December 11, 2013

Our File: 2221-48783-0/2.0

City of Courtenay
830 Cliffe Avenue
Courtenay, BC
V9N 2J7

Attention: Lesley Hatch, P.Eng.
Municipal Engineer

Dear Sir:

RE: COURTENAY INTEGRATED FLOOD MANAGEMENT STUDY

Enclosed please find three [3] copies of the Courtenay Integrated Flood Management Study – Final. We are issuing the report as a second draft, to seek your input and comment.

We have completed all tasks set out under Change Order 6, which included a review of the hydrology and hydrodynamic modelling based on the review from the Provincial Diking Authority. The changes to the hydrologic assumptions associated with the 200 year return period flood have led to significant increases in upstream impacts due to potential mitigation options. Subsequently, we have reviewed the overall recommendations from the first draft, and have updated them accordingly. Overall, the key recommendations from the study remain consistent:

- The City should be looking at their bylaws and zoning and make amendments to reflect the recommendation herein with respect to Flood Construction Levels and reviews for developments within the floodplain.

- The Tsolum River Floodwall Concept would still provide benefit to the local area for more frequent floods like that experienced in 2009 and 2010 without significant impacts upstream. However, the Province would not support the project financially or allow the dike to be registered. This leaves the City to consider this independently, and should include all affected stakeholders (both positively and negatively) in the process.

- Larger diking schemes have higher upstream/downstream effects than previously reported. Should the City want to proceed with more significant mitigation schemes, they should consider the potential additional costs of the incremental effects to neighbouring land owners. These costs could include increased protection for properties outside the dike; upgrades to existing protected properties; negotiated compensation deals; and/or property acquisition.

The recommendations contained herein are based on all the assessments and consultations with you and the public stakeholders. These recommendations require your close scrutiny to ensure that they align with the City perspective.

We would be pleased to meet with you upon review to receive your comments and finalize the document.

Sincerely,

McELHANNEY CONSULTING SERVICES LTD.

Mark DeGagné, P.Eng.
Branch Manager

MD:dn
Encl.

Final Report

Courtenay Integrated Flood Management Study

Project No. 2221-48783-0
December 2013

McElhanney Consulting Services Ltd.
www.McElhanney.com

Contact: Mark DeGagné, P.Eng.
mdegagne@mcelhanney.com

Table of Contents

EXECUTIVE SUMMARY

The floodplain of the Puntledge, Tsolum and Courtenay Rivers overlaps with parts of the City of Courtenay, the Comox Valley Regional District and the K'ómoks First Nation. Seasonal flooding and related risks have been a historic concern. In January of 2012, the City of Courtenay received notice from the Province of BC that an application for funding under the BC Flood Protection Program had been approved. This Integrated Flood Management Study (IFMS) summarizes the completed hydrotechnical, environmental and socio-economic assessments.

The integration of the technical analyses with the public engagement process facilitates a direction for future planning of flood mitigation strategies. The proposed strategies range from conventional "hard" engineering measures, like diking, to softer strategies, including the cessation and/or retreat of development from the floodplain. The IFMS and mapping has reviewed flood risks, providing information that will support refinement of Flood Construction Levels. The work also identifies potential immediate flood mitigation strategies to reduce current risks.

