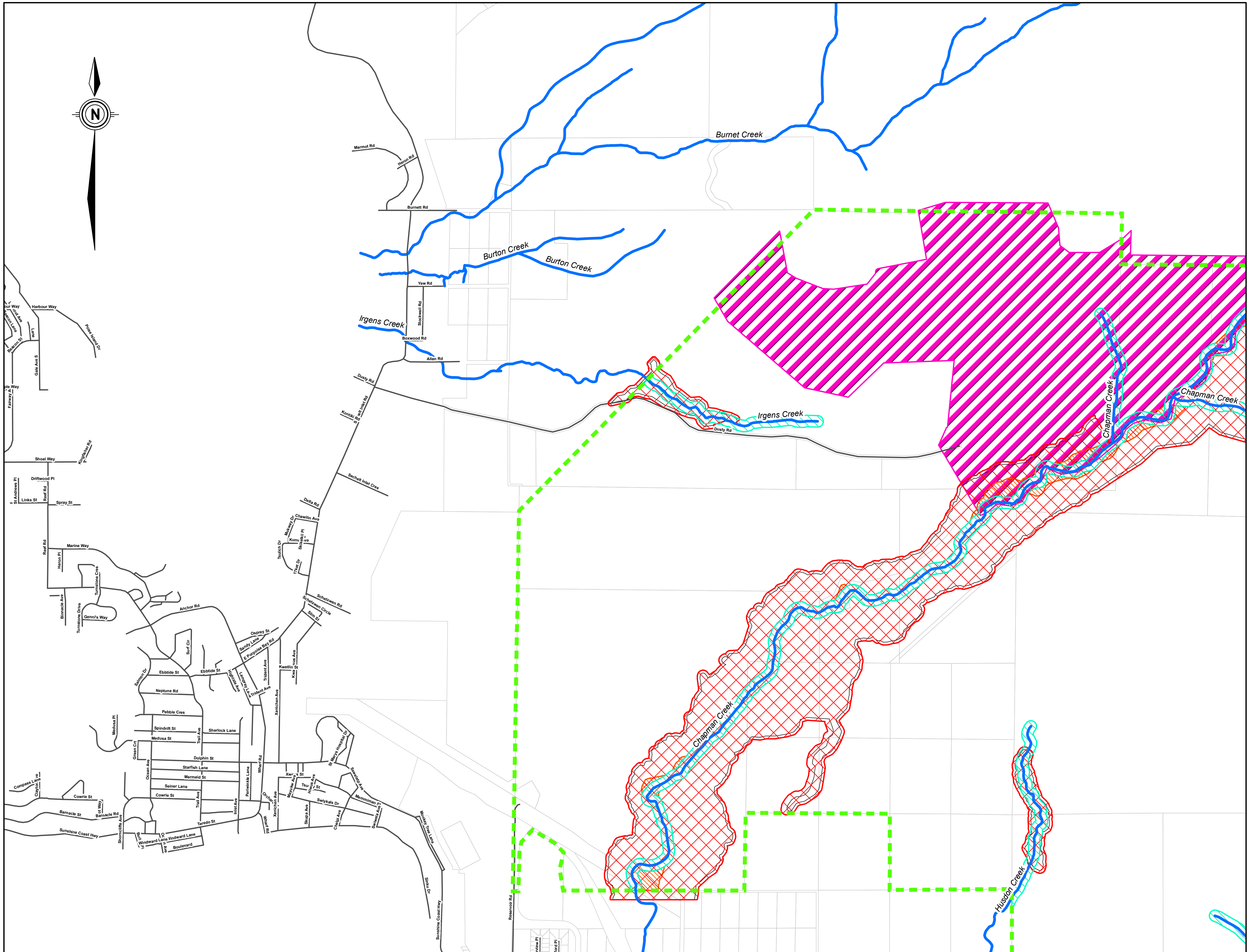

Geotechnical Hazards Report:
Roberts Creek
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Legend

- **OCP Boundary**
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- DPA Zone 1A: Coastal Flooding
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- Parcels

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Project No.	Date
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Roberts Creek
Proposed DPAs (Sheet 3)

Figure 4-3

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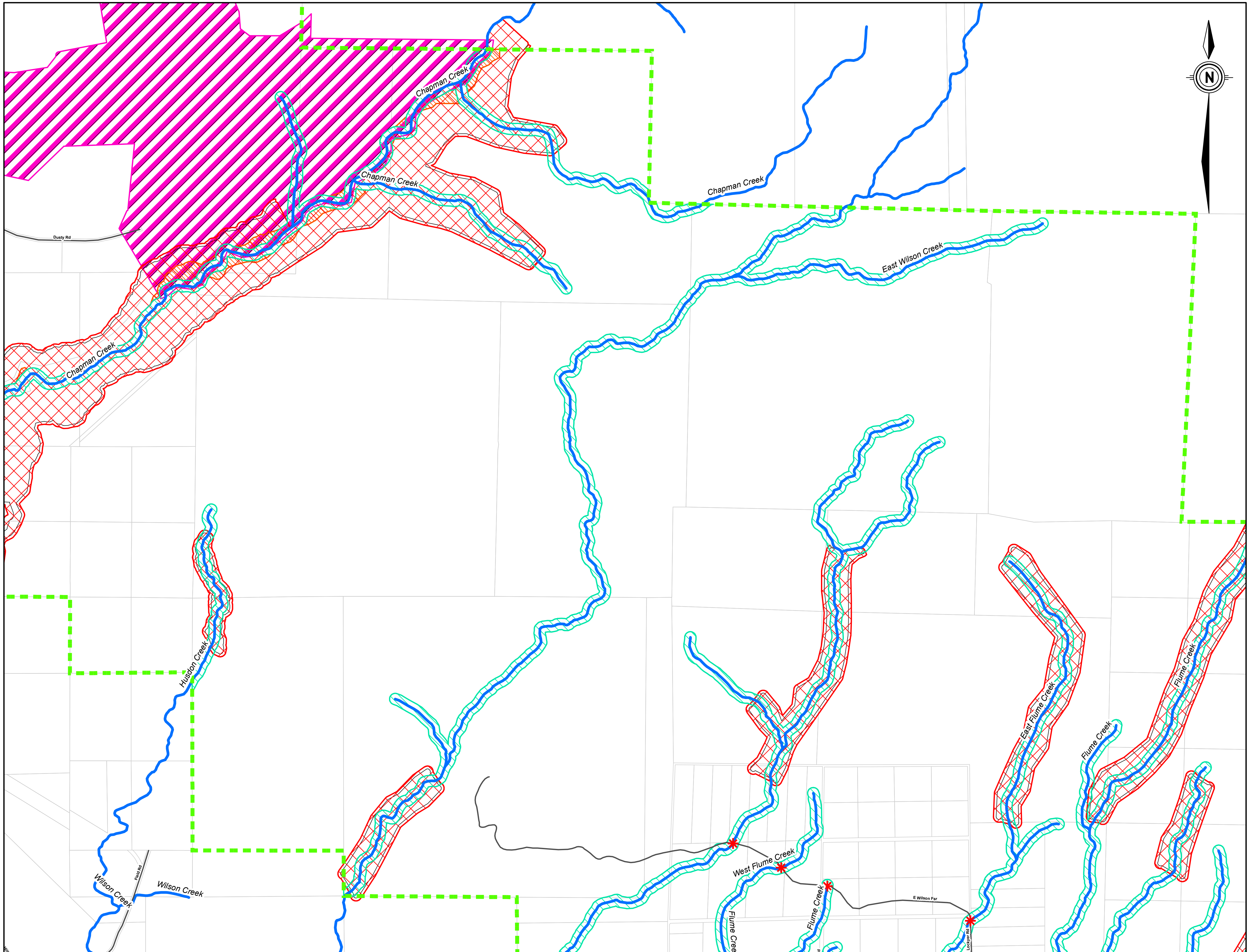

