Ausenco Sandwell

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Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use

Guidelines for Management of Coastal Flood Hazard Land Use

27 January 2011

Ausenco Sandwell

Revision Status

Revision	Date	Description	Contributors FirstName LastName	Position Title	Reviewer FirstName LastName	Position Title	Approver FirstName LastName	Position Title	Signature
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Ausenco Sandwell

1 Introduction and Application of This Document

1.1 General

This document provides guidelines for the management of lands that are exposed to coastal flood hazards arising from their exposure to the sea and to expected sea level rise due to climate change.

This document will supersede the related sections of the existing **"Land Use Guidelines 2004",** which means the Flood Hazard Area Land Use Management Guidelines, May 2004, prepared by the Ministry of Water, Land and Air Protection (now Ministry of Environment).

The existing document is focussed primarily on river flood risks and the existing section on exposure to flooding by the sea (Section 3.5) is essentially based on the historical slow rise in sea level on the coastlines of BC over the last century. Recent and future sea level rise is now understood to be occurring at faster rates and in the future is anticipated to be rising at a rate that is approximately 10 times faster than the historical rate.

This document provides guidelines intended to help local governments, land-use managers and approving officers develop and implement land-use management plans and make subdivision approval decisions for lands exposed to coastal flooding hazards and Sea Level Rise (SLR).

The Sea Level Rise (SLR) projections and potential responses considered in this document are drawn from the **Policy Discussion Paper 2010**[1]**.**

Current BC guidelines require flood-proofing behind dikes (i.e. raising the habitable areas of buildings to the Flood Construction Level); however, where sea dikes are upgraded to new design guidelines, as defined in the companion document **"Sea Dike Guidelines 2010"** [2], relaxation of flood-proofing guidelines may be considered. The relaxed flood-proofing must be compatible with the design of the sea dikes.

This document, and the companion document **"Sea Dike Guidelines 2010"** [2] are specific to flood hazards arising from the exposure of BC lands to the sea. In some locations, specifically river estuaries, the lands will also be exposed to other sources of flooding. These new documents are companion documents to the existing guideline documents which still address flooding hazards from rivers. Analysis of flooding hazards from all sources – rivers and the sea - will be required in estuaries.

1.2 Acknowledgment

Preparation of this document and its companion documents was made possible through funding by Natural Resources Canada's Regional Adaptation Collaborative program and administration by the Fraser Basin Council.

[1] Draft Policy Discussion Paper - Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use in BC. Rev 0". Prepared by Ausenco Sandwell for the British Columbia Ministry of Environment.

[2] Sea Dike Guidelines - Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use in BC. Rev 0". Prepared by Ausenco Sandwell for the British Columbia Ministry of Environment.

2 Background

2.1 Scope

This guideline document describes the principles for determining the exposure of low lying lands to a flooding hazard due to their exposure to the sea and provides guidelines and direction for their management.

2.2 Reference Documents

2.2.1 Standards and Guidelines

A national standard or guideline for the management of lands exposed to coastal flood hazards does not exist. This document is intended to provide guidance for coastal exposure in British Columbia.

2.3 Definitions

A summary of definitions and terminology used in this document is provided in Appendix A.

Where possible the same terminology and definitions as used in the existing document; **Land Use Guidelines 2004**[3] are used; however, as the existing terminology and definitions sometimes need modification, clarification or expansion to be appropriate for coastal conditions, in some cases new or revised terminology and definitions are proposed. It is recommended that the reader of the updated documents familiarize themselves with the updated terminology and definitions in Appendix A as necessary.

2.4 Updated Definitions

In the existing documents the definition of the management parameters; Flood Construction Level (FCL) and Setback, is based on the defined location of the Natural Boundary – a position defined in law, and in the existing definitions, but which has a tenuous technical basis. The Natural Boundary is a position that can be identified on an existing shoreline as indicated in Figure 2-1. It is not possible to identify the Natural Boundary for a future higher water level. Further background and discussion is provided in Appendix B.

A brief summary of necessary changes is provided below and is summarized in Figure 2-2.

In general terms the reference point for the FCL and for the Setback becomes centred on an estimated location for a future Natural Boundary, the location of which will change over time as sea level rises. The reference point can be estimated by defining:

1. The Designated Flood Level (as indicated in Figure 2-2)
2. An estimated future Natural Boundary location (as indicated in Figure 2-2):

The Designated Flood Level is defined as:

Designated Flood Level (DFL) = Future SLR Allowance
+ Maximum High Tide (HHWLT)
+ Total Storm Surge during Designated Storm

[3] **"Land Use Guidelines 2004"** means the Flood Hazard Area Land Use Management Guidelines, May 2004, prepared by the Ministry of Water, Land and Air Protection.

The expected location of the future Natural Boundary is then defined by estimating the additional influence of waves and their effect on the slowly changing shoreline. The elevation of this reference point, defined as the Flood Construction Reference Plane (FCRP), Figure 2-2, is defined as:

Flood Construction Reference Plane (FCRP) = Designated Flood Level (DFL) + Estimated Wave Effect

The Estimated Wave Effect can be defined to be 50 per cent of the calculated Wave Run-up on the estimated future shoreline. This percentage is based on an analysis of existing data (2010), described below, and may be revised as more information, including site specific surveys or detailed engineering investigations undertaken by qualified professionals, becomes available.

The role of the existing legal Natural Boundary is preserved for defining the Sea Level Planning Area, as also indicated in Figure 2-2.

The Flood Construction Level (FCL), which will also vary for a both a given target year, and a specific area, is defined as:

Flood Construction Level = FCRP + Freeboard

The Freeboard allowance should be the greater of:

- 0.6m, or;
- For flood proofing fill – the crest elevation of an equivalent sea dike (see Sea Dike Guidelines 2010)
- For exposed vertical building foundations – the wave-structure interaction;
- For tsunami areas – the runup elevation of the appropriate tsunami hazard.

Setbacks remain essentially unchanged.

Further details of the basis and relationship between the Existing Definitions and the Updated Definitions are provided in Appendix B.

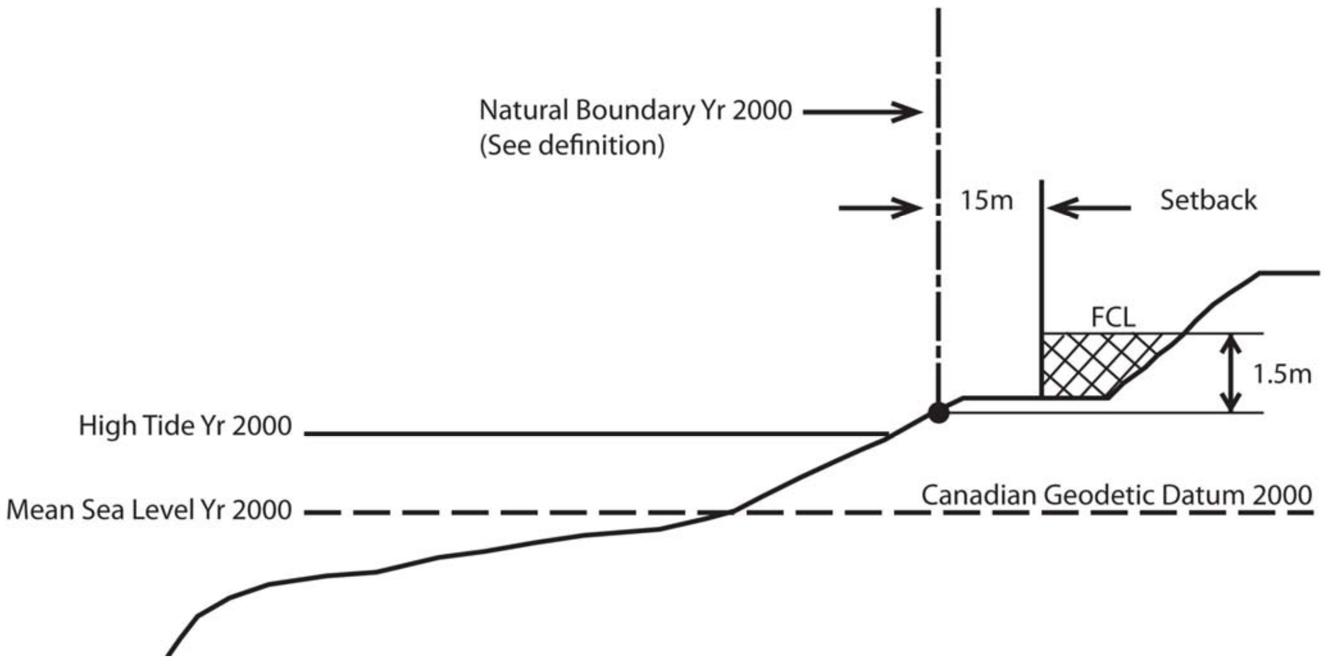

Figure 2-1: Existing Definitions for FCL and Setback

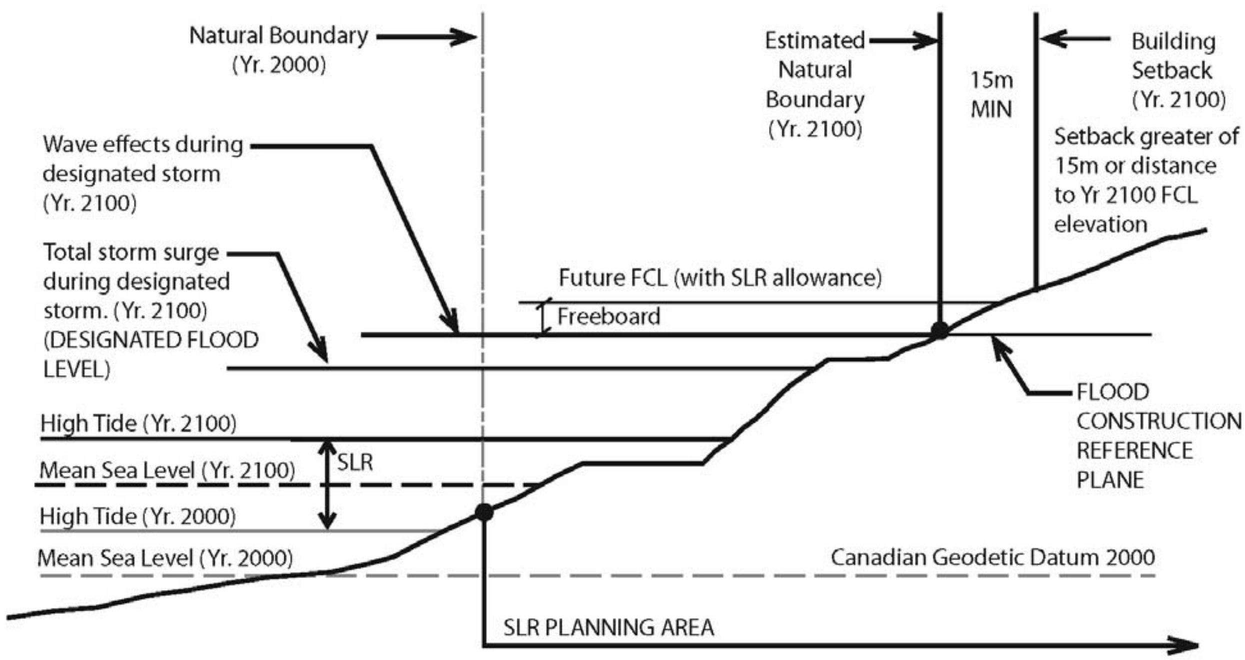

Figure 2-2: Definitions for Updated FCL and Setbacks

3 Climate Change Impacts on Coastal Land Use Management

This section is a summary of more detailed information provided in the companion **Policy Discussion Paper 2010**[1], and provides a background for management of land use, building elevations and related planning and approvals processes in areas that are at risk of flooding from the sea.