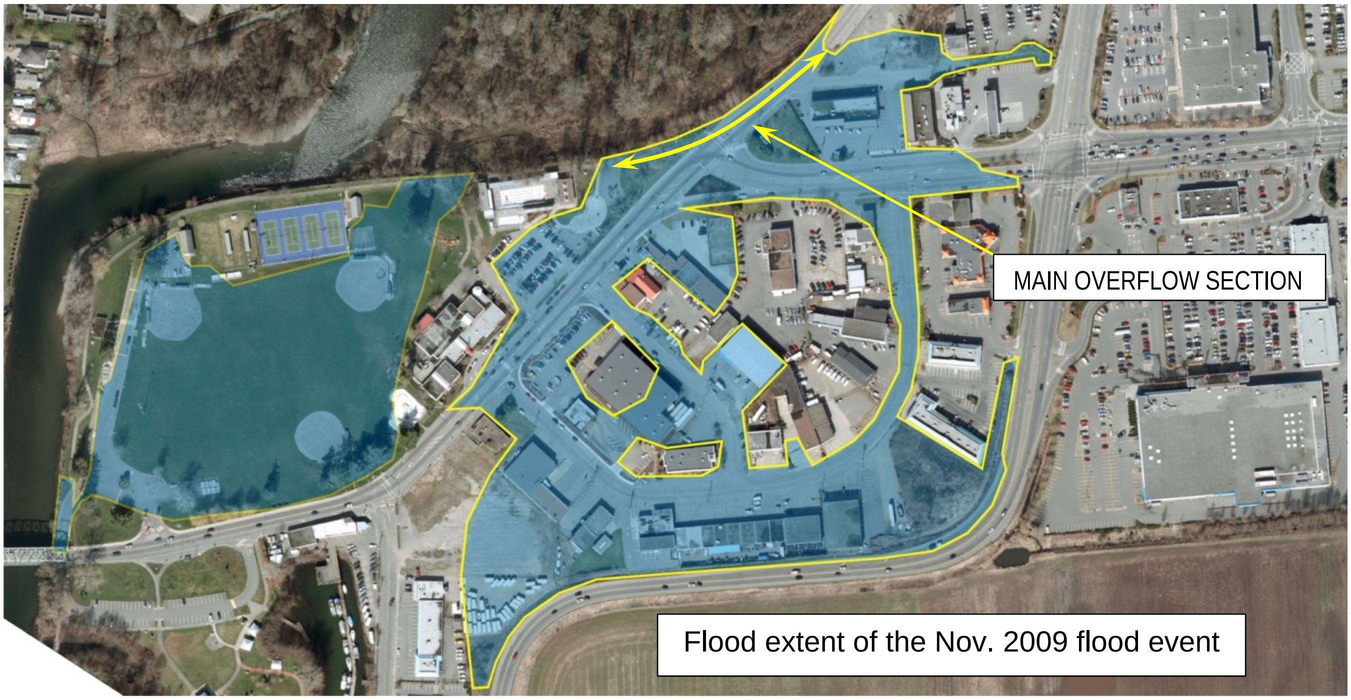
Throughout the process, the community has been engaged to solicit public and senior government sentiment and concerns associated with the flooding issues and to garner support for a preferred direction for flood mitigation. 5 stakeholder events were conducted, including:

1. An introductory event (June 28, 2012) for the public to provide information related to the scope and intent of the IFMS;
2. A regulatory review workshop (June 28, 2012) to ensure that all government information and policies relevant to the project were compiled;
3. Once preliminary results of flood modeling were known, an options community workshop (November 15, 2012) was held to introduce the approximate flood extents and general options for flood mitigation to community stakeholders;
4. Direct contact with First Nation representatives was undertaken on December 14, 2012; and
5. Draft recommendations were presented to the community at a final workshop held on January 30, 2013

The process produced an informative discussion of the issues and constraints surrounding flooding in Courtenay. Public stakeholders generally preferred the approach of managed retreat, which would see the floodplain restored to a more natural state over the very long term. The public acknowledged the need to protect existing assets in the short to medium term and emphasized the need to maintain key transportation links between east and west Courtenay.

Environmentally sensitive areas were mapped throughout the study area, identifying key areas requiring either further protection or enhancement for both flora and fauna. The general conclusion was that the Courtenay River and Estuary provide important rearing habitat for juvenile salmonids and that the diversity of upland habitats is also of concern.

The impetus for the study has been recent flood events in 2009 and 2010 that have inundated the Ryan Road Commercial Area, shutting down key transportation corridors between east and west Courtenay, and causing considerable amounts of damage. The hydrologic and hydraulic modeling have been completed and calibrated to these well documented events, which have been a result of a combination of the relatively high peak flows in the Puntledge River and/or Tsolum River in conjunction with high tides in Comox Bay.



The hydrodynamic modeling considered the following scenarios to determine current flood conditions, and expected flood conditions due to Sea Level Rise (SLR) and increased river flows resulting from climate change.