**Geotechnical Hazards Report:
Roberts Creek
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- Ravines: 15 m crest setback line
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- DPA Zone 3: Slope Hazards
- Parcels

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Project No.	Date
724-022	May 2013

**Roberts Creek
Proposed DPAs (Sheet 4)**

Figure 4-4

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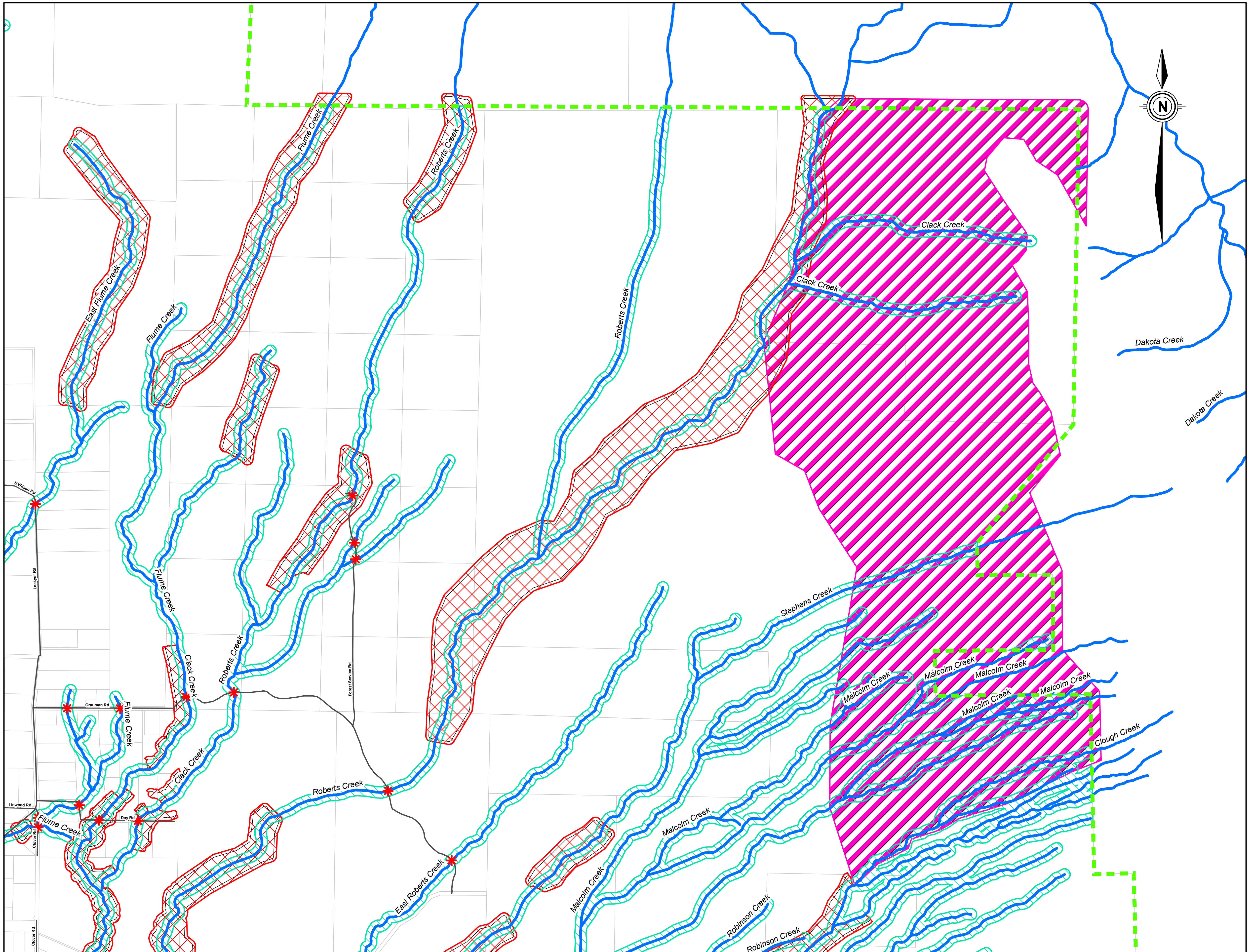
Geotechnical Hazards Report:
Roberts Creek
Sunshine Coast Regional District



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- DPA Zone 2B: Ravines
- Ravines: 15 m crest setback line
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- DPA Zone 3: Slope Hazards
- Parcels

FINAL DRAFT

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Project No.	Date
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Roberts Creek Proposed DPAs (Sheet 5)

Figure 4-5

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Author: CDavey

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Section 5

Guidelines for Development

5. Guidelines for Development

5.1 DPA 1: Ocean Hazards

A Development Permit on lands identified as being within DPA 1 is required 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.

Different hazards have been identified within the general category of "ocean hazards": applications for subdivision, building permit or land alteration shall include a report from an appropriately qualified Professional Engineer or Professional Geoscientist that considers all relevant potential ocean hazards.

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.

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.		

A regional study may be appropriate for the Sunshine Coast to 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.

DPA 1B – Coastal Slopes Guidelines

If applicable, the report shall include the following:

- Surveyed slope profiles with documentation of the limits of slope instability. Consideration shall 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 shall also 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

A Development Permit on lands identified as being within DPA 2 is required 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 2A/C/D – Creek Corridor / Floodplain / Low Channel Confinement Guidelines

- A review of the property by an appropriately qualified Professional Engineer or Professional Geoscientist shall be required as part of a development permit review process. The report shall include an 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.
- Flooding and associated creek processes are subject to assessment 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 shall consider upstream channels and floodways, debris dams, culverts, sources of debris (channels and eroded banks) and related hydrologic features.

- Analysis shall 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.

DPA 2B – Ravines Guidelines

- 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.
- Development within ravine slope setbacks will be subject to the reporting requirements for DPA 3.
- A field definition of the required setback from the top of a ravine or other steep slope.
- The report shall 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.

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

- Where identified as a possible mechanism (Table 3-2), potential debris flow and debris flood creeks shall be assessed by an appropriately qualified professional. 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) around debris flow or debris flood creeks shall 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).

5.3 DPA 3: Slope Hazards

A Development Permit on lands identified as being within DPA 3 is required 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.

Both open slope failures and rockfall hazards fall within this DPA. Applications for subdivision, building permit or land alteration shall 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 shall include the following:

- Slope profiles with documentation of the limits of slope instability shall be provided. Consideration shall 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 shall also 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 rock fall shadow area, including an indication of the appropriate buffer zone and required protective works.

5.4 Exemptions

The following general exemptions may be granted 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.
- 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 2 trees over 20 centimetre diameter breast height or 10 square metres of vegetated area of per calendar year per lot, provided there is replanting of 4 trees or re-vegetation of the same amount of clearing.

5.5 Report Submission

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.