3.1 Incremental Sea Level Rise

Sea Level Rise is predicted to be moderate in the period from 2010 to 2025. However, the rate is predicted to increase more quickly in the period leading up to 2100, and then continue to increase steadily. For the purpose of this document the current definition of the expected Sea Level Rise is provided in Figure 3-1. The basis for this definition is provided in the policy document: **Policy Discussion Paper 2010**[1].

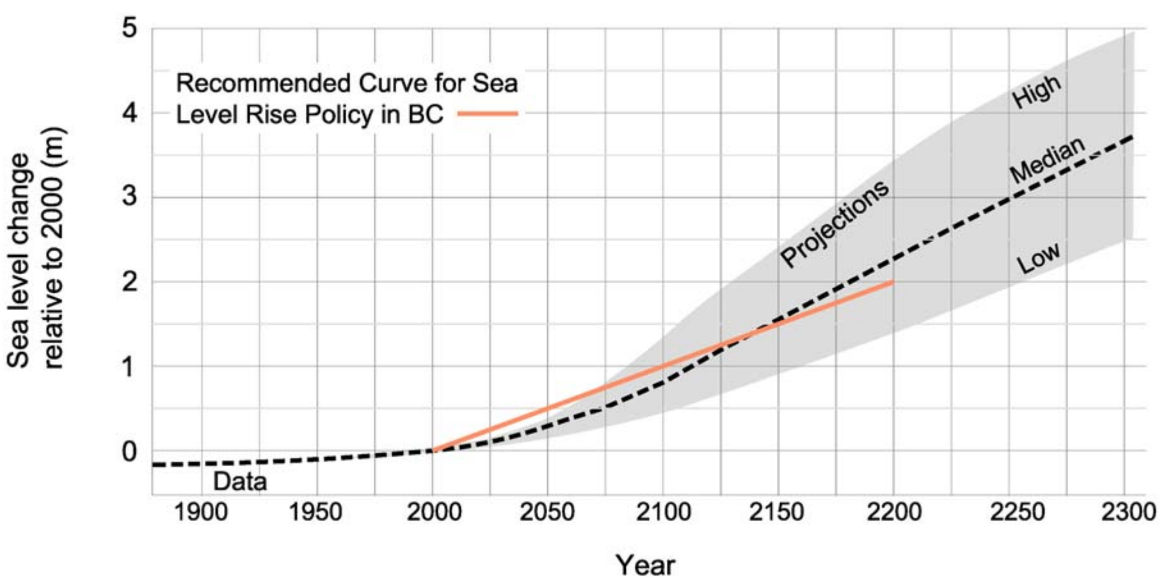

Figure 3-1: Projections of Global Sea Level Rise

Figure 3-1 illustrates the range of uncertainty in projections, showing a median projection, as well as a range in projections from low to high. The uncertainty increases into the future. To protect the large investment that buildings involve, and respecting current trends in SLR, a precautionary principle is followed to create the Recommended Curve for Sea Level Rise Policy in BC. As new SLR predictions become available with more accuracy, allowances for SLR in coastal BC areas may be adjusted, up or down, reflected in a change to these guidelines in the future.

The combination of certain sea level change - but at an uncertain rate into the future - creates complexity for the determination of Designated Flood Level (DFL) and related Flood Construction Level (FCL).

Both DFL and FCL will need to change over time as sea level rise continues. The pace of sea level rise and the arrival of more accurate projections will inform how often a revision to FCLs needs to take place. Given current information, a review in five years, and then again by 2025, as well as at least once every 25 years thereafter, is warranted.

3.2 Building Life Cycle and Sea Level Rise

In considering FCL in the face of an evolving sea level, it is necessary to consider the longevity of the buildings, structures or land use under consideration. A range of 50 to 100 years of practical service life is expected for most buildings, although some building life may extend well beyond that lifespan. Given the prospect of rising sea level, it is necessary to establish a FCL that anticipates a flood level applicable to the end of the lifespan of the proposed building.

Figure 3-2 illustrates how planning for the 100 year lifespan of a structure or land use brings future SLR increases into immediate focus. The graphic illustrates, in 100 year steps, how building elevations may need to be incrementally adjusted higher to accommodate gradual SLR.

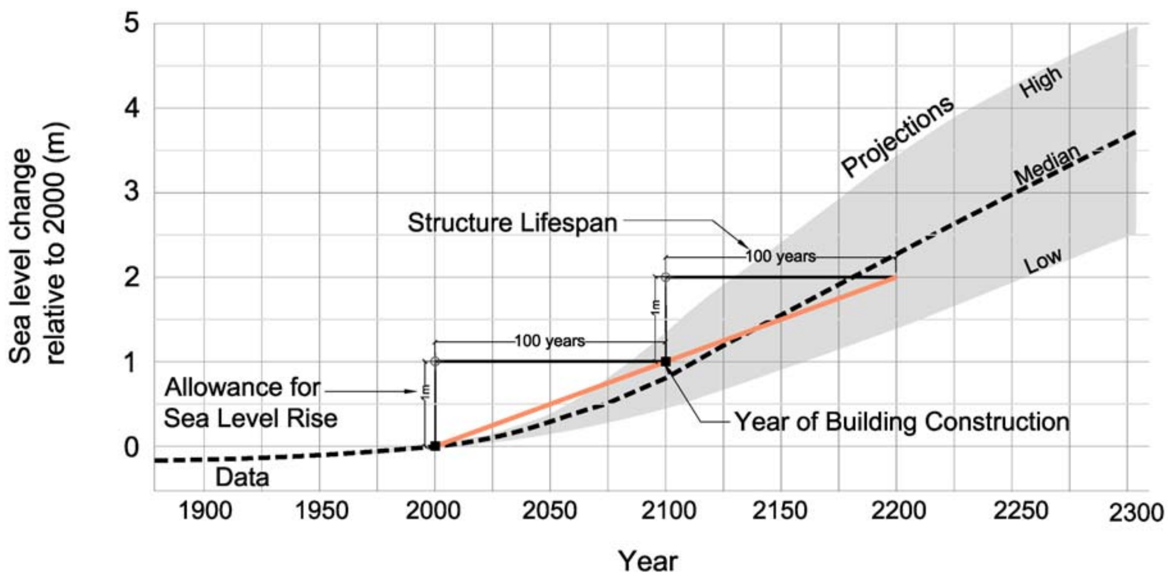

Figure 3-2: Incremental Sea Level Rise Effect on Planning for 100 Year Life Structures

For land use management guidance in BC, allowances for Sea Level Rise until the Year 2100 should be used in current planning and building approvals.

This guideline should apply for the period from 2010 until the next SLR review, which should be completed by 2015.

Figure 3-2 shows how high SLR projections could affect a building that has an expected lifespan extending to the Year 2100. An allowance of 1.0 m of SLR plus or minus regional effects (e.g. crustal uplift or subsidence) could be required. Figure 3-2 also extends the allowance out to the Year 2200, indicating that an additional SLR of approximately 1.0 m, for a total allowance of approximately 2.0 m, can be expected over the 200 year period.

SLR over the next centuries will continue to increase the pressure for ever higher building elevations to adapt to the risk of flooding from the sea.

3.3 Sea Level Rise and Building Flood Construction Level

In coastal areas, calculation of the Flood Construction Reference Plane (FCRP) and a Flood Construction Level (FCL) that reflects expected SLR is complex, and will vary depending on the local tide conditions, shoreline orientation and exposure and other factors that change allowances for local storm surge and wave effects.

An example of the calculation of the FCL for an exposed location at Victoria, where a recent surveyed elevation of a present Natural Boundary is available, is provided in Table 3-1, based on the existing guidelines; **Land Use Guidelines 2004**[3]**,** and for these updated guidelines, for application up to the years 2100 and 2200.

'**Guideline**' provides recommended values for current planning for the BC Coast for the indicated years as indicated in Figure 3-1. '**Possible**' represents the highest potential values as defined in the companion "**Policy Discussion Paper 2010**"[1] and indicated by the upper envelope curve in Figure 3-1. The "**Possible**" scenario is only included to illustrate the potential implication of the present upper bound of all global scenarios.

The updated estimate for 2010 in Table 3-1 shows that the change from relying on the elevation of the present Natural Boundary to one which is based on expected water levels makes no significant difference to the estimation of a FCL for 2010. The results in Table 3-1 also show that planning today for a FCL of 5.9 m CGD essentially means that anticipation of an extreme SLR by 2100 simply provides an allowance that may provide protection until the year 2200, depending on actual SLR.

Table 3-2 provides preliminary FCRPs and FCLs for various areas of the BC coast for the year 2100, based on the Recommended Sea Level Rise Curve in Figure 3-1 and annual exceedence probabilities (AEP) defined in the companion document **Policy Discussion Paper 2010**[1]. It should be noted that these preliminary values should vary due to a number of factors that are site specific, including: the local rate of crustal uplift or subsidence, the nature of the tides, anticipated local storm surge effects that depend on local bathymetry and the particulars of the anticipated storms associated with the storm surge. The preliminary values provided in Table 3-2 are provided for guidance. Further analysis is required to provide FCRPs and FCLs for specific sites.

SLR Planning Areas should be established along the BC Coast to provide a basis for local calculations and guidance on required Flood Construction Levels, and to provide a basis for management of the expected ongoing increases in SLR as it affects land use and buildings. Proposed terms of reference for SLR Planning Areas are introduced in Section 4

Table 3-1: Example Calculation of Coastal Flood Construction Level
Location: Exposed Waterfront - Victoria

<table>
<tr><th></th><th>Existing (2010)</th><th>Updated (2010)</th><th colspan="2">2100</th><th colspan="2">2200</th></tr>
<tr><td rowspan="2">Regional SLR Allowance [1] (above 2000 level)</td><td rowspan="2">0 m</td><td rowspan="2">0 m</td><td>Guideline</td><td>Possible [6]</td><td>Guideline</td><td>Possible [6]</td></tr>
<tr><td>0.88 m</td><td>1.88 m</td><td>1.76 m</td><td>3.16 m</td></tr>
<tr><td>High Tide (HHWLT) [2]</td><td rowspan="4">Existing Definition implicitly merges these all together to equal: Elevation of the Natural Boundary + 1.5 m Survey data from Victoria Waterfront shows elevation of the Natural Boundary ≈ 2.5 m CGD</td><td colspan="5">1.5 m CGD</td></tr>
<tr><td>Surge Allowance [3]</td><td colspan="5">1.3 m</td></tr>
<tr><td>Wave Effect Allowance [4]</td><td colspan="5">0.65 m</td></tr>
<tr><td>Freeboard [5]</td><td colspan="5">0.6 m</td></tr>
<tr><td>Flood Construction Level (FCL)</td><td>4.0 m CGD</td><td>4.05 m CGD</td><td>4.9 m CGD</td><td>5.9 m CGD</td><td>5.8 m CGD</td><td>7.2 m CGD</td></tr>
</table>

[1] Estimate based on Recommended Sea Level Rise in Figure 3-1 and an uplift rate of 1.2 mm/yr for Victoria

[2] Varies by site and location in BC, as defined in Tide Tables, Volume 5, CHS for Victoria

[3] Recommended value for a 1/500 yr AEP based on "**Policy Discussion Paper 2010**[1]" and assuming the Total Storm Surge equals the Storm Surge in deepwater.