1. Existing conditions (2013) for a 200-Year flood considered the combination of high tides, storm surges and coincident peak river discharges from all tributaries to the Courtenay River
2. The "Year 2100" scenario considered the 200-Year event to include a 1m rise in sea-level and a 15% increase in peak river discharges due to climate change
3. The "Year 2200" scenario considered a further 1m rise in sea-level (total of 2m from present day), plus an additional 15% increase in peak river discharges due to climate change

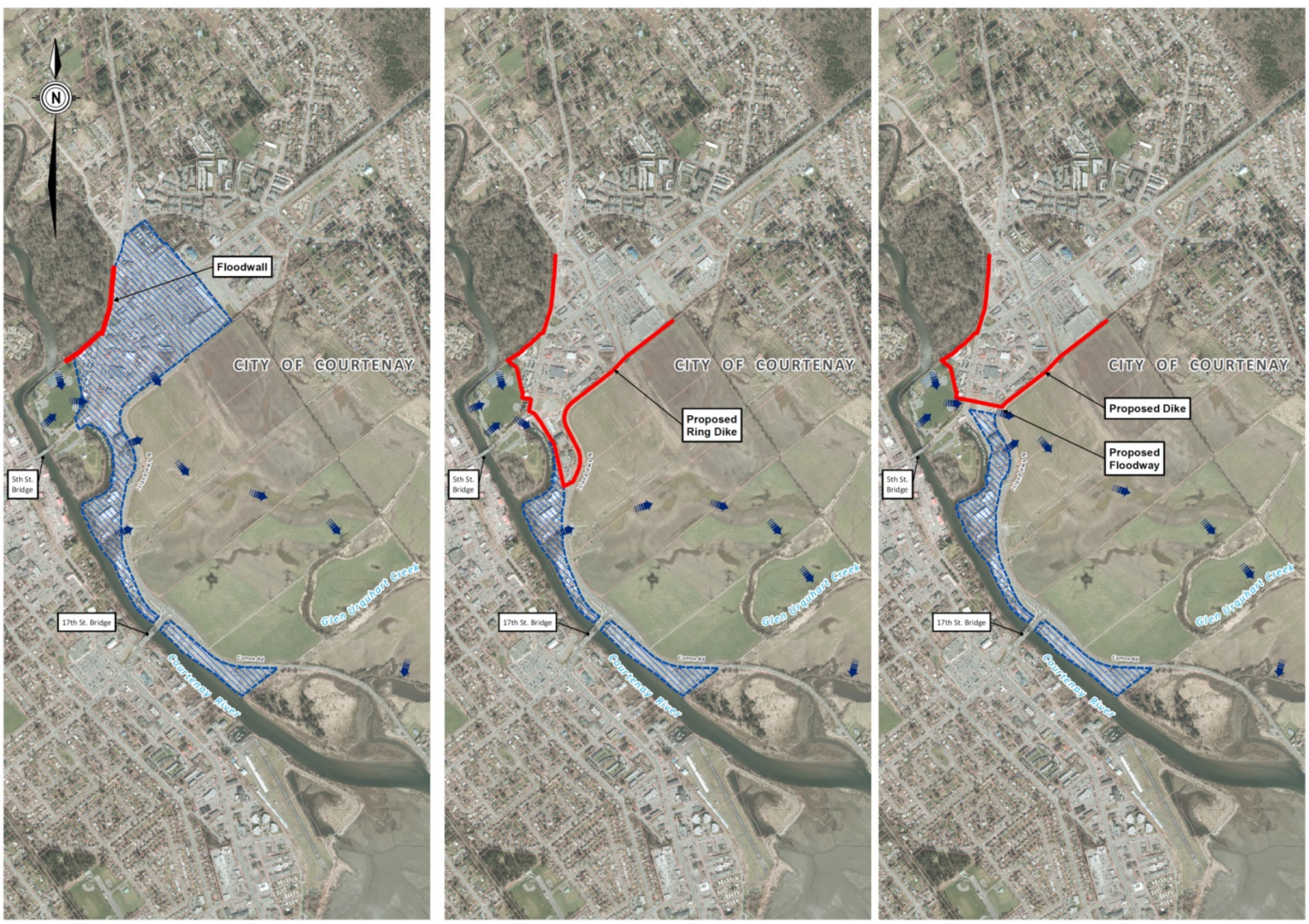
The resultant floodplain mapping shows the extent of flooding for each scenario, along with the recommended Flood Construction Levels (FCLs), for current conditions as a series of water surface contours lines.

Three flood mitigation strategies were also explored to assist Courtenay in planning for the future, both in terms of regulating development and potential infrastructure upgrades.