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Fluvial Geomorphologist

Reviewed by:

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References

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Geotechnical Hazards Report: West Howe Sound

Final Report
May 2013
KWL Project No. 724.024-300

Prepared for:

Sunshine Coast Regional District

Statement of Limitations

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Revision History

Revision #	Date	Status	Revision	Author
0	Feb 22, 2013	Draft	Draft Hazard Screen (submitted to SCRD).	CED/DTM
1	March 26, 2013	Final Draft	Following review meeting .	CED/DTM
2	May 15, 2013	Final Draft	Client Review	CED/DTM

Contents

Figures

Tables

Section 1

Introduction

1. Introduction

1.1 Background

The OCP area of West Howe Sound is located on the Sunshine Coast, approximately 20 km east of Sechelt. West Howe Sound is the gateway to the Sunshine as it contains the Langdale ferry terminal that services the lower mainland. The Sunshine Coast Highway (Highway 101) is the main route through the community of West Howe Sound. The OCP area is bounded by Howe Sound to the east and the town of Gibsons to the south.

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 to the east are sources of potential landslide activity that may affect lower slopes;
- Creeks support 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 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 Halfmoon Bay, Elphinstone and West Howe sound based on the RFP closed in July, 2012.

The work scope was to assess and recommend revisions to the existing Development Permit Area (DPA) included in the Official Community Plans pertaining to the areas of Halfmoon Bay, Elphinstone and West Howe Sound. The study provides the SCRD with technical guidance on possible amendments to existing DPAs. Each OCP area is discussed in separate reports. The report herein pertains to West Howe Sound.

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, BC Building Code, the Riparian Areas Regulation, and the SCRD Risk Assessment and Liability Policy); and

- Propose DPA areas 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:

- David Matsubara, M.Eng., P.Eng., KWL (Project Manager);
- Mike Currie, M.Eng., P.Eng., KWL (Senior Technical Review);

- Chad Davey, M.Sc., KWL (Fluvial Geomorphologist); and
- Pierre Friele, M.Sc., P.Geo., PG (WA), Cordilleran Geoscience (Senior Geoscientist).

Section 2

Data Sources

2. Data Sources

2.1 Background Reports

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

- "Reconnaissance Study of Geotechnical Hazards Elphinstone and West Howe Sound Official Community Plans" (Thurber, 1990);
- West Howe Sound Official Community Plan (SCRD, 2011);
- "Hazard Risk and Vulnerability Analysis for the Sunshine Coast Regional District" (EmergeX Planning, 2005);
- West Howe Sound: An Overview Study. Province of BC, Environment and Land Use Committee Secretariat (1980); and
- Surface geology maps for Sunshine Coast.

Brief summaries of selected reports are provided below:

Thurber (1990)

This report summarized a reconnaissance geotechnical hazard evaluation for the Elphinstone and West Howe Sound OCP's. The work touched upon several areas of concern, including: Hutchinson Creek (mid-slope fan, flooding), Langdale Creek (flooding), Soames Hill (rock fall hazard), area north of Thornbrough Road (landslides), Hopkins Landing (landslides), and Soames Point (rockfall). Recommendations by Thurber include more detailed drainage study's along creeks if further development is anticipated and a detailed flood hazard study on the Langdale alluvial fan.

EmergeX Planning (2005)

EmergX Planning conducted a general hazard 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 Air Photographs

Hard copy air photographs were obtained from the SCRD and UBC's airphoto library and reviewed (Table 2-1).

Table 2-1: Summary of Air Photographs Reviewed

Date	Roll/Photo Number	Scale
1998	30BCB98007 #231-244	~1:10,000
1976	BC5722 #842-88, 122	~1:10,000
1972	BC5492 #215,216	~1:40,000

In general, the relatively small size of the creeks in combination with the forest canopy cover prevented detailed observations of the channels. Thus, airphotos 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;
- general confinement noted for the creeks except in select locations.

2.3 GIS Analysis

GIS data were obtained from the SCRD including:

- Topographic data:
  - 1 m contours and LiDAR (x, y, z) (partial coverage of OCP area, from ocean to above highway);
  - 20 m contours (full coverage of OCP area);
- Creeks and rivers;
- Geology, surficial geology and soils data;
- Administrative data:
  - OCP Boundary (old and revised);
  - Parcels;
  - Existing DPA areas;
- Roads; and
- Orthophotos (2009).

In addition, the Provincial 1:50,000 scale DEM data were downloaded to provide full coverage of the watersheds that are contained, or cross, the West Howe Sound OCP.

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Section 3

Hazard Analysis

3. Hazard Analysis

3.1 Background

Topography

The West Howe Sound OCP area is generally concave in vertical profile, rising from sea-level (Georgia Strait) to elevations of 1,200 m at the divide (Elphinstone Mountains). Development is typically 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.

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 occur as a result of rain or rain-on-snow runoff events from September through March.

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 Figures 3.3 through 3.6 (Sheets 1 through 4).

3.3 Coastal Zone Hazards

Coastal hazards include flooding from a combination of regular tidal processes (e.g. surge, waves, etc), but also could occur from rare seismically included 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 are indicating 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.

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.

Tidal Condition

Tidal fluctuations occur daily, and the magnitude of high tides varies 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 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

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

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

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 be greater 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), resulting in a 500-year return period value of 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 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 setback a minimum of 15 m 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).

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

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.

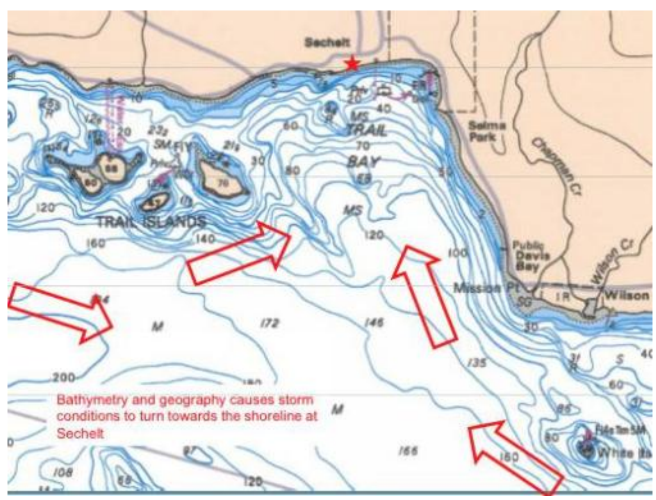
Example – Trail Bay Seawall

A recent cursory study 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 **Error! Reference source not found.**.

Table 3-1: Summary of 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. Typical coastal water level values for the near term quickly reach 5.5 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. This additional metre provides a planning elevation for assessment of 7.15 m CGD or more simply 8 m.

The 8 m CGD planning area ensures that any sites below this elevation are assessed by a qualified professional to address flood hazards, but does not preclude development.

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 West Howe Sound OCP 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 1-2 m.

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 3 times horizontal setback is applied to 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 approach outlined in the provincial guidelines (Ausenco Sandwell, 2011).

In some isolated areas, due to shoreline and slope geometry, this setback may extend beyond the shoreline property. These areas have been shown on the maps for clarity, but these areas are not included in the DPA area at present.

3.4 Creek Hazards

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 5-10 m/s. These events leave sheets of poorly sorted debris ranging from sand to cobbles or small boulders. The peak discharge (flow rate) of debris floods and flows is commonly 2 to 5 times higher than that of 200 year return period water floods (Jakob and Jordan, 2001).

These types of events would be expected to initiate higher in the 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 flood and debris flow 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 West Howe Sound watercourses are confined within incised channels and ravines, and potential hazards are restricted to the immediate creek or river corridor. Areas without good confinement are usually 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.