[4] Based on wave runup on natural gravel – pebble beach shoreline.

[5] Assumes no Flood Proofing.

[6] Potential SLR levels at the High range of projections from scientific authorities.

Table 3-2: Preliminary Flood Construction Reference Plane (FCRP) and FCL for 2100 for Specific Areas in Coastal British Columbia

Elevations relative to CGD

	Fraser River Delta	Vancouver Harbour	Squamish River Delta	East Vancouver Island	West Vancouver Island	Central and North Coast
Global SLR Allowance	1.0 m					
Regional Adjustment [1]	+0.21 m	0 m	0 m	-0.17 m	-0.27 m	-0.22 m
High Tide [2] (HHWLT m CGD)	2.0 m	1.9 m	2.05 m	1.6 m	2.0 m	3.8 m
Surge Allowance [3]	1.7 m	1.4 m	1.3 m	1.3 m	1.3 m	1.7 m
Wave Effect Allowance [4]	0.65 m	0.65 m	0.65 m	0.65 m	0.65 m	0.65 m
Flood Construction Reference Plane (FCRP)	**5.6 m**	**5.0 m**	**5.0 m**	**4.4 m**	**4.7 m**	**6.9 m**
Freeboard [5]	0.6 m	0.6 m	0.6 m	0.6 m	0.6 m	0.6 m
Flood Construction Level (FCL)	**6.2 m**	**5.6 m**	**5.6 m**	**5.0 m**	**5.3 m**	**7.5 m**

[1] Based on current values for areas (Vancouver and Squamish taken to be neutral due to regional variations or present lack of site specific data)

[2] Varies by site and location in BC, as defined by CHS Tide Tables for areas, – Cowichan Bay used for East Vancouver Island – Tofino used for West Vancouver Island - Queen Charlotte City used for Central and North Coast.

[3] Recommended value for AEP based on “Policy Discussion Paper 2010” – includes allowances for local wind setup.

[4] Based on wave runup on natural gravel – pebble beach shoreline.

[5] Assumes no Flood Proofing, specific Building Foundation type, or Tsunami.

3.4 Adaptive Risk Management in the Face of Uncertainty

To provide balance between economic development objectives and the precautionary principle, an Adaptive Risk Management approach to Sea Level Rise is warranted.

Land use and building approvals based on FCL for 2100 should also include provisions for adaptive management of land uses to Sea Level Rise to the Year 2200 and beyond. The long term view should also apply when approval of a lot parcel or a building implies a change (increase) in the intensity of land use that extends beyond the life of building.

An Adaptive Risk Management Approach to SLR would plan how short term land uses and structures can be occupied with reasonable risk for their lifespan, but at the same time recognize and allow that future SLR may require the redesign to a higher elevation or relocation of the next generation of land uses and structures at a given coastal site.

The FCL and Setback for a given site may vary at the point that a building has ended its planned lifespan.

For example, a building constructed in 2010 with a 90 year lifespan would meet the guideline if sited to allow for SLR of 1.0 m minimum over Year 2000 levels plus or minus any regional adjustments. When rebuilt in or about 2100 this building would need to accommodate FCL at the time, which might be 2.0m higher than Year 2000 levels, requiring that the building FCL be 1.0 m higher than approved in 2010. The actual required FCL in the year 2200 will not be known with accuracy until much closer to that date.

In the building example above, there is ongoing economic use, with the costs of adaptation distributed through the centuries.

This approach will minimize the initial costs of considering SLR, and the future costs of adaptation.

Beyond examples of individual buildings, the SLR Planning Area approach described in Section 4 provides a method to gradually adapt larger scale land use patterns to SLR including impacts on drainage, access and other factors affecting the land use.

4 Sea Level Rise (SLR) Planning Areas

SLR creates serious risks for public health and property in lowlands on the BC coast. It is necessary to minimize the risk and costs of SLR, to both public and private interests, by proactive planning for future land use. SLR Planning Areas should be defined for both settled and new development areas that are at risk of SLR inundation or related erosion.

4.1 Extent of SLR Planning Area

This section describes how to determine the extent of SLR Planning Areas, and introduces the proposed scope of planning.

Figure 4-1 illustrates in concept the proposed SLR Planning Areas. They would extend from the existing Natural Boundary of the sea landward to the contour elevation of a future Flood Construction Level (FCL). Each SLR Planning Area would have two parts:

- SLR Planning Area Year 2100 would extend from Natural Boundary at the sea to the guideline FCL elevation projected for Year 2100.
- SLR Planning Area Year 2200 would extend from Natural Boundary at the sea to the guideline FCL elevation projected for Year 2200.

For the purposes of determining the extent of SLR Planning Areas, the presence of existing sea dikes or coastal defences should be ignored. However, if the Management Option selected for the Area is to protect the Area in perpetuity with sea dikes, then the design of the dikes should be considered in the determination of appropriate FCLs. Land use policies must then address the land needs required to upgrade the existing sea dikes.

Flood Construction Levels for SLR Planning Areas should be calculated specific to the local conditions of shoreline terrain and vegetation, tides, wind fetch and upland topography. Each location may have a different allowance for High Tide, Sea Level Rise, Storm Surge, and Wave Effects which together with Freeboard determine the FCL.

Planning policy and land use designations within the SLR Planning Area must consider how land uses can adapt to the projected future Flood Construction Levels.

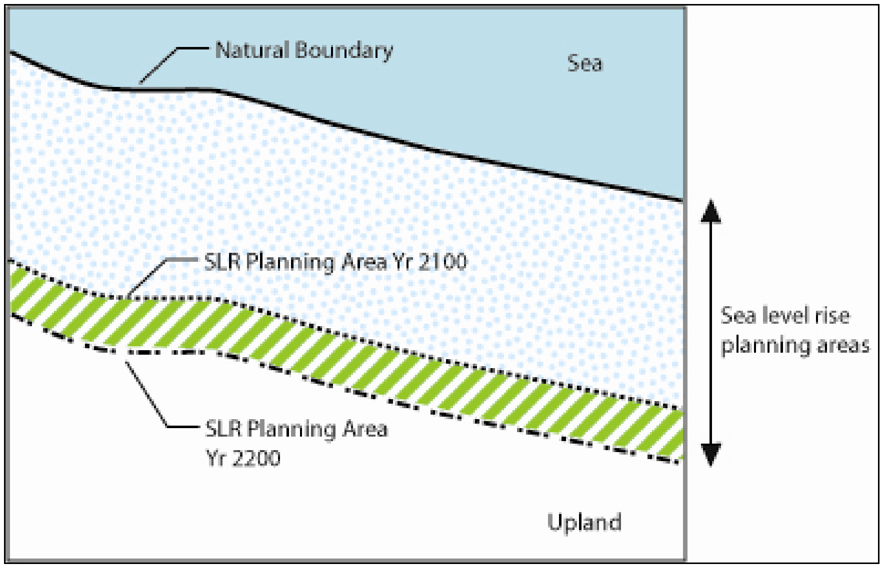

Figure 4-1: Concept Plan of SLR Planning Area

Figure 4-2 and Figure 4-3 show in section and plan the proposed SLR Planning Areas in estuarine locations where inundation levels are affected by river-based flooding as well as SLR.

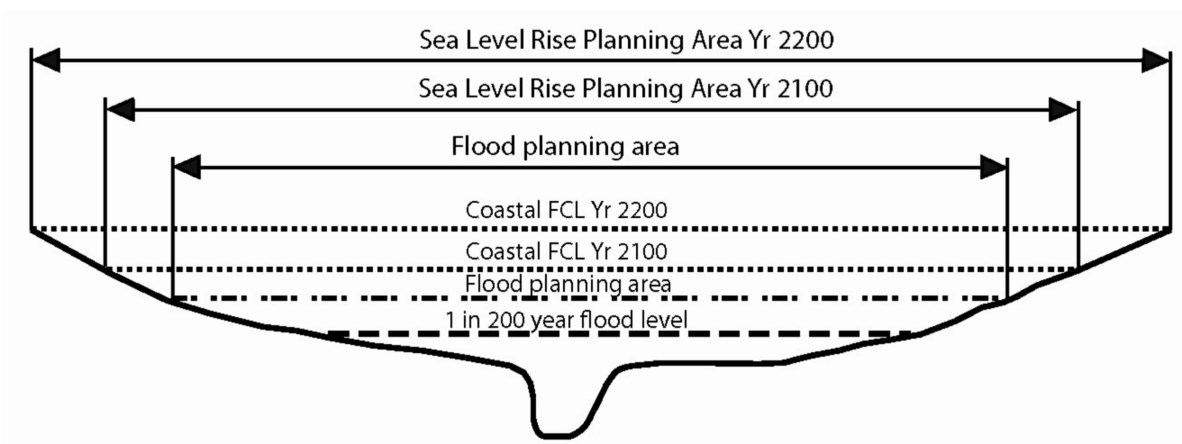

Figure 4-2: Concept Section of SLR Planning Areas at Estuary Floodplain

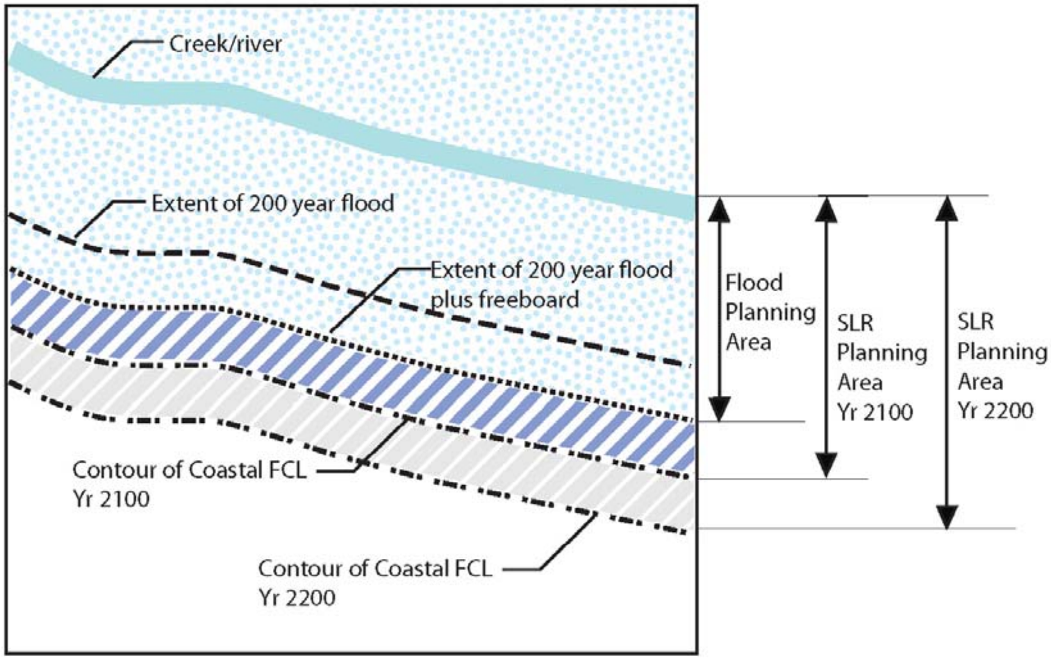

Figure 4-3: Concept Plan of SLR Planning Areas at Estuary Floodplain

4.2 Scope of SLR Planning

Scope of SLR Planning Area analysis, for both Year 2100 and Year 2200:

- Calculate local anticipated values of High Tide Level, Total Storm Surge and Wave Effects, and determine resulting FCL including Freeboard;
- Interpret approximate related location of the Estimated Future Natural Boundary;
- Establish a Setback line, shown as the greater of 15m from Estimated Future Natural Boundary or the Contour of the Future FCL; with consideration of potential shoreline erosion or accretion given the shoreline characteristics. It is the intent that all new buildings are provided a 15m setback, to protect from wave and related splash impacts on buildings which may be an increased risk due to SLR;

Scope of SLR Planning Area objectives, policies and guidelines,

- for the SLR Planning Area Yr 2100:
  - Establish requirements for new buildings to meet FCL and Setbacks in accordance with Provincial Guidelines, or to meet flood protection requirements as established by Qualified Professionals. Written design and construction standards from Qualified Professionals should be required for any variance to setbacks at the sea or coastal bluffs;
  - Identify adaptation measures for existing buildings, including approaches to minimize the impacts of flooding from the sea and provisions for evacuation during extreme storm events;
  - In consideration of zoning or rezoning applications; encourage or permit land uses that are compatible with coastal flooding risks;
  - Provide guidelines for land use practices that minimize the impacts of flooding on high value economic and environmental assets.

   - Require covenants on title of new buildings or properties to require buildings and land uses to adapt to future SLR and FCL requirements.

- for the SLR Planning Area Yr 2200:

   - Identify strategies on how proposed land uses and buildings can be adapted to guideline SLR, FCL and Setbacks that might occur in the Year 2200.

SLR Planning Area strategies may also include planning dates in addition to Year 2100 and 2200. For instance, existing buildings may have a lifespan that expires in about 2050, and the planning authority may deem it relevant to project requirements to building reconstruction at that date – perhaps by planning for FCL and Setback requirements for new buildings with a lifespan to Year 2150.

Some building uses may have a lifespan of shorter than 100 years. With assistance by Qualified Professionals, it is appropriate to consider whether these shorter lifespans could be considered for reduced approval requirements. However, approving officials are cautioned in these cases to ensure that proponents plan and covenant for adaptation of the next generation of buildings and land uses on the site to SLR at the Year 2100 and Year 2200 or other appropriate thresholds.

It is recommended that SLR projections and related FCL requirements should be reviewed in 5 years time (Year 2015) as well as Year 2025 and every 25 years after that at a minimum. The guidelines and requirements in SLR Planning Areas will need to be reviewed in these same intervals, with a focus on updating FCL elevation requirements, which may move up or down as projections for SLR become more accurate.

The term of SLR Plans will also move with the review intervals – with the general intent that SLR planning looks ahead approximately 100 and 200 years from the date of the plan. For example, in the Year 2050 the SLR Planning Area boundaries (FCL contours) may reflect Years 2150 and 2250.

4.3 Building Setbacks from the Sea

In un-diked areas, SLR will have the long-term effect of moving the Natural Boundary landward. This effect will be more pronounced on gently sloping shorelines or low coastal benches than in steeper shoreline terrain or where bedrock is present. Coastal Bluffs will require special consideration.

Sea Level Rise may increase the risk of coastal erosion and accelerate the retreat of shorelines. Higher risks will occur on sandy shorelines, with moderate risks at gravel or estuarine settings. The changes in risk will relate to increased frequency of wave action at shorelines and at the toe of related slopes or bluffs. The rate of retreat will be highly dependent on the wind and wave characteristics at the site and the material of the shoreline and backshore bluffs.

Where lands are to remain un-diked, setbacks for buildings from the sea must anticipate SLR for the lifespan of the building.

Figure 4-4 illustrates SLR to the Year 2100 in a relatively flat and rolling shoreline condition. SLR will increase the elevation of High Tide, and with storm surge, wave effects and freeboard added, the cumulative effect is to increase the Flood Construction Level (FCL) by an amount related to SLR and the local storm exposure. This increase in sea level and wave runup will gradually move the Natural Boundary to a higher level.

Building Setback should be established as '**the greater of 15 m from the future Estimated Natural Boundary or a distance to where the native land elevation equals the Flood Construction Level'.** This setback would apply to non-erodible bedrock cliffs as well as other shoreline types. In cases of coastal bluffs, greater setbacks would apply, consistent with the **Land Use Guidelines 2004.**

In Figure 4-4, the steep future shoreline means that the 15m minimum setback from Natural Boundary supersedes the FCL contour elevation.

In Figure 4-5, which illustrates the Year 2200 projected condition, additional SLR has moved the future Natural Boundary further inland, and combined with the increase in FCL has made the building constructed in 2010 not fully protected from the sea. The building is also likely to be at the end of its lifespan around 2100. Rebuilding on or after 2100 should undertake a MANAGED RETREAT, and respect the Year 2200 FCL and Setback.

If rebuilding is not proposed, the building will be at risk. Short of relocating the building, preparing the lower parts of the building to ACCOMODATE flooding from the sea should be required – through such measures as leaving only floodable uses such as parking on the lower floor, moving habitable quarters to the upper floor, or using water resistant materials on the lower floor.

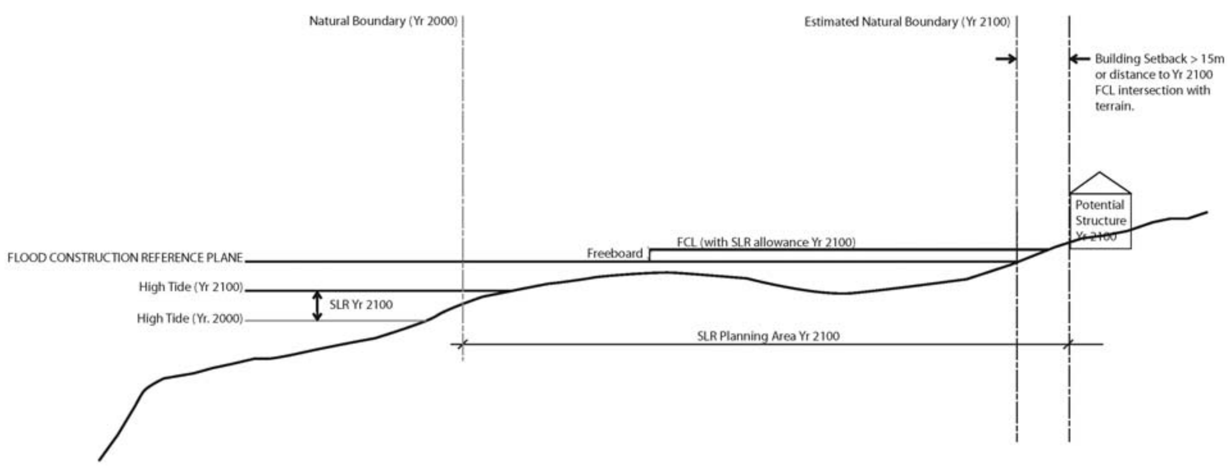

Figure 4-4: Concept Section of SLR Planning Area Yr 2100

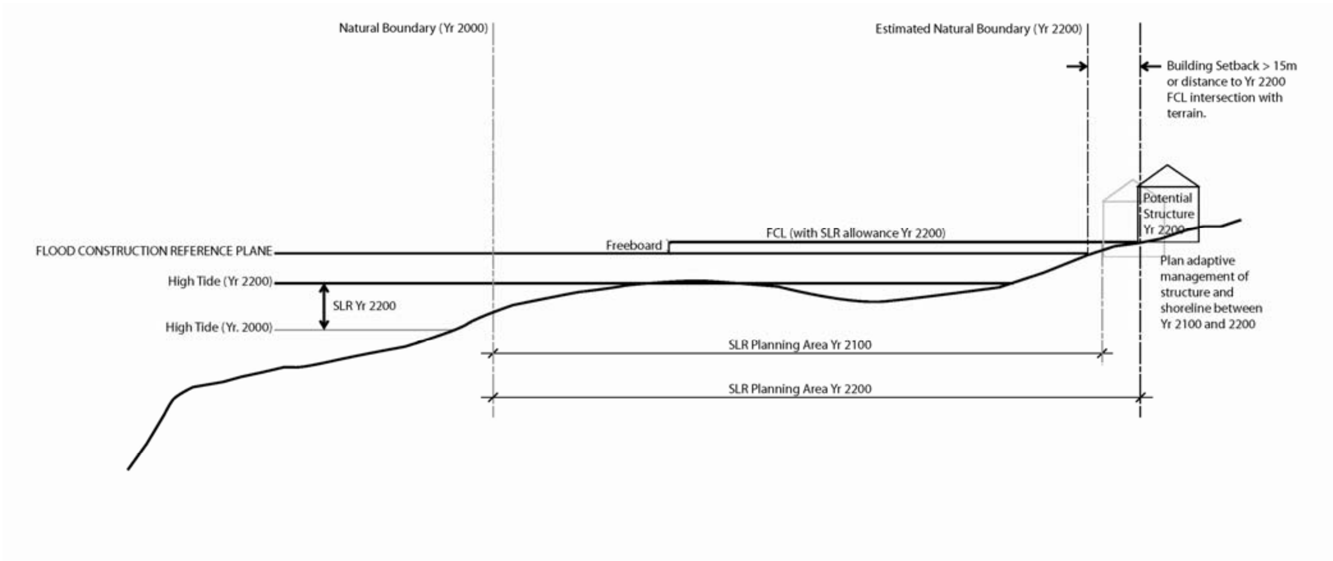

Figure 4-5: Concept Section of SLR Planning Area Yr 2200

4.4 Land Use Planning Strategies

Beyond concerns about individual buildings, the long-term nature of SLR provides an opportunity to minimize risks and impacts by land use planning strategies.

During planning for land use and development, careful mapping and planning strategies for SLR Planning Areas will minimize costs and hazards for both the public and private landowners / insurers.

Figure 4-6 introduces in plan view, the concept that a SLR Planning Area extent varies with shoreline and backshore terrain. Where shorelines are relatively steep and rocky, typical of bedrock points of land, the minimum 15m setback combined with a steep slope would mean the areal extent of SLR will be limited. In shoreline areas where gentle beaches, beach dunes and flat or rolling backshores exist, SLR impact could affect a considerable land area. A first step in land use planning for SLR is to establish the future FCL allowances for Year 2100 and 2200, and map the associated FCL lines on detailed contour maps. The SLR Planning Area lines will be, in effect, contour lines representing allowances for the FCL levels in Year 2100 and Year 2200.