Option 1 proposes a floodwall along the Old Island Highway abutting the Old Tsolum Channel bank. The structure would be constructed from the west side of the Headquarters Road intersection to a connection point in Lewis Park, where the existing floodwall terminates.

Option 2 proposes the development of dike structures along the Old Island Highway north of Ryan Road, building a dike or raising the existing dike along the Old Tsolum Channel bank west of Old Island Highway then along the east boundary of Lewis Park, raising Comox Road adjacent to the Courtenay Slough and a section of South Island Highway and constructing a dike along the south-east boundary (behind SuperStore) of the commercial development area.

Option 3 proposes raising Old Island Highway north of Ryan Road, building a dike along the Old Tsolum Channel bank west of Old Island Highway and along the east boundary of Lewis Park and then from the Old Island Highway and Comox Road across the parking area to South Island Highway, raising the section of South Island Highway east of the new dike and building a dike to tie into the high ground along the south-east boundary of the commercial/industrial development area.



OPTION 1 - Floodwall Option | **OPTION 2 - Ring Dike Option** | **OPTION 3 - Partial Ring Dike and Floodway Option**

A review of the options considering the technical, socio-economic and environmental costs and benefits is summarized on the table below.

Review Criteria	Option 1 Floodwall	Option 2 Ring Dike	Option 3 Ring Dike/Floodway
200-Year Flood Levels Upstream Changes*	0.10 m	0.41 m	0.30 m
Other Mitigate / Compensation Costs	Low	High	Moderate-High
Level of Flood Protection for Old Island Highway/Ryan Road	Between 20-year and 50-year return period	200-year Return Period	200-year Return Period**
Relative Capital Cost	Low	Moderate-High	Moderate-High
Land Use Benefits	Low	Moderate-High	Moderate
Habitat Impacts	Low	Low	Low
Emergency Response Benefits	Low	Moderate-High	Moderate-High
Adaptability to Climate Change	Low	Moderate	Moderate
Public Response	Moderate-High	Low-Moderate	Moderate
Cost Sharing Potential	To be determined	To be determined	To be determined

* As calculated at the confluence of the Tsolum and Puntledge Rivers
** As calculated at the agricultural fields

Cost estimates for the three options have been prepared at a conceptual level for this study, without the benefit of detailed engineering. They include considerable contingency for uncertainty of both scope and price. The estimated costs for Options 2 and 3 are approximately $5.0 million. Less protection is afforded by option 3 for roughly the same cost of construction. However, additional benefits (such as lower backwater effects, etc.,) arising from either option must be considered, over and above the level of flood protection afforded.

The following recommendations provide the City of Courtenay with a direction for moving forward to address the current and expected future flooding in the floodplain:

1) Continue to protect the majority of the floodplain, imposing compatible land uses that will accommodate floods over the long-term (Managed Retreat 2100 and beyond).

2) Consider the Tsolum River Floodwall Concept (Option 1) as an interim solution to an overall flood mitigation strategy.
3) Review Emergency Plans for Today, Year 2100 and 2200
4) Identify where and when additional diking might be warranted for consideration, subject to the general direction in item 1 above, such that diking along the watercourses will be very limited in area and scope.
5) Evaluate diking options including financial / cost sharing analysis.

The City should be reviewing and updating its applicable bylaws and Official Community Plan on the short term, with a view for the long-term effects of climate change and SLR. Part of the implementation strategy should include continued public outreach and education, as well as monitoring the regulatory and scientific progress of these two phenomena within the adaptive management plan.

It is very important that land use decisions be made with a full awareness of the evolving flood risk, so that there are adequate mechanisms in place to balance life and safety, environmental, economic and public/private investment responsibility. Applications for land use change in the floodplain should provide a clear flood mitigation strategy prior to being formally considered by City Council. Any additional flood risk assessment carried out as part of land development applications should follow the APEGBC Legislated Flood Assessment Guidelines, where appropriate.

New construction within the floodplain should be assessed using the hydraulic model, prepared as part of this study, to ensure that the proposed development does not have any significant effects on neighbouring properties. Impacts due to the magnitude of the 1:200 year return period flood are likely to occur on neighboring properties, especially if the proposed development is of substantial size (big box store developments for example).