Defining the Dominant Creek Hazard

GIS data were used to assess the creeks draining through the West Howe Sound OCP 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:

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

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 Figures 3-1 and 3-2, and summarized in Table 3-2.

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)
South Ouillet Creek	N/A[2]	Flood
Unnamed Creek #6	Flood	N/A[1]
Hutchinson Creek	Flood/debris flood	Debris flow
Langdale Creek	Flood	Debris flood
Gibsons Creek	Debris flow	Debris flow
Soames Creek	Flood	N/A[1]

Notes:
1. Very little or no drainage area upstream of existing development according to mapping.
2. Drainage area within existing development is outside West Howe Sound OCP boundaries.

As indicated by the results of the screening summary, Gibsons Creek and Upper Hutchinson Creek (east) may experience debris flows. Upper Langdale may experience debris floods.

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.

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), we have followed RAR definitions, including:

- **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.

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.

Creek-Road Crossings

The majority of the major crossings in the OCP are reported to be Ministry of Transportation and Infrastructure assets, and 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 the current study; 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, the Ministry of Transportation and Infrastructure (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. Figures 3-1 and 3-2), extra allowance should be provided for sediment.

Where debris flows are anticipated (e.g. Figures 3-1 and 3-2), analysis of the debris flow recurrence interval should be conducted, and findings should inform the design, before it is finalized.

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, we have not recommended DPAs based on slope categories alone, without additional consideration of hazard mechanism.

Open Slope Failures and Associated Hazard Area

In the terrain typical of the West Howe Sound OCP, open slope landslides are generally shallow slides, in which weaker organic or weathered overburden soils fail over more competent glacially-compressed soils or rock.

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 at higher elevations along the north and west boundary of the West Howe Sound OCP. 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 we have applied travel angles to predict areas within the West Howe Sound OCP 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) debris flows 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 result was compared to the method proposed by Horel (2007) and found to be conservative.

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 West Howe Sound 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.

3.6 Fieldwork

A field visit of the West Howe Sound OCP was conducted in late February 2013. The following observations were made:

- The channel along South Ouillet Creek upstream of the Port Mellon Highway has low channel confinement and shows evidence of recent flooding (Photo 3.1). The flooding in this area could be the result of the culvert placement beneath the Highway. The South Ouillet Creek encounters the highway 100 m further north than where the culvert is situated; during high flows, it is possible that this could result in a backwater event.
- The north branch of Hutchinson Creek was investigated for debris flow activity. Upstream of the Port Mellon Highway the north branch of Hutchinson Creek splits into two tributaries. The northern most tributary is largely unconfined and evidence of a debris flow deposit is present. A hummocky lobe of poorly sorted sediment approximately 80-100 m wide was observed (Photo 3.2). The down slope edge of the deposit extends to the confluence of the two north branches of Hutchinson Creek, approximately 50 upslope from the Highway. The upslope extent of this deposit was not investigated.
- Evidence of rock falls along the base of the steep slopes at the large bedrock hummock north of Williams Landing Road is present (Photo 3.3). A section of vegetation has been cleared along the southern side of this bedrock hummock (Photo 3.4) near a power line ROW. A small unmapped creek and associated ravine is also present along the southern toe of this bedrock hummock (Photo 3.5).
- An alluvial fan in the upper Hutchinson Creek watershed along the southern branch was identified during the hazard screening. Upon field inspection, it appears that this fan may no longer be active and the southern branch of Hutchinson Creek may have started to become incised within this fan. However, a more detailed investigation is needed to confirm this finding. Thus, this fan feature will remain delineated as an area of low channel confinement.
- Several small, unmapped tributaries between the two South branches of Hutchinson Creek were observed along the Port Mellon Highway. One of these tributaries crosses beneath the

highway along a small wooden stave that shows sign of damage and erosion along the outer perimeter (Photo 3.6).

- Several seeps exiting the gravel/sand road cut in Hopkins Landing along North Road were observed (Photo 3.7).
- Evident of historic and active rockslides were present along the south and east facing slopes along Soames Hill (Photos 3.8).
- Upstream of Marine Drive, Soames Creek contains a small floodplain. Evidence of large floods depositing cobbles and gravel were evident (photo 3.9). Soames Creek downstream of Marine Drive is partially developed with residential properties that appear to be abandoned. Near the mouth of Soames Creek it flows adjacent to an abandoned house (Photo 3.10).

Photo 3.1: A section of low channel confinement was observed near the Port Mellon Highway along the South Ouillet River.

Photo 3.2: Evidence of a debris flow deposit was observed along the north branch of the Hutchinson River.

Photo 3.3: Evidence of rockfall activity was observed along a large bedrock hummock north of Williams Landing Road.

Photo 3.4: Vegetation along a large bedrock hummock north of Williams Landing Road has been cleared.

Photo 3.5: A small, unmapped creek was observed flowing along the south toe of the bedrock hummock north of Williams Landing Road.

Photo 3.6: A wooden stave beneath the Port Mellon Highway at the south Branch of Hutchinson Creek has had erosion of the road fill occur.

.

Photo 3.7: Several seeps exiting the gravel/sand road cut in Hopkins Landing along North Road were observed.

Photo 3.8: Evidence of rockfall activity was observed along the south and east facing slope of Soames Hill.

Photo 3.9: Evidence of flooding and deposition of large lobes of gravel and cobbles along Soames Creek upstream of Marine Drive was observed.

Photo 3.10: The Soames Creek channel near the mouth is situated very close to an abandoned house.