Figure 4-7 shows typical planning responses, at the land use level, to risks of SLR in areas that will not be diked. An initial response should be to concentrate development outside the SLR Planning Area, to AVOID risks associated with SLR.

Increases in SLR will gradually move the natural boundary landward. Land use in the area that will be inundated in the future should be managed to adjust to the change in shoreline and to the increased risk of sea flooding during the Designated Storm. Uses such as agriculture, parks, open space and limited industrial or short-term uses would be preferred.

In cases of estuarine or coastal wetlands, the zone of wetlands may tend to move shoreward. Where coastal defences or existing rock geology stops the shoreline from moving, intertidal areas and their associated ecosystems are at risk of being 'squeezed out'[4]. SLR Planning should consider what areas of land should be set aside to allow migration of coastal ecosystems, or to support ecosystem restoration or habitat banking.

SLR Planning Areas, or applicant supported studies by Qualified Professionals, should also be used to customize building "setback" based on coastal risk assessments that consider how SLR combined with wave action and coastal geomorphology may alter shoreline locations, shape and backshore erosion. Guidelines for location of buildings should be based on these planning studies and the expected life of the at-risk asset.

Salinization of surface freshwater and groundwater may also increase in shoreline areas, potentially affecting both ecosystems and drinking water supplies from coastal wells. SLR Planning should consider how to mitigate the impacts of salinization. Drainage may also be impeded by higher groundwater levels.

Land managers may decide to PROTECT some parts of a SLR Planning Area by building a new dike or placing landfill to meet FCLs. If dikes are used as protection, such areas must meet the requirements of the "**Sea Dike Guidelines 2010**".

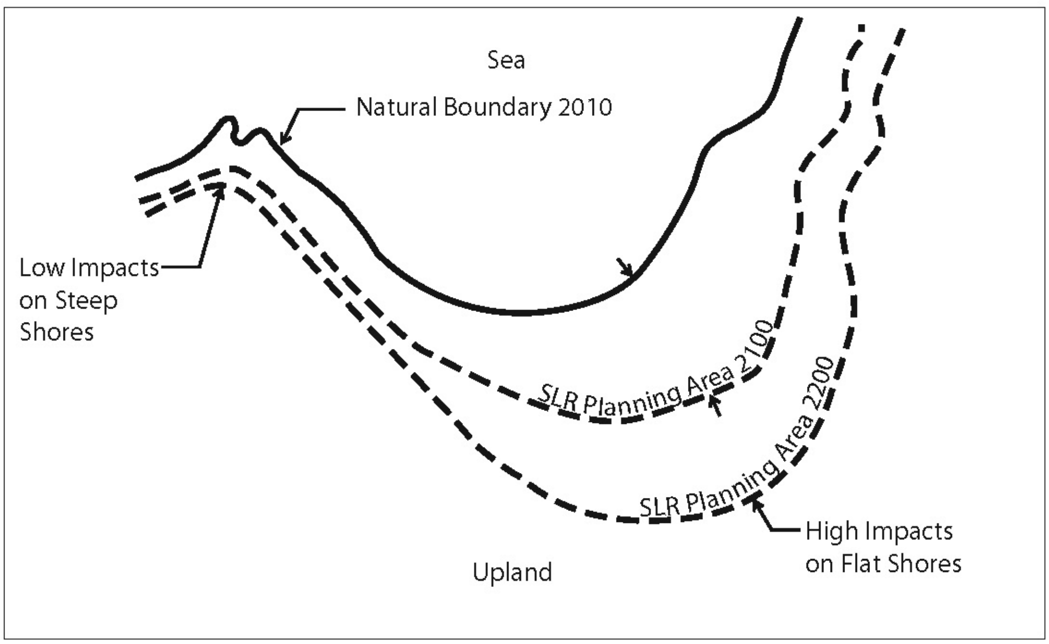

Figure 4-6: Concept Plan of SLR Planning Area Varying with Terrain

[4] *Technical Report on Local Climate Change Visioning for Delta: Findings and Recommendation Report,* prepared for Corporation of Delta, February 22, 2010, The Collaborative for Advance Landscape Planning at UBC

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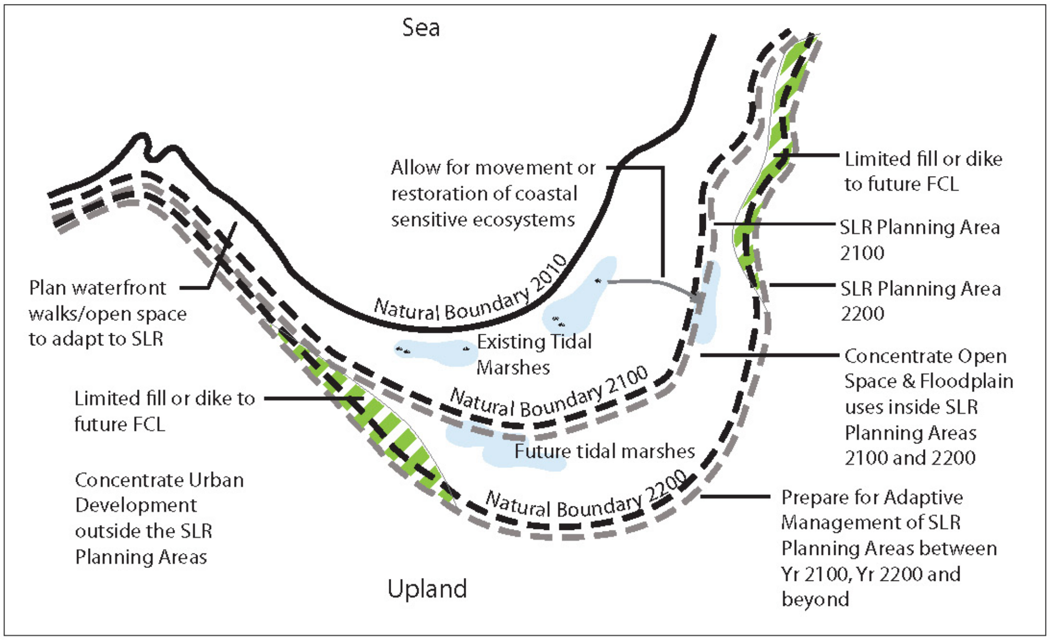

Figure 4-7: Concept Plan of Typical Planning Responses to SLR

For ease of land use planning administration within SLR Planning Areas, planning authorities may find it useful to establish 'areas' of similar planned structure lifespan, as opposed to allowing a mix of buildings with short, medium and long-term lifespans in a small area. Note, however, this requirement is not intended to discourage mixed land use communities. With new legislative support, a building lifespan requirement could be an added clause to a Development Permit Area or a Zoning Bylaw. Associated with the planned structure lifespan would be a FCL and shoreline setback. A covenant on title would provide legal notice that the FCL and setback rules may change for reconstruction at the end of the structure lifespan period.

However, the recommended planning approach is to set FCL based on a precautionary principle and a reasonably long building lifespan (i.e.100 years), and then allow those applicants that need to challenge these FCLs to commission studies by a qualified professional to consider the science and site conditions and recommend a site-specific and structure-specific FCL. This approach is similar to that used in the BC Riparian Area Regulation. In these cases a covenant on title would provide notice on the allowances and restrictions on the land use and structure use, and would give notice that future FCL levels may vary depending on future SLR projections and the lifespan of future buildings.

In the meantime until SLR Planning Areas are defined, local governments could consider adding requirements to development information statutes stating that applicants proposing to construct at elevations below those outlined in Table 3-2 provide Qualified Professional expertise to determine appropriate flood protection in keeping with the 2010 Guidelines. This would be an interim measure only until more cost-efficient neighbourhood scale SLR Planning could be done.

4.5 Zoning for Risk

Land Use Zoning should match land use permissions to the risk of SLR. An example of "Risk Zoning" is provided in Table 4-1.

Table 4-1: **Zoning for Risk Areas**
adapted from: **Policy Discussion Paper 2010**[1]

Zone	Planning Response
Little or no risk areas: Outside SLR Planning Area	• No constraints on planning due to flood risk
Low to medium risk areas: e.g.: SLR Planning Areas for Year 2200	• Not usually necessary to consider flood risk unless local conditions indicate otherwise. Suitable for development other than essential services. • A flood risk assessment may be required at upper end of the probability range (0.5% or 200 year average return period) or where the nature of the development or the local circumstances indicates heightened risk. Water-resistant materials and construction may be required. • Generally not suitable for essential civil infrastructure/services such as hospitals, fire stations, emergency depots. Where such services or infrastructure have to be located in these areas or they are being substantially expanded or upgraded, they must be capable of remaining operational and accessible during extreme flooding events.
Medium to high risk areas: e.g.: SLR Planning Areas for Year 2100	• Generally not suitable for essential infrastructure such as hospitals, fire stations, emergency depots, schools, ground-based electrical and telecommunications equipment. Flood proofing may be acceptable. • In areas already built up: May be suitable for residential, institutional, commercial and industrial development, provided flood prevention measures to the appropriate standard already exist, are under construction, or are planned as part of a long-term development strategy. In allocating sites, preference should be given to those areas already defended to that standard. Use water-resistant materials and construction as appropriate. • In undeveloped and sparsely populated areas: Generally not suitable for additional development of any type. Exceptions may arise if a location is essential for operational reasons; e.g., for navigation and water-based recreation uses, agriculture, transport or some utilities infrastructure, and an alternative lower-risk location is not achievable. Such infrastructure should be designed and constructed to remain operational during floods. • May be suitable for some recreation, sport, amenity and nature conservation uses provided adequate evacuation procedures are in place. Job-related accommodation (e.g., caretakers and operational staff) may be acceptable. New trailer or mobile home should generally not be located in these areas. • If built development is permitted, flood prevention and alleviation measures are required and the loss of storage capacity minimised. Water-resistant materials and construction as appropriate. • Land should not be developed if it will be needed or have significant potential for coastal managed realignment (retreat) or creation of wetlands as part of an overall flood defence.

5 Community/Land Use Planning and Hazard Management

Climate Change literature often refers to four main strategies to manage SLR:

- Avoid
- Protect
- Accommodate
- Retreat.

Each of these strategies has been named in prior examples. For a more in-depth description of each of these strategies, refer to the "**Policy Discussion Document 2010**".

5.1 Land Use Management Tools

Tools that local governments can use to apply one or more of the land use strategies discussed in this chapter include:

- Official Community Plans - hazard land identification and SLR Planning Area designation,
- Zoning bylaws – "risk zoning", as discussed above.
- S 910 Flood Plain Bylaw
- OCP Development Permit Area for Protection of Development from Hazardous Conditions – guidelines and requirements for developing in hazard areas.
- Restrictive covenants.
- Public education – about the hazards and ways that individuals can address them.
- Early warning and emergency preparedness programs.

Requirements for FCL and Setback in the planning documents would vary periodically in accordance with an Adaptive Risk Management approach – establishing new levels as Sea Level Rise projections become more defined.