1 INTRODUCTION

1.1 FLOODPLAIN MANAGEMENT VISION FOR COURTENAY

The floodplain of the Puntledge, Tsolum and Courtenay Rivers overlaps with parts of the City of Courtenay, the Comox Valley Regional District, and the K'ómoks First Nation. Seasonal flooding and related risks have been a historic concern. In January of 2012, the City of Courtenay received notice from the Province of BC that an application for funding under the BC Flood Protection Program had been approved. The resulting project (this assignment) includes flood modeling, focused on the floodplain area. Models have been created noting results of prior watershed studies.

The work has resulted in two main deliverables: new floodplain mapping and an Integrated Flood Management Study (IFMS). Existing Flood Construction Levels (FCL) in City bylaws establish the minimum building height for habitable land uses. The IFMS and mapping were developed enabling a reassessment of flood risks, and providing information that will support refinement of Flood Construction Levels. The work also identifies flood mitigation strategies to reduce current risks.

As required by Provincial policy, the work also considered gradual Sea Level Rise, and reviewed conceptual adaptations to potential sea levels at Year 2100 and 2200. Given the slow pace of Sea Level Rise, these longer term adaptations should be considered as and use decisions are made concerning areas within the floodplain, and should be revisited formally on an ongoing basis.

Figure 1.1[1] provides a vision for flood management in the Courtenay River floodplain. The 'solution space' to management of flood risk is not found only in hard structures like dikes, dams, levees or floodways. There are also a myriad of 'soft' solutions that should be part of the plan, ranging from regulatory mechanisms like zoning and land use control, through public education and response actions; including flood warnings, public awareness campaigns, emergency management reponses (evacuation), and a role for insurance.

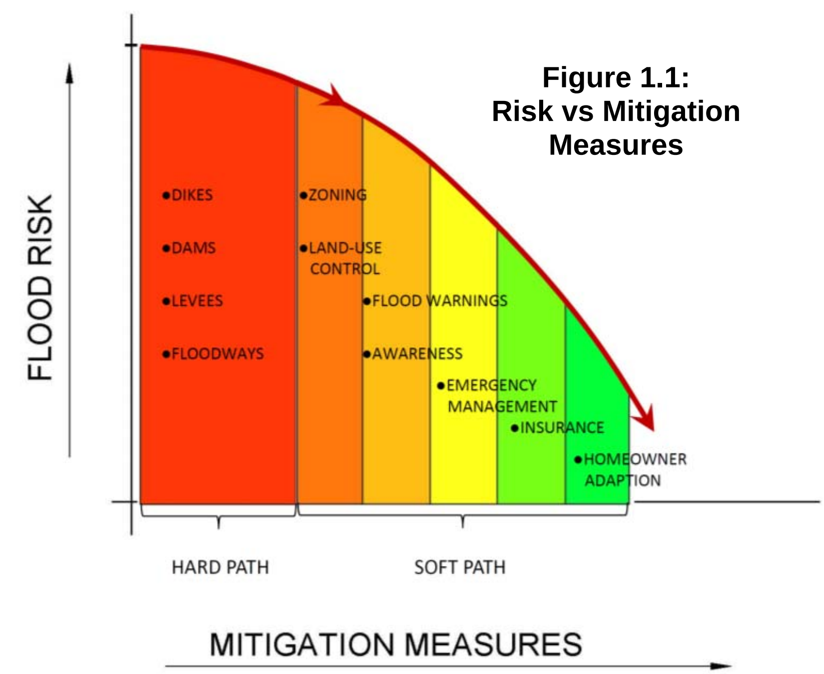


Figure 1.1: Risk vs Mitigation Measures

[1] Developed by Derek T. Richmond-M.Eng., P.Eng., CSci., C.WEM (Manager of Engineering)

In most cases, investment in ‘hard ‘solutions is reserved for cases of highest risk to life or property. Where risks of flooding are less severe or more rare, a reasonable cost-benefit is often gained by ‘soft’ solutions. In all cases, the vision is to avoid or minimize loss of life risks in the face of flood. Protection of property is an important, but secondary, goal. Protection of the environment (our community’s property in-common) is considered of equal importance with protection of private property.