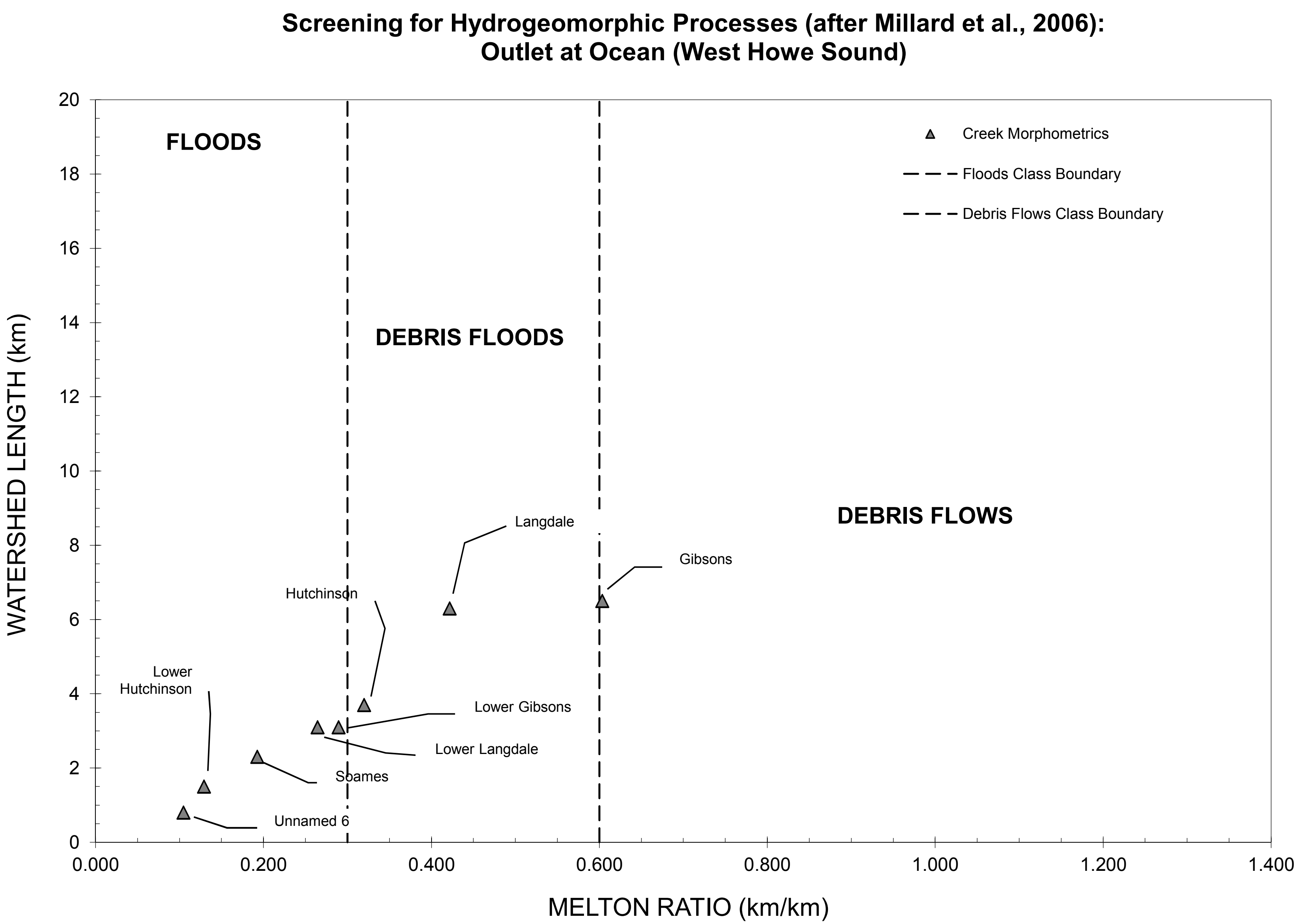
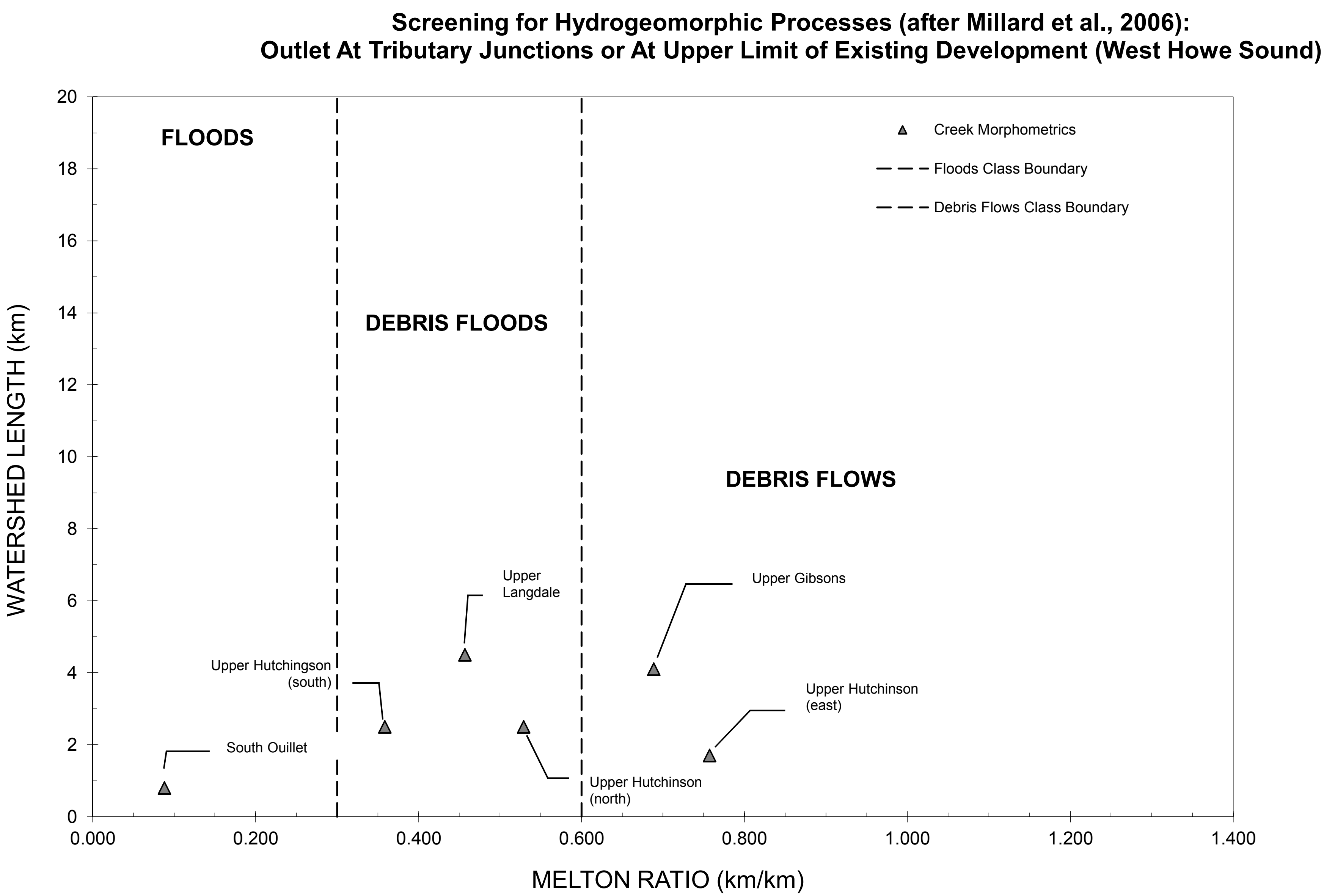

Screening for Hydrogeomorphic Processes (after Millard et al., 2006):
Outlet at Ocean (West Howe Sound)
FLOODS
DEBRIS FLOODS
DEBRIS FLOWS
Creek Morphometrics
Floods Class Boundary
Debris Flows Class Boundary
Langdale
Gibsons
Hutchinson
Lower Hutchinson
Lower Gibsons
Lower Langdale
Soames
Unnamed 6
WATERSHED LENGTH (km)
MELTON RATIO (km/km)
0
2
4
6
8
10
12
14
16
18
20
0.000
0.200
0.400
0.600
0.800
1.000
1.200
1.400