5.2 On-Going Guidance

Examples of different methods of adapting to SLR in southern BC are under development by a parallel project also sponsored by the Natural Resources Canada Regional Adaption Collaborative (RAC)[5].

[5] http://www.fraserbasin.bc.ca/programs/bcrac/flood_planning_in_delta.html

6 Application to Lands Subject to Future Flooding

This section applies to land uses that are not protected by Standard Dikes. In areas protected by sea dikes that meet BCMOE requirements, FCLs may not apply and land use behind those sea dikes may not be restricted. Building setbacks will be required on the landside of dikes as needed for dike maintenance and to provide land for future dike raising and reconstruction.

Sea Level Rise will create an increasing risk of periodic inundation to existing low lying undeveloped lands along the BC Coast and in lower reaches of river deltas near the Coast.

These guidelines are not meant to preclude the use of these lands or of existing structures on these lands. The goal is to ensure that development of new structures or redevelopment/replacement of existing structures recognizes and can appropriately accommodate the projected impacts of sea level rise on coastal hazards and flooding over time.

6.1 General Guidelines - FCL and Setback

The FCL shall be established for specific coastal areas during the SLR Planning Areas process. FCL shall be a minimum elevation for habitable floor level or underside of wood construction, and shall be based on and include allowances for Year 2100 SLR and High Tide levels, associated storm surge and wave effects for the Designated Storm, and Freeboard.

Building Setback shall be the greater of 15m from the future Estimated Natural Boundary of the sea at Year 2100, or a horizontal distance until the natural ground elevation contour reaches the Year 2100 projected FCL. Landfill or structural support (e.g. pilings) for a coastal development shall be treated as a Dike structure – refer to the **"Sea Dike Guidelines 2010"** for guidance.

6.2 Subdivision of Undeveloped Lands

All lots created through subdivision shall comply with the general FCL and Setback guidelines noted above.

To regulate redevelopment at the end of the building lifespan, the development approving official shall require a restrictive covenant stipulation of reconstruction requirements to meet the FCL and setbacks in force at the time of redevelopment, and identifying the hazard, building requirements, and liability disclaimer if reconstruction does not take place at or before the planned lifespan of the building.

6.3 Development on Existing Undeveloped Lots

On existing lots, if meeting the guidelines noted above would sterilize the lot (i.e., not allow even one of the land uses or structures permitted under the current zoning), the development approving official may agree to modifying setback requirements as recommended by a Qualified Professional, provided this is augmented through a restrictive covenant stipulation of the hazard, building requirements, and liability disclaimer.

6.4 Lots with Coastal Bluffs

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 15m 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 15m 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 15m 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.

   Outside the Strait of Georgia, setback requirements would be similar but should be adapted to include tsunami effects. Land use specific provisions in the existing guidelines would still apply.

6.5 Renovations or Additions to Existing Buildings

Renovations to existing buildings within the existing footprint of the building are not affected by these guidelines.

Additions of up to 25% of the floor area, at the elevation of the existing building can be allowed, provided that the addition is no closer to the existing natural boundary than the existing building.

6.6 Reconstruction of Existing Buildings

Replacement or redevelopment of a building on an existing low lying lot must meet the new FCL and Setback guidelines. If meeting the new guidelines would sterilize the lot (i.e., not allow even one of the land uses or structures permitted under the current zoning), the development approving official may agree to modifying setback requirements as recommended by a Qualified Professional, provided this is augmented through a restrictive covenant stipulation of the hazard, building requirements, and liability disclaimer.

Outside of the Strait of Georgia the requirements would be similar but adapted to include Tsunami considerations and a 30m minimum setback. Land Use Specific provisions in the existing guideline would still apply.

Ausenco Sandwell

Appendix A – Definitions, Terminology and Acronyms

Ausenco Sandwell

Contents

1 Definitions

The incorporation of climate change related sea level rise considerations into existing BC Ministry of Environment documents is structured into three documents:

- **Draft Policy Discussion Paper 2010**
- **Sea Dike Guidelines 2010**
- **Guidelines for Management of Coastal Flood Hazard Land Use 2010**.

The definitions in these documents follow, where possible, the definitions and terminology that are either consistent with the existing documents or consistent with existing practise worldwide. In some cases existing definitions or terminology require modification or clarification for application to coastal flooding or sea dike application in a climate change driven sea level rise scenario.

Existing definitions are provided below in italics followed by any necessary modification, clarification or addition to the definitions or terminology in the existing documents.

Acronyms associated with the definitions that are used in the text are shown in brackets.

1.1 Annual Exceedence Probability (AEP)

The probability, likelihood or chance of a particular event (e.g., a storm or a storm surge) being equalled or exceeded in any one year. It is defined either as a number between 0 and 1 or as a corresponding percentage.

An AEP of 0.01 means there is a 1% chance of an event, of a given magnitude or larger, occurring in any single given year. An AEP of 0.01 or 1/100 yr also suggests that on average, under certain conditions, the Average Return Period, or interval between recurrences of this event, is approximately 100 years.

1.2 Average Return Period

Over a long period of time, the average number of years between occurrences of a particular event. In general, the average return period is the reciprocal of the AEP – the relationship is illustrated in the following table:

AEP probability	**AEP per cent**	**Average Return Period (years)**	
0.5	50%	2	**Probability decreases** ↓
0.1	10%	10	
0.01	1%	100	
0.005	0.5%	200	
0.001	0.1%	1000	
0.0005	0.05%	2000	
0.0002	0.02%	5000	
0.0001	0.01%	10000	

Using AEP to define the likelihood of hazard events is preferable to the average return period as return period can lead to a false sense of security created by the belief that the indicated number of years will pass before the next event of that magnitude occurs.

1.3 Designated Flood

A flood, which may occur in any given year, of such a magnitude as to equal a flood having a 200-year recurrence interval based on a frequency analysis of unregulated historic flood records or by regional analysis where there is inadequate streamflow data available. Where the flow of a large watercourse is controlled by a major dam, the designated flood shall be set on a site-specific basis.

In coastal areas, the existing definition of a Designated Flood is not appropriate as the probability of flooding from the sea is the result of the joint occurrence of tide and a storm crossing the coastal waters of British Columbia and at some time in the future, sea level rise due to climate change.

In estuaries, where a river discharges into the sea, the definition of the Designated Flood applies to the river.

In these documents the definition “Designated Flood” is replaced with the term “Designated Storm” as defined below.

1.4 Designated Flood Level (DFL)

The observed or calculated elevation for the Designated Flood and is used in the calculation of the Flood Construction Level.

In coastal areas, the Designated Flood Level (DFL) includes the appropriate allowance for future sea level rise, tide and the total storm surge expected during the designated storm.

1.5 Designated Storm (DS)

A storm, which may occur in any given year, of such a magnitude as to equal a storm having the designated annual exceedence probability (AEP).

The Designated Storm has several phenomena associated with it that will define components of the Designated Flood Level, including storm surge, wind set-up, wave run-up and overtopping for the storm. These include:

- A time series of atmospheric pressure during the passage of the storm over the area in question
- A time series of wind speed and direction during the passage of the storm over the area in question
- A time series of wave conditions, including wave heights, periods and directions during the passage of the storm in question.

1.6 Diking Authority

(a) *The commissioners of a district to which Part 2 of the* _Drainage, Ditch and Dike Act_ *applies,*

(b) *A person owning or controlling a dike other than a private dike,*

(b1) *If the final agreement of a treaty first nation so provides, the treaty first nation in relation to dikes on its treaty lands,*

(c) *A public authority designated by the minister as having any responsibility for maintenance of a dike other than a private dike, or*

(d) *A regional district, a municipality or an improvement district.*

1.7 Flood Construction Level (FCL)

Uses the Designated Flood Level plus an allowance for Freeboard to establish the elevation of the underside of a wooden floor system or top of concrete slab for habitable buildings. In the case of a manufactured home, the ground level or top of concrete or asphalt pad, on which it is located, shall be equal to or higher than the above described elevation. It also establishes the minimum crest level of a Standard Dike. Where the Designated Flood Level cannot be determined or where there are overriding factors, an assessed height above the natural boundary of the water-body or above the natural ground elevation may be used (as defined in the Land Use Guidelines 2004).

In coastal areas the FCL does not relate to the crest level of a sea dike, nor does it relate to the crest level of flood proofing fill exposed directly to the designated flood level. The FCL does; however, include wave – structure interaction effects, to be determined at the location of the site of the building.

1.8 Flood Construction Reference Plane (FCRP)

The vertical elevation of an estimated future Natural Boundary from which the FCL is determined.

1.9 Flood Plain

A lowland area, whether diked, flood proofed, or not, which, by reasons of land elevation, is susceptible to flooding from an adjoining watercourse, ocean, lake or other body of water and for administration purposes is taken to be that area submerged at the Designated Flood Level.

In coastal areas the concept of the Flood Plain has been extended to a "Sea Level Rise Planning Area"; defined below. Special measures may be warranted in this area.

1.10 Flood Proofing

The alteration of land or structures either physically or in use to reduce flood damage and includes the use of building setbacks from water bodies to maintain a floodway and allow for potential erosion. Flood Proofing may be achieved by all or a combination of the following:

- *Building on fill, provided such fill does not interfere with flood flows of the watercourse, and is adequately protected against floodwater erosion*
- *Building raised by structural means such as foundation walls, columns, etc.*
- *A combination of fill and structural means.*

In coastal areas exposed to flooding, construction of fill as a flood proofing measure may substantially increase the freeboard required to define the FCL, if the fill is directly exposed to the Designated Flood Level. In this case, the FCL must be equivalent to the crest level of a sea dike with the same characteristics as the seaward face of the fill..

1.11 Freeboard

A vertical distance added to the Designated Flood Level. Used to establish the Flood Construction Level.

In coastal areas, the vertical distance to be added to a Designated Flood Level is site and structure specific.

1.12 Natural Boundary

Means the visible high watermark of any lake, river, stream or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river, stream or other body of water a character distinct from that of the banks thereof, in respect to vegetation, as well as in respect to the nature of the soil itself (Land Act, Section 1). In addition, the natural boundary includes the best estimate of the edge of dormant or old side channels and marsh areas. For coastal areas, the natural boundary shall include the natural limit of permanent terrestrial vegetation.

Natural Boundary is an established concept in BC law – and reflects a change in vegetation and soil based on effects of the sea. In the **Flood Hazard Area Land Use Guidelines 2004,** building setbacks were established from Natural Boundary, on the unstated assumption that the location of Natural Boundary is relatively static (other than erosions and accretions).

Natural boundary is, in practice, often difficult to determine in the field or from remote survey. In coastal areas, the Natural Boundary reflects a snapshot historical record of tide, storm surge and wave runup effects, which may be the mark of a recent storm in an ordinary year or it may be the mark of the most severe storm in recent times. There is no way of knowing for certain. A technical basis for the Natural Boundary in coastal areas is site and time specific. In the future the location and elevation of a Natural Boundary will change from time to time due to changes associated with sea level rise and it will likely lag sea level rise. It is also unlikely to immediately reflect the action of the water, especially the storm surge and waves, during a Designated Storm.

1.13 Project Life

The number of years a particular project; including a sea dike, a building or a community, is intended to serve before it is replaced, upgraded or dismantled. Regular maintenance to ensure the project provides the intended purpose is expected during the project life.