1.2 GOALS AND OBJECTIVES FOR THE INTEGRATED FLOOD MANAGEMENT STUDY

The goal of the IFMS is to increase awareness and preparation of the local governments, First Nations and citizens of the Courtenay Floodplain toward adaptations in response to future flooding risks.

Specific objectives and deliverables of the study included:

1. Integration of detailed topographic survey (river bathymetry and LIDAR imaging).
2. Technical modeling of river and sea interactions with various storm events (current conditions, Year 2100 and Year 2200 projections).
3. Identification of existing land use and environmental values in the floodplain.
4. Review of existing land uses and proposed land use designations that might be affected by these new flood levels.
5. Develop options, at the conceptual level, to adapt to the flood risks, and gain input on values of community stakeholders.
6. Development of a long-term strategy to reduce impacts of flooding on the community while protecting the ecological, economic and cultural values of the river and floodplain.

A parallel design exercise involving a localized floodwall on the Tsolum channel was undertaken. The decision on funding/proceeding with these capital works in the short term is discussed herein.

The study is intended to integrate the socio-economic and environmental values into the decision matrix, along with the modeling results to confirm a number of flood related issues, including:

1. Providing flood level estimates within the floodplain to determine the extent and duration of flooding, with the goal of producing new floodplain mapping within the study area.
2. The establishment of new Flood Construction Levels (FCL) for new buildings in the floodplain
3. Exploring mitigation measures for flood protection, including the Tsolum River Floodwall concept and determine their effect on the floodplain both in terms of changes in water levels and durations.

Review of existing land uses and proposed land use designations that might be affected by calculated flood levels.

1.3 OPPORTUNITIES FOR COMMUNITY ENGAGEMENT

The planning process intentionally dynamic, with the input from key stakeholders sought early on. Stakeholder issues were sought from and discussed with the City, the K'omoks First Nation, the Comox Valley Regional District, BC Hydro, stewardship groups such as the Comox Valley Project Watershed Society, the Tsolum River Restoration Society, the Courtenay River Estuary Working Group, property owners and rate payers in the floodplain.

Five events were held: an introductory public event, a regulatory agency workshop, a K'omoks First Nation outreach, and a series of two events with Community Stakeholders. The five events were supported by a facilitator, providing a forum to share information gathered to date, and encouraged public comments or questions. Responses were collated, attached as Appendix A.

The workshops were designed to promote constructive dialogue. Response forms provided at each workshop allowed written input on values that should be considered in future decision making or on-going planning processes that follow.

Introductory Event (June 28, 2012)

At the Filberg Centre Rotary Hall on June 27, 2012 from 7:00 to 9:00 p.m., the City hosted an introductory public event. All interested parties were welcome to attend. A presentation of the study scope, stakeholder input process and known issues were followed by a facilitated discussion of issues and information relevant to the project.

Regulatory Review Workshop (June 28, 2012)

To ensure that all government information and policies relevant to the project were compiled, a Regulatory Review Workshop was held early in the process. Invitations were made to representatives of City of Courtenay, Town of Comox, Comox Valley Regional District, provincial and federal agencies, and K'omoks First Nation. Most, including the FN, were represented at the event.

Options Community Workshop (November 15, 2012)

Once preliminary results of flood modeling were known, a workshop was held to introduce the approximate flood extents and general options for flood mitigation to community stakeholders. This workshop focused on providing information about current flood risks, as well as the trends towards increased risks stemming from climate change and Sea Level Rise. Early ideas on how to adapt to these evolving risks was presented, including examples of what other communities have considered in similar circumstances. Respondents were asked to provide input on options that warrant further study, and to express "values" that would be relevant to selection of preferred options.

K'omoks First Nations Outreach (December 14, 2012)

In parallel with the Options Community Workshop, direct contact with First Nation representatives was undertaken. This meeting allowed a two-way conversation focused on the traditional knowledge of the First Nation, and expression of values relevant to adaptation of K'ómoks lands to flood risks.

Draft Recommendations Community Workshop (January 30, 2013)

After considering stakeholder input and completing technical analyses, draft recommendations were developed. To review and refine these recommendations prior to presenting to City Council, a second community workshop was held. This workshop asked for specific comments on key recommendations, looking for both points of consensus, as well as remaining issues requiring further effort.