Figure 3-1



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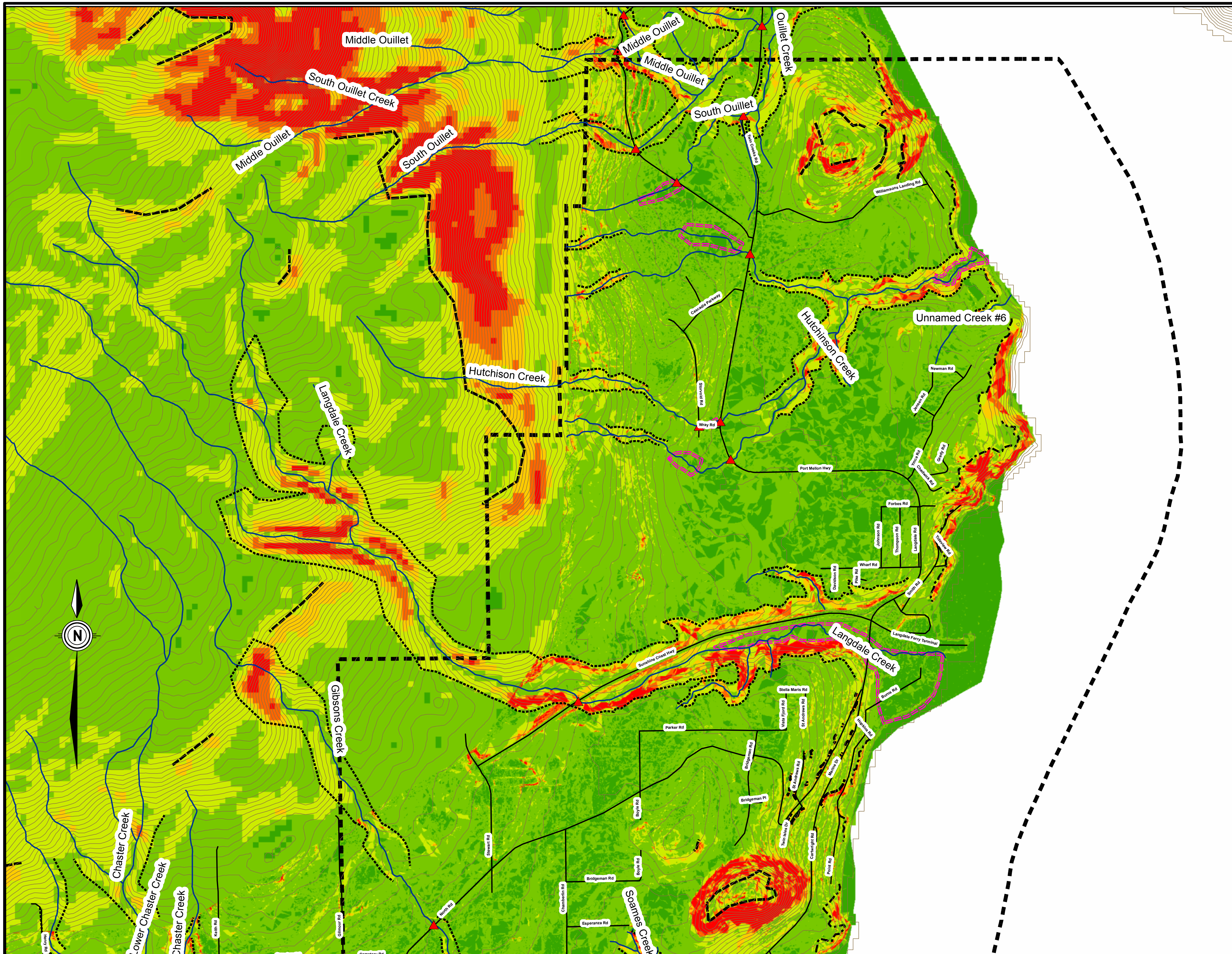
O:\0700-0799\724-024\400-Work\Morphometric Analysis\DebrisFloodFlow-MorphometricScreen-WHS-724024

Figure 3-2



Geotechnical Hazards Report:
West Howe Sound
Sunshine Coast Regional District

Legend

- Ravine Crest
- Creek-Road Crossings
- Roads
- Creeks/Rivers
- 10 m Contours
- Oceanfront Slope Crest
- Open Slope Failure Initiation Line
- Low Channel Confinement (Fan)
- West Howe Sound OCP Boundary
- 0 - 5
- 5 - 30
- 30 - 50
- 50 - 60
- 60 - 70
- \>70

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Project No.	Date
724-024	May 2013

West Howe Sound Hazards Screen (Sheet 1)

Figure 3-3

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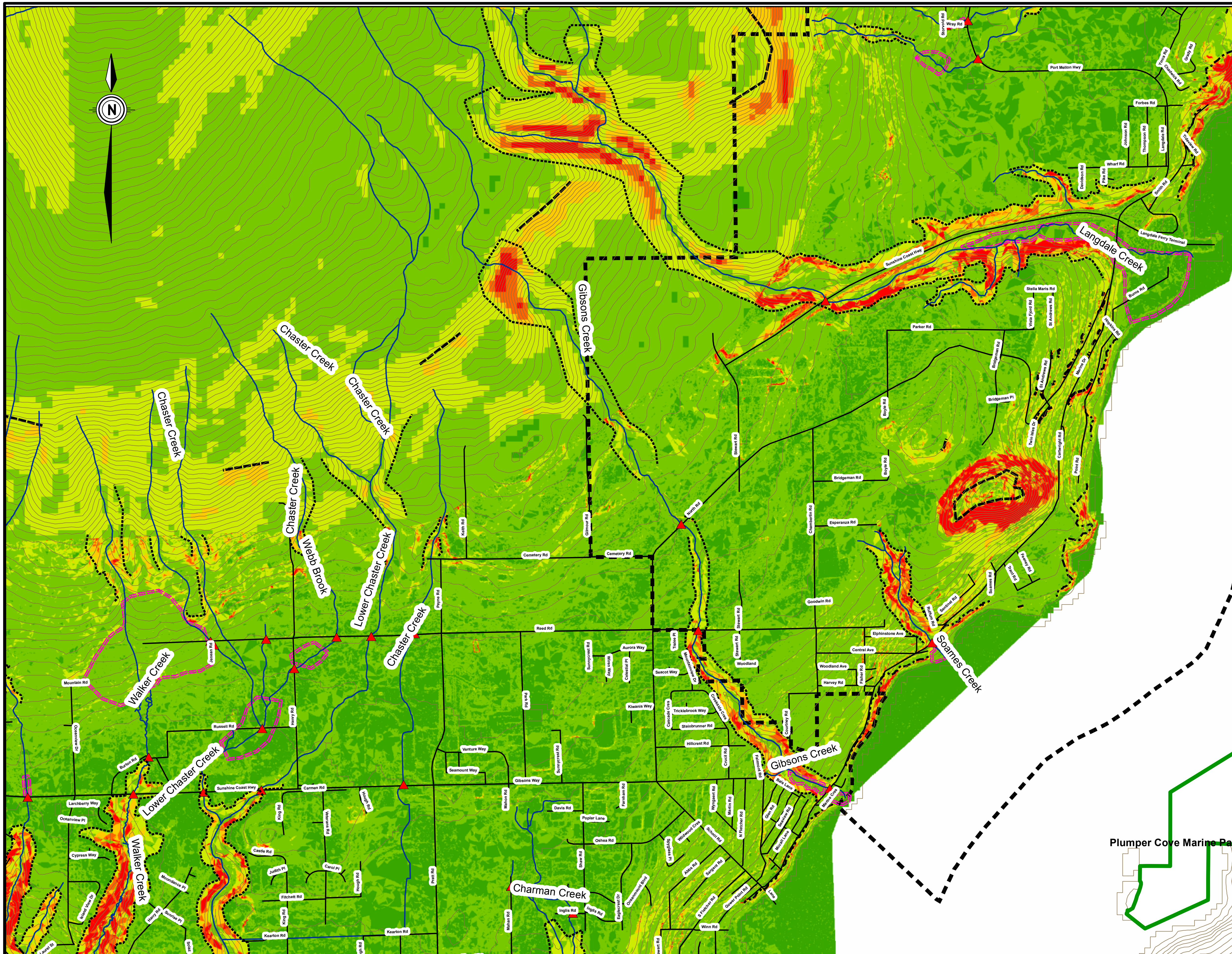

Geotechnical Hazards Report:
West Howe Sound
Sunshine Coast Regional District

Legend

- Ravine Crest
- Creek-Road Crossings
- Roads
- Creeks/Rivers
- 10 m Contours
- Oceanfront Slope Crest
- Open Slope Failure Initiation Line
- Low Channel Confinement (Fan)
- West Howe Sound OCP Boundary
- Provincial Park Boundary
- 0 - 5
- 5 - 30
- 30 - 50
- 50 - 60
- 60 - 70
- >70

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Project No.	Date
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West Howe Sound Hazards Screen (Sheet 2)

Figure 3-4

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Section 4

Proposed DPA Framework

4. Proposed DPA Framework

4.1 Overview

The following sections outline the proposed development permit area (DPA) framework for hazardous areas in the West Howe Sound 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.
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.