1.14 Sea Dike

A dike, floodwall or any other thing that prevents flooding of land by the sea. As defined in the Dike Maintenance Act, "dike" means "an embankment, wall, fill, piling, pump, gate, flood box, pipe, sluice, culvert, canal, ditch, drain".

1.15 Sea Dike Crest Elevation

Sea Dike Crest Elevation has essentially the same meaning as "*dike crest height*" in the existing document "**Dike Design and Construction Guide 2003**". However, the existing definition of dike height suggests that consideration of wave run-up and set-up is optional. The term Sea Dike Crest Elevation is defined to specifically cover scenarios where wave run-up, overtopping and wind and wave setup must be included in defining the height of the dike.

1.16 Sea Dike System

A system of: dikes, dunes, berms or natural shorelines that provide a similar function; and associated engineering works (e.g., tidal gates, outfalls, outlet structures, seawalls, quay walls, ramps, adjacent building features, etc.) used to protect land from flooding or inundation.

In the Netherlands where dike systems are highly evolved, a dike system is termed a "dike ring" that forms the flooding defence for a region. There are approximately 95 such rings in the Netherlands and each ring is the responsibility of a separate organizational entity, subject to national overview.

In BC, multiple Diking Authorities may share responsibility for the same sea dike system.

1.17 Sea Level Rise (SLR)

An allowance for increases in the mean elevation of the ocean associated with future climate change, including any regional effects such as crustal subsidence or uplift.

1.18 Sea Level Rise Planning Area (SLR Planning Area)

An area of land that may be subject to future flooding due to Sea Level Rise. This area defines a future coastal flood plain. The SLR Planning Area extends from the existing Natural Boundary landward to the highest predicted point of potential flooding related to SLR plus flooding expected from the combination of high tide, total storm surge and expected wave runup during the Designated Storm.

Predictions of SLR for the SLR Planning Area definition shall use best predictions for minimum periods of 90-100 years and 200 years forward. From time to time, both the Natural Boundary and the predictions for SLR are subject to change, and therefore the extent of a SLR Planning Area may be revised at regular intervals in the future.

1.19 Seastate

The term "seastate" is used to encapsulate, in a general way, all of the parameters and characteristics that may be needed during design to define the waves at a given instant in time. The sea state is the general condition of the free surface of a body of water—with respect to wind waves and swell—at a certain location and moment. The sea state is characterized by statistics, including wave height(s), period(s), distribution and power spectrum. The sea state varies with time, as the weather or oceanographic factors change. For engineering purposes the seastate is often characterized by the significant wave height, H_s.

1.20 Setback

Means withdrawal or siting of a building or landfill away from the natural boundary or other reference line to maintain a floodway and to allow for potential land erosion.

1.21 Standard Dikes

Dikes built to a minimum crest elevation equal to the Flood Construction Level and meeting standards of design and construction approved by the Ministry of Environment and maintained by an ongoing authority such as a local government body.

1.22 Storm Surge

A change in water level caused by the action of wind and atmospheric pressure variation on the sea surface. The typical effect is to raise the level of the sea above the predicted astronomical tide level, although in some situations, such as when winds blow offshore, the actual water level may be lower than that predicted. The magnitude of a storm surge on the BC coast will be dependent on the severity and duration of the storm event in the North Pacific, its track relative to the BC coast and the seabed bathymetry at the site.

1.23 Total Storm Surge

The combination of the storm surge generated in deep water plus the additional local surge or wind setup generated by the effect of the winds during the Designated Storm over shallow water at a particular site. In general the deep water storm surge is nearly the same as that recorded at a tidal gauging station. Additional surge may occur at other sites. For planning purpose, winds during a Designated Storm will start to generate local surge in water depths less than 30 m.

1.24 Wave Run-up

The vertical distance that waves run-up the seaward slope of a structure or a shoreline. The vertical distance is measured from the mean water level, which is the same as the Designated Flood Level.

For coastal flooding hazard management the Wave Run-up is taken as 50 per cent of the calculated run-up elevation on the natural shoreline. This ratio is based on analysis completed for this assignment (2010) and may be revised as more information becomes available.

For defining a Sea Dike Crest Elevation the Wave Run-up is taken to be the vertical distance exceeded by no more than 2% of the waves during the Designated Storm at the toe of the sea dike

1.25 Wave Set-up

An increase in mean water surface close to the shoreline caused by wave action; important during storm events as it results in a further increase in water level above the tide and surge levels, landward of the location where waves start to break. Wave set-up will lead to larger waves existing at the seaward toe of a sea dike than might otherwise be expected.

1.26 Wave Overtopping

The passage of water over the top of a sea dike as a result of wave runup or related surge and setup. Water overtopping a sea dike may pass over the dike as a flow of water or as spray and the specific characteristics are site and structure specific.

1.27 Wind Set-up

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.

2 Acronyms and Symbols

2.1 CD

Tide and chart datum – in Canadian waters the plane below which the tide will seldom fall. Tide datum and chart datum is usually the same provided the chart is the largest scale available chart for area. For a site specific survey tide and chart (sounding) datum may be different and the specifics should be stated explicitly.

2.2 CGD

Canadian Geodetic Datum. In 2010 the vertical reference plane in Canada is in the process of being changed from a MSL related datum plane – technically known as CGVD28 – to a geoid based datum plan. The update program is described at http://www.geod.nrcan.gc.ca/hm/index_e.php. The term CGD is taken to mean the datum as defined in 2010 and approximately equal to MSL.

2.3 CHS

Canadian Hydrographic Service

2.4 CIRIA; CUR; CETMEF

European agencies sponsoring the “Rock Manual”

2.5 DPA

Development Permit Area

2.6 EA, ENW, KFKI

European agencies sponsoring the “EurOtop” Manual

2.7 GCM

Global Climate Model

2.8 GHG

Green house gases

2.9 $H_{1/10}$

Mean height of the highest 10 per cent of waves in a given seastate

2.10 H_s

Significant wave height – the mean height of the highest 1/3 of waves in a given seastate – approximately equal to the wave height estimated at sea by experienced observers.

2.11 HHWLT

Higher high water large tide

2.12 HHWMT

Higher high water mean tide

2.13 IPCC

International Panel on Climate Change

2.14 LLWLT

Lower low water large tide

2.15 LLWMT

Lower low water mean tide

2.16 MWL

Mean water level

2.17 QRA

Quantitative Risk Analysis

2.18 $R_{2\%}$

Wave run-up height exceeded by 2% of waves in a given seastate

Ausenco Sandwell

Appendix B – Fundamentals and Definitions for BC Coastal Flood Hazard

Ausenco Sandwell

Contents

Ausenco Sandwell

1 Introduction

The incorporation of Sea Level Rise considerations into an update of the existing documents for the BC Ministry of Environment is structured into three documents:

Policy Discussion Paper 2010

Sea Dike Guidelines 2010

Guidelines for Management of Coastal Flood Hazard Land Use 2010

To aid the reader in understanding the updates to the existing documents there is a need to understand fundamental concepts and definitions relating to BC Coastal Flood Hazards. This Appendix provides a summary of the fundamental concepts and definitions.

2 Fundamental Concepts in BC Coastal Flood Hazard

The existing document: **Flood Hazard Area Land Use Guidelines 2004** was focussed on river flood risks. The section on flooding by the sea (Section 3.5) did not fully anticipate sea level rise and assumed a static sea level.

Sea Level Rise (SLR) is now understood to be a certainty in the future and very likely to result in an increase of 1.0 m by 2100. However, the rate and height of SLR has considerable uncertainty. The **Policy Discussion Paper 2010** summarizes the range of projections for SLR that apply to BC.

Figure B1 illustrates the elements relating to the risks from the sea in the existing **Flood Hazard Area Land Use Guidelines 2004.**

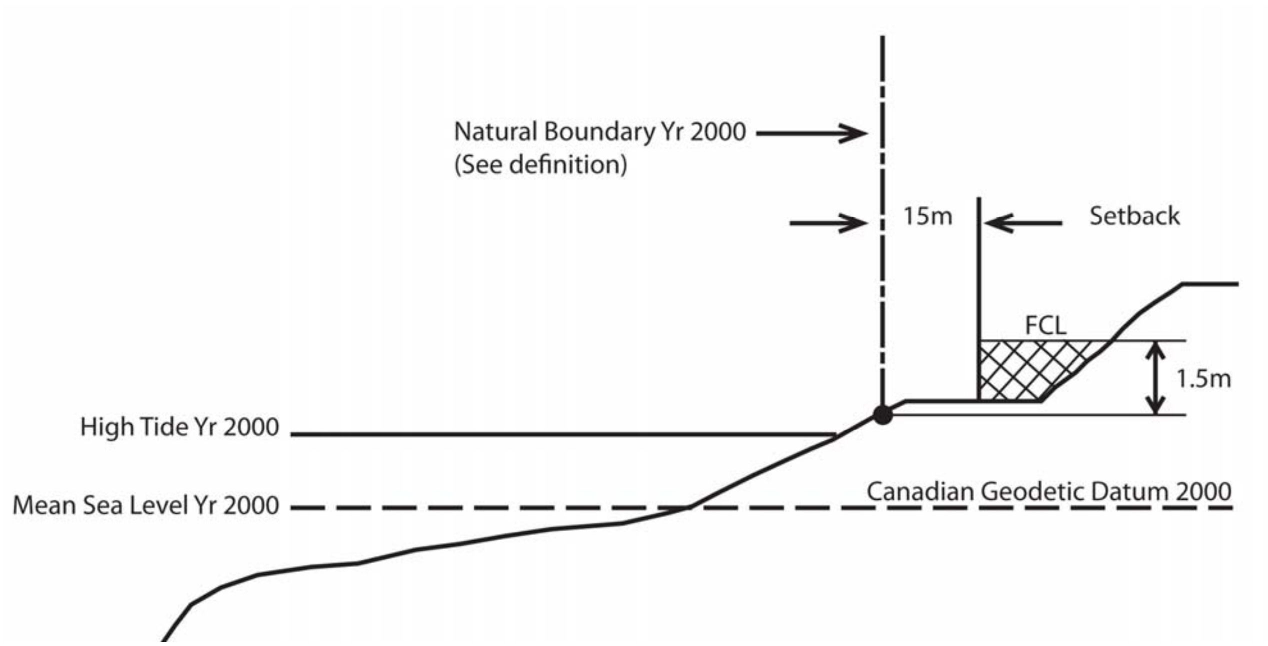

Figure B1: Coastal Flood Hazard – Existing (2004) Definitions

In Figure B1, Mean Sea Level is essentially the same as the terrestrial vertical datum plane of Canadian Geodetic Datum = 0 m. The tides, which are nominally centred about mean sea level, are established by the definable gravitational interactions between the earth, the sun and the moon and are reasonably predicable. Although the difference between mean tide and high tide varies from place to place and from time to time, these levels are defined by the Canadian Hydrographic Service and available for many locations in coastal British Columbia.

The Natural Boundary shown on Figure B1 is an established concept in BC law – and reflects the change in vegetation and the soil based on effects of the sea. In the **Flood Hazard Area Land Use Guidelines 2004,** building setbacks were established from Natural Boundary, on the assumption that the location of Natural Boundary was relatively static (other than erosions and accretions).