Whereas this process could reasonably seek consensus on short term flood mitigation actions, measures aimed at long term adaptation to climate change and Sea Level Rise will likely be finalized by broader community processes such as future Official Community Plan reviews. The IFMS provides science and options, as well as initial stakeholder comments, and provides a clear basis for next steps for initial and on-going implementation.

Events held were very well attended, and offered thoughtful questions and discussions.

The events were structured around a variety of formats for understanding and input, including:

- Consultant presentation of issues and progress
- Question and answer sessions
- Information discussion at display panels
- Public response forms, both in paper form and available on-line
- Seeking of further correspondence (letters and email input).

Please refer to Appendix A for the complete record of Community Engagement.

2 THE STUDY AREA

The last comprehensive floodplain study covering the Courtenay Floodplain was completed in 1989-1990[2]. That study defined 200 year flood limits and elevations for the three rivers which drain into the floodplain, and included mapping of the valley as it existed at that time. The previous study area covered the floodplain of the Tsolum River to the confluence of Headquarters Creek and the Puntledge River to the BC Hydro Power House. The current IFMS focuses on those sections of the Courtenay River, Puntledge River and Tsolum River that lie within or are near the City of Courtenay boundaries as well as those lands near Comox Bay. The extent of the study area for the IFMS includes the following:

- The Courtenay River from Comox Bay to the confluence with the Puntledge and Tsolum Rivers
- The Puntledge River from the confluence to just downstream of the BC Hydro Power House and Fish Hatchery at the Fish Hatchery weir
- The Tsolum River from Dove Creek Road Bridge to the confluence of the Tsolum River.
- The Old Tsolum River Channel adjacent to the Old Island Highway and Headquarters Road
- Floodplain areas including the Tsolum River floodplain, the Puntledge River floodplain, Lewis Park and Simms Millennium Park, the area near the intersection of Ryan Road/Old Island Highway and the agricultural lands surrounding Glen Urquhart Creek
- Comox Bay from the Courtenay River Estuary to a line between Goose Spit and Royston.

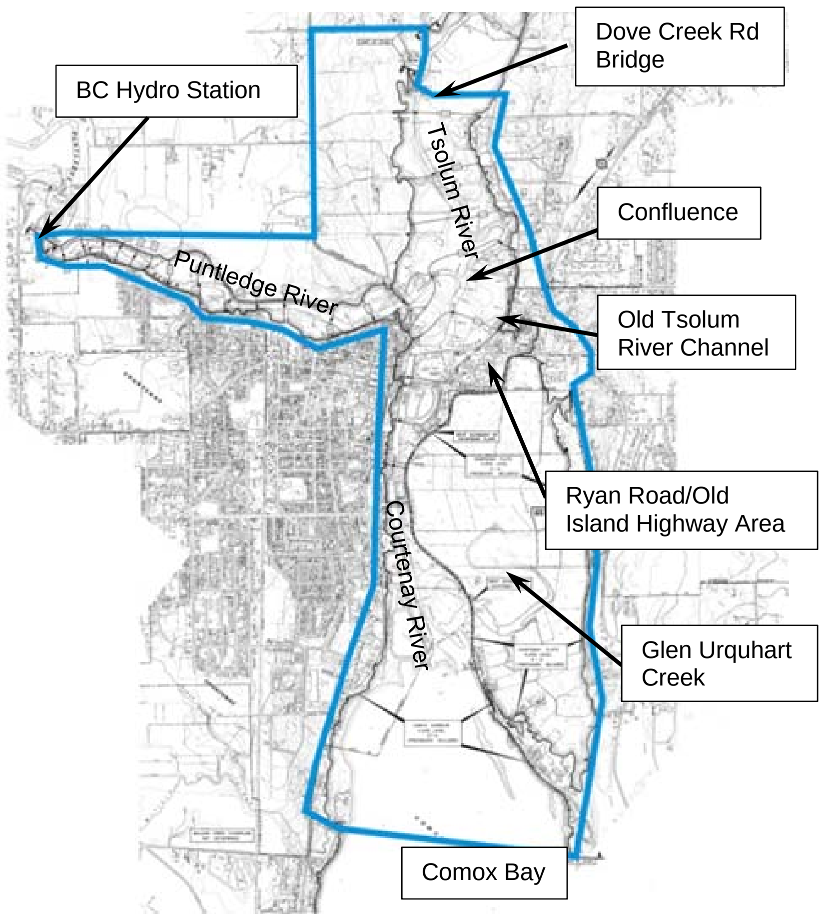


Figure 2.1: Study Area Boundary

[2] Ker, Priestman & Associates Ltd., Floodplain Mapping Program: Courtenay, Puntledge and Tsolum Rivers, January 1990