Uncertainty

The goal of the DPA boundary delineation is to apply a uniform screening criterion 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 site specific surveys may be used 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.

DPA 1A: Coastal Flooding

The DPA extends from the coastal DPA boundary to 8 m CGD[4]. Within the DPA, development applications would require a coastal flood hazard assessment to define the coastal flood components, namely wave runup, wave setup, and possibly wind setup by a qualified professional, or siting development above 8 m CGD.

DPA 1B: Coastal Slopes

The recently released Guidelines report addresses 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 3 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.

Within the DPA, landslide risk assessment will be required to determine building setbacks and foundation design.

[4] Elevation referenced to Canadian Geodetic Vertical Datum.

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).

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.

Riparian, flood, debris flood and debris flow hazard assessments will be required within DPA 2A.

DPA 2B: Ravines

Ravine areas were defined using the crest lines mapped in the GIS. Based on consideration of stable angles of repose and the typical terrain seen in the West Howe Sound OCP area, the following approach has been adopted:

- A 30 m setback from ravine crests defines the area that falls within DPA 2B. A 15 m setback line is also indicated.
- A minimum 15 m setback from ravine crest is required for all development.
- For ravines that are deeper than 15 m, the setback from ravine crest will be 30 m. An engineering report from an appropriately qualified professional will 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 they fall into.

DPA 2B will require a landslide assessment for ravine sidewalls.

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, which is not captured in DPA 2A.

Flood and erosion hazard assessment will be required within DPA 2C.

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 air photographs and contour mapping have been used to identify potential areas of low channel confinement, which are included in DPA 2D.

Flood and erosion, and channel avulsion hazard assessment will be required within DPA 2D.

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 shall meet general MOTI criteria outlined in Section 3.

Any culverts on major road crossing have been identified on the mapping, a requirement to review those crossings for development permit applications in close proximity (e.g. 300 m) and should be implemented as a Development Approval Information Area - General Condition in the OCP.

4.4 DPA 3: Slope Hazards

Three sub-categories of slope hazards are identified that are applicable to the West Howe Sound OCP area: open slope failures, rockfall hazards and seisimic-initated slope hazards. Open slope failures and rock fall hazard sub-categories are delineated under 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.

Open Slope Failures

Potential for open slope failures in the West Howe Sound OCP were identified where there are areas of moderately steep and steep terrain. Potential landslide impact areas were only 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). Open slope crests where initiation of a landslide may occur (bluffs higher than 10 m) are delineated in the DPA maps.

Landslide risk assessments will be required within DPA 3.

Rockfall

Within the 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 present a low hazard and have not been specifically mapped.

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

Seismic-Initiated Slope Hazards

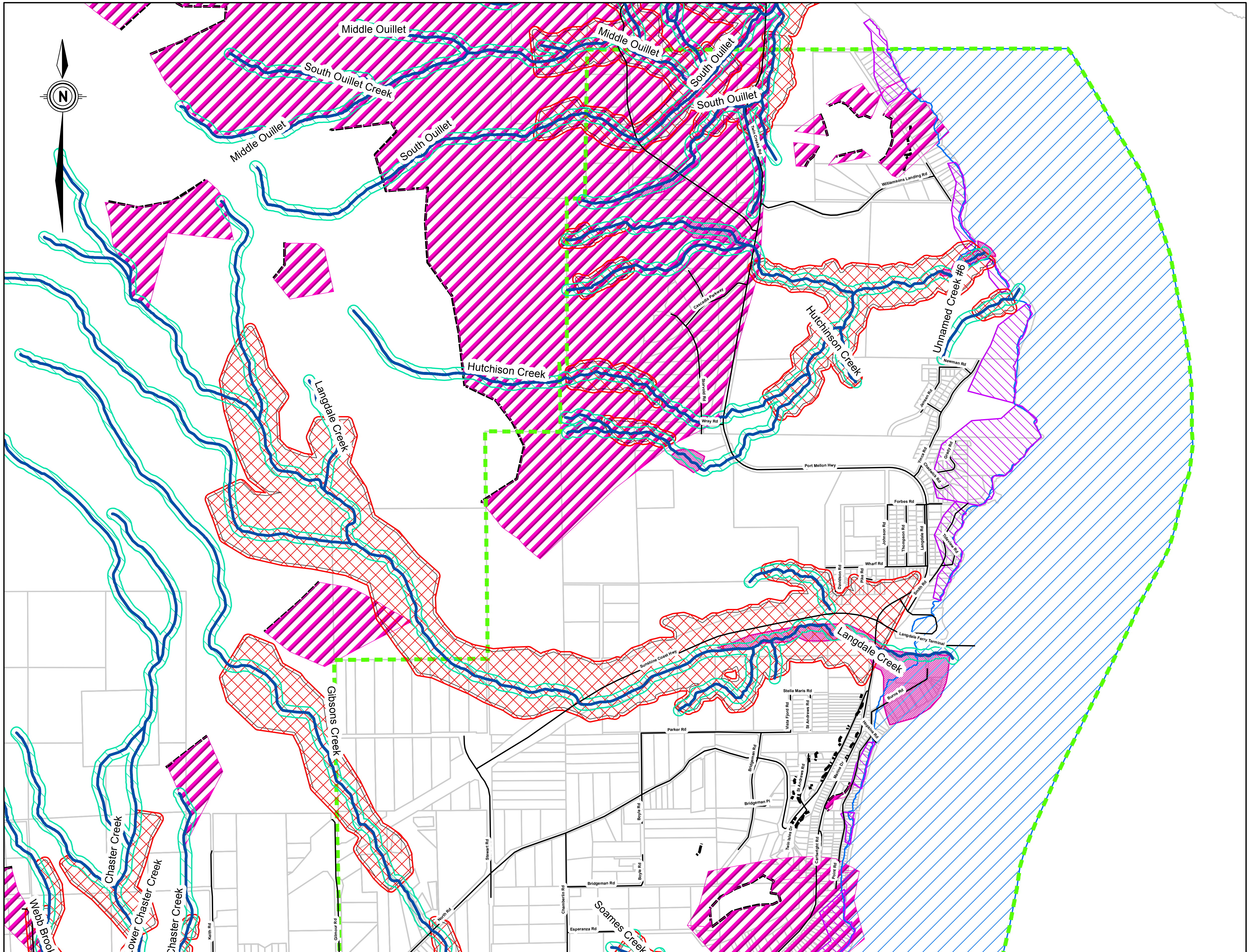
Seismic-initiated slope hazards need to be considered under the current guidelines for assessment of slope hazards developed by the Association of Professional Engineers and Geoscientists BC (2008).