The Natural boundary is, in practice, often difficult to determine in the field or from remote survey.

Flood Construction Level (FCL) is established in the 2004 Guidelines as a general minimum of 1.5m above the elevation of the Natural Boundary at the Sea. There are several exceptions to these guidelines, including:

- Coastal Bluffs, where the toe is closer to the Natural Boundary than 15m, or when the toe is subject to coastal erosion.
- Bedrock or designed shore protection might allow a reduced setback.
- Lands behind Standard Dikes have setbacks and minimum elevations established in the Sea Dike Guidelines.
- Lands outside the Strait of Georgia are subject to tsunami hazard, and that generally prevails over the sea flooding guideline;
- Lands exposed to other sources of flooding e.g. from river estuaries, may have flooding hazards that are higher than the requirements for a hazard from the sea.

Figure B2 provides a more detailed interpretation of the flooding concepts for the sea in the the existing **Flood Hazard Area Land Use Guidelines 2004.** In particular:

- The location of the Natural Boundary is generally higher and further inland than the location of the line marking predicable High Tide. Two natural processes essentially then define the location of Natural Boundary:
    - o The water level during an “ordinary year”, which results in water and wave actions strong enough to mark the shoreline sediments in a distinct manner. Implicitly this suggests that it is likely associated with a commonly occurring storm or “Ordinary Storm”.
    - o Wave related actions during the ‘Ordinary Storm’.
- the 1.5m additional vertical requirement that defines the Flood Construction Level therefore needs to account for two additional considerations:
    - o an additional allowance for storm surge and wave effects for conditions greater than the “Ordinary Storm”.
    - o A Freeboard allowance.

These considerations are shown in Figure B2. If a freeboard allowance of 0.6 m is considered, based on the freeboard allowance in the existing companion document **Dike**

Design and Construction Guide 2003[1], then an amount of 0.9 m remains to account for storm surge and wave effects for conditions greater than the “Ordinary Storm”. An allowance of 0.9 m is a reasonable allowance in many situations to allow for a rise in the total water level during a severe storm.

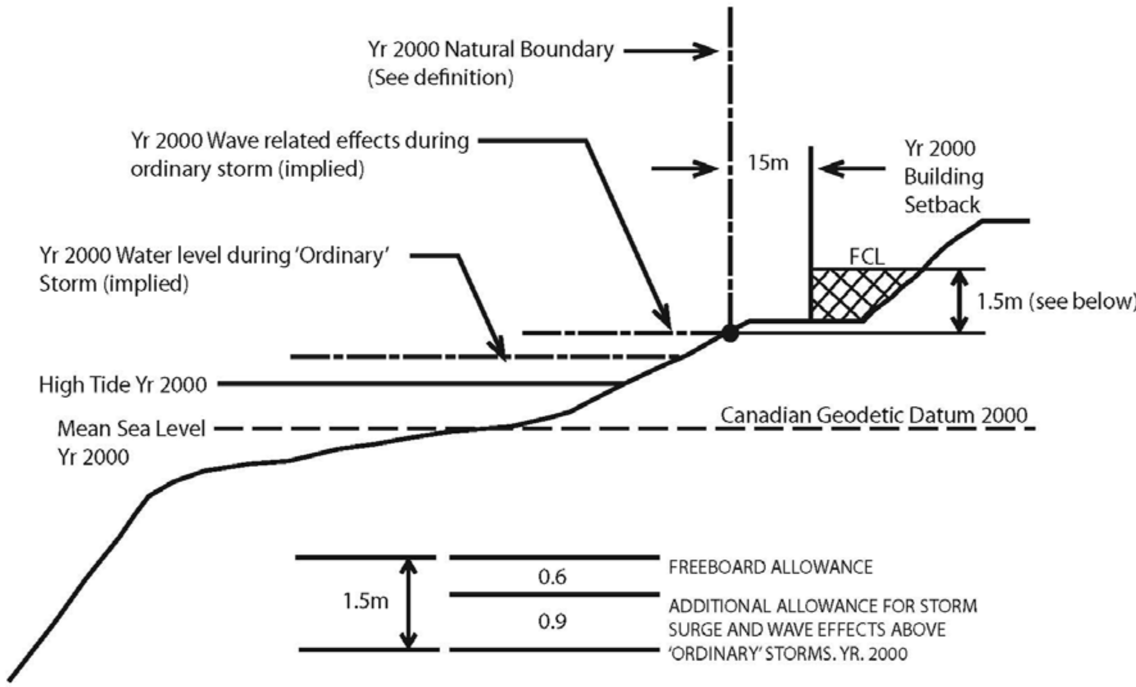

Figure B2: Coastal Flood Hazard - Interpretation of Existing 2004 Definitions

Figure B3 extends this interpretation of the Existing Definitions to include a specific allowance for Sea Level Rise (SLR) and the expected effects during a ‘Designated Storm’ – i.e.: a storm that meets a stated risk criteria. These combined influences define the total water level expected at any time in the future for any designated annual exceedence probability (AEP). (See Definitions in Appendix A).

[1] “Dike Design and Construction Guide – Best Management Practices for British Columbia”, July 2003, published by the Province of British Columbia, Ministry of Water, Land and Air Protection (now the Ministry of Environment)

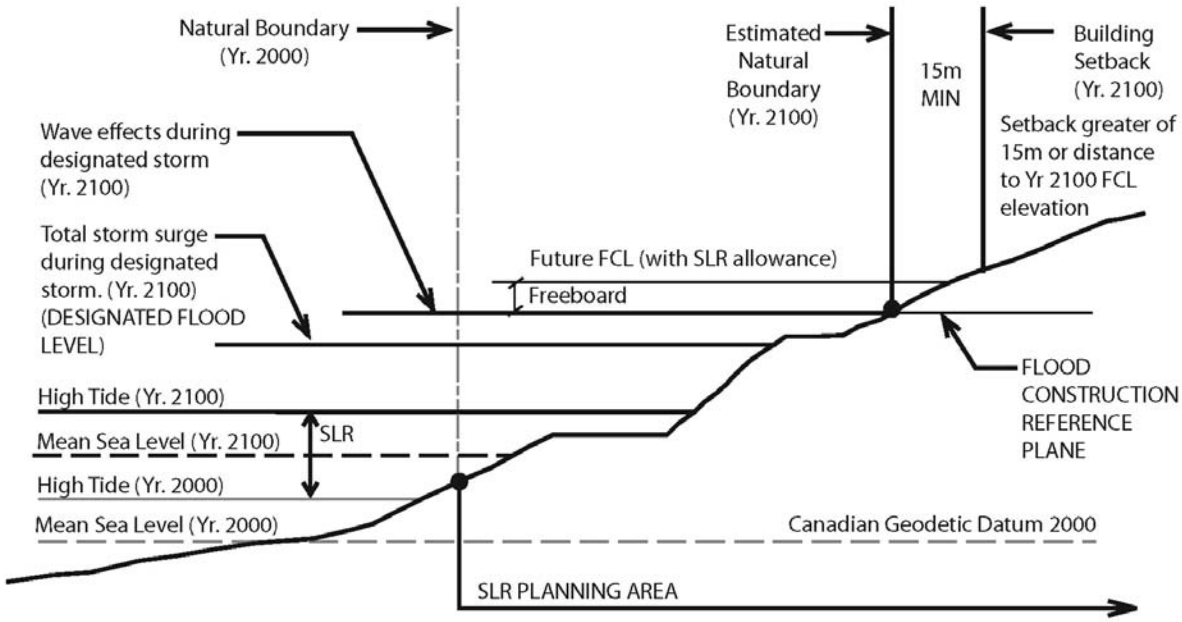

Figure B3: Coastal Flood Hazard – Adaptation for Climate Change

Sea Level Rise will gradually raise both the mean sea level (MSL) and the tidal levels along the BC Coast. Both MSL and tidal levels will rise in approximately equal amounts in response to SLR. For example, if the MSL rises 1.0m, all tide levels, including High Tide, also will rise by 1.0m. Over time this will mean that MSL is no longer approximately the same as the terrestrial vertical datum plane (CGD), unless the terrestrial datum plane is adjusted at the same rate.

As sea level rises, the storms that occur will leave a mark on the slowly changing shoreline. In particular the 'Designated Storm' will define; in conjunction with the local coastal exposure, the nearshore bathymetry, shoreline orientation and topography, a Total Storm Surge and an additional wave related runup (Wave Effects). The combination of antecedent storms and the Designated Storm will move the existing Natural Boundary landward to a new Natural Boundary location at the top of the wave affected zone. At any given time in the future, the actual mark of this tide, storm and wave action will reflect the latest storm events, which may or may not be "ordinary" and the response of the particular stretch of shoreline.

It is recommended that a combination of the 'Designated Flood Level' and an estimate of the expected shoreline response be used to establish the future Estimated Natural Boundary for planning purposes, as this is a more predictable and practical tool than relying on future vegetation or soil response interpretations, in particular when SLR changes may be faster than the new shoreline sediment or vegetation responds. It is also not clear that at any particular time the mark on the shoreline will reflect an "ordinary" year. The elevation of this Estimated Natural Boundary location is defined as the Flood Construction Reference Plane (FCRP).

To calculate the FCL a Freeboard allowance is added above the Flood Construction Reference Plane (FCRP) to allow for uncertainty. This Freeboard allowance may include uncertainties in the future changes to storm surge, wave run-up, and the effects of sea level rise on delta flooding and coastal sediment supply.

The Freeboard allowance should be the greater of:

- 0.6m, or;
- For flood proofing fill – crest elevation of equivalent sea dike (see Sea Dike Guidelines 2010)
- For exposed vertical building foundations – the wave-structure interaction;
- For tsunami areas – the runup elevation of the appropriate tsunami hazard.

In summary the general concept for calculating Future Flood Construction Level with SLR Allowance is:

- Future SLR Allowance +
- Maximum High Tide (HHWLT) +
- Storm Surge During Designated Storm +
- Wave Effects During Designated Storm +
- Freeboard Allowance

The FCL calculation will vary for a given target year, and will vary for local areas in calculation of both High Tide as well as storm surge and wave effects.

Appendix C – Sample Planning Wording

Ausenco Sandwell

Contents

Ausenco Sandwell

1 Sample Planning Wording

The Official Community Plan Policies Template (Form 1, Appendix B of the existing guideline document **Land Use Guidelines 2004**[1]) should have the following statement appended:

"In coastal and estuarine lowland areas of BC, Sea Level Rise may increase the risks of flooding to existing and proposed developments. The OCP text and maps describe Sea Level Rise Planning Areas and associated Flood Construction Levels based on best current Sea Level Rise projections. The OCP and maps describe the locations and Flood Construction Levels for buildings based on the planned building lifespan. Where buildings are to be constructed within the SLR planning area, they shall be subject to a restrictive covenant stipulation of the hazard, building requirements, and liability disclaimer"

The text of the OCP should also state that the policies related to Sea Level Rise will be subject to refinement as more data and information becomes available on SLR elevations and risks for the plan area.

[1] Flood Hazard Area Land Use Management Guidelines, May 2004, prepared by the Ministry of Water, Land and Air Protection (now Ministry of Environment)