No map-based screening tool is currently available to identify seismic slope hazard areas and therefore is not a Development Permit area, and should be implemented as a Development Approval Information Area - General Condition in the OCP.

4.5 Proposed Revised DPAs for West Howe Sound OCP

Proposed revised DPA zones are presented in Figures 4-1 and 4-2.

Geotechnical Hazards Report:
West Howe Sound
Sunshine Coast Regional District



Legend

- DPA Zone 1A: Coastal Flooding
- DPA Zone 1B: Coastal Slopes
- DPA Zone 2A: Creek/River Corridor
- DPA Zone 2B: Ravines (30m)
- DPA Zone 2B: Ravines (15m)
- DPA Zone 2C: Floodplain
- DPA Zone 2D: Low Channel Confinement (Fan)
- DPA Zone 3: Slope Hazards
- Creeks/Rivers
- Roads
- West Howe Sound OCP Boundary
- West Howe Sound Parcels

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West Howe Sound Proposed DPAs (Sheet 1)

Figure 4-1

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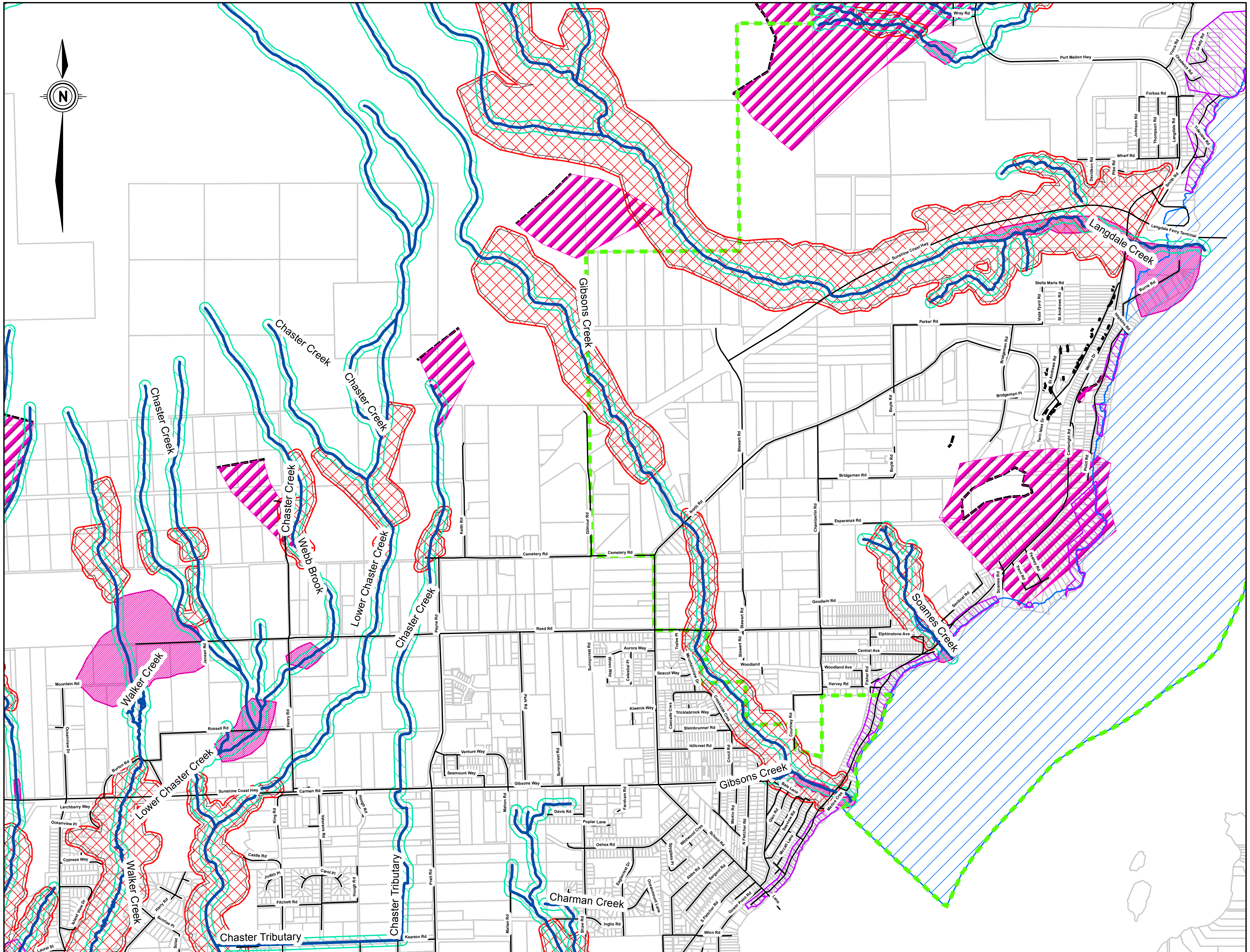
Geotechnical Hazards Report:
West Howe Sound
Sunshine Coast Regional District



Legend

- DPA Zone 1A: Coastal Flooding
- DPA Zone 1B: Coastal Slopes
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- Roads
- West Howe Sound OCP Boundary
- West Howe Sound Parcels

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Project No.	Date
724-024	May 2013

West Howe Sound Proposed DPAs (Sheet 2)

Figure 4-2

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Section 5

Guidelines for Development

5. Guidelines for Development

5.1 DPA 1: Ocean Hazards

A Development Permit on lands identified as being within DPA 1 is required 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.

Different hazards have been identified within the general category of "ocean hazards": applications for subdivision, building permit or land alteration shall include a report from an appropriately qualified Professional Engineer or Professional Geoscientist that considers all relevant potential ocean hazards.

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.

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.		

A regional study may be appropriate for the Sunshine Coast to 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.

DPA 1B – Coastal Slopes Guidelines

If applicable, the report shall include the following:

- Surveyed slope profiles with documentation of the limits of slope instability. Consideration shall 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 shall also 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

A Development Permit on lands identified as being within DPA 2 is required 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 2A/C/D – Creek Corridor / Floodplain / Low Channel Confinement Guidelines

- A review of the property by an appropriately qualified Professional Engineer or Professional Geoscientist shall be required as part of a development permit review process. The report shall include an 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.
- Flooding and associated creek processes are subject to assessment 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 shall consider upstream channels and floodways, debris dams, culverts, sources of debris (channels and eroded banks) and related hydrologic features.

- Analysis shall 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.

DPA 2B – Ravines Guidelines

- 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.
- Development within ravine slope setbacks will be subject to the reporting requirements for DPA 3.
- A field definition of the required setback from the top of a ravine or other steep slope.
- The report shall 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.

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

- Where identified as a possible mechanism (Table 3-2), potential debris flow and debris flood creeks shall be assessed by an appropriately qualified professional. 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) around debris flow or debris flood creeks shall 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).

5.3 DPA 3: Slope Hazards

A Development Permit on lands identified as being within DPA 3 is required 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.

Both open slope failures and rockfall hazards fall within this DPA. Applications for subdivision, building permit or land alteration shall 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 shall include the following:

- Slope profiles with documentation of the limits of slope instability shall be provided. Consideration shall 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 shall also 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 rock fall shadow area, including an indication of the appropriate buffer zone and required protective works.

5.4 Exemptions

The following general exemptions may be granted 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.
- 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 2 trees over 20 centimetre diameter breast height or 10 square metres of vegetated area of per calendar year per lot, provided there is replanting of 4 trees or re-vegetation of the same amount of clearing.

5.5 Report Submission

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