2.1 MAPPING

New analytical tools used in this study demand, and benefit from, greater precision in representation of the surface topography. As a result, the study area was newly mapped with digital aerial photography, and topographic mapping using LiDAR. LiDAR is the acronym for Light (or Laser Imaging) Detection and Ranging. The LiDAR scanner is housed in an aircraft along with the aerial photography equipment, and scans the land over the flight path. Thousands of data points are collected to produce a digital elevation model (DEM) of the valley. LiDAR does not work under water, so the LiDAR data was collected during a low tide event, maximizing the resulting coverage.

To supplement the LiDAR data, a bathymetric survey of the Courtenay River channel and mouth was completed at high tide and extended up to the northern limit of Lewis Park. The Tsolum River and Puntledge River Channels were surveyed with conventional instruments at cross-sections consistent with previous study to both enhance the current modeling and support the geomorphological review of physical changes of all three rivers.

The resultant base map includes high precision topographic dataset overlain on a digital orthographic photo mosaic. A sample of the map figure is shown on Figure 2.2, with a complete full scale map attached as Map A.

Figure 2.2: Sample of Digital Aerial Photograph and Topographic Data

2.2 THE ENVIRONMENT

Integrating environmental issues into the floodplain management study is critical toward achieving a balance between mitigating future floods and protecting the environment. Before proceeding with recommendations for flood mitigation, it is therefore necessary to take stock of the environmental values in the floodplain area. Ecofish Research Ltd. (Ecofish) was contracted to complete a "Sensitive Habitat Screening" of the study area as a first step in connecting the floodplain environment to flood mitigation. Full details of the screening report are provided in Appendix B.

Habitat information was gathered from a number of sources including literature searches, on-line databases and personal communications with key organizations, such as Fisheries and Oceans Canada (DFO), Puntledge River Hatchery, Project Watershed, local biologists, the City of Courtenay and the British Columbia Conservation Federation (BCCF). The majority of sensitive habitat data was obtained from previously collected and archived sensitive ecosystem inventory.

As is evident from the attached "Preliminary Assessment of Environmentally Sensitive Areas", the floodplain from the Estuary up to the end of the study area provides high value habitat for both flora and fauna, especially fish.

The Courtenay River and Estuary provide important rearing habitat for juvenile salmonids. In addition, the confluence of the Tsolum and Puntledge River was indicated as providing a key holding pool for adult Chinook Salmon, which hold in this area in large numbers before migrating upstream with the tide. The area just downstream of the confluence along the left riverbank provides important habitat for juvenile Chinook Salmon and Coho Salmon. Those areas specifically identified as important habitat by Tryon (2011) and Frank (pers. comm. 2012) are included in the sensitive habitat map.

In terms of terrestrial habitat and wildlife, several areas were deemed important; identified as coastal bluff, terrestrial herbaceous, older forest, riparian, sparsely vegetated, wetland, woodland, seasonally flooded agricultural fields and older second growth forests. Additional sensitive habitat was observed for eelgrasses, wetlands, and non-sensitive occurrences of endangered species and ecosystems (western brook lamprey pop. 1 Morrison Creek population, Green Heron, Barn Owl, Western Screech-owl, Ermine, Anguinae subspecies, and Henderson's checker-mallow and Chaffweed). The sensitive habitat map also includes spawning habitat for anadromous and resident fish within the Puntledge River, identified by Darcy Miller, Manager DFO Puntledge Hatchery. Fisheries enhancement habitat built in association with the BC Hydro Puntledge River Facility was noted, designed to produce off-channel spawning and rearing habitat in the lower section of the Puntledge River.

Appendix B includes a listing of Courtenay Estuary Restoration Options obtained from Tryon (2011) as part of the Investigation of Restoration and Protection Options for Juvenile Salmonids in the Courtenay Estuary, prepared for Comox Valley Project Watershed Society, Courtenay BC. While not specific to the health of juvenile salmonids, two options for improved "Flood Control" were documented as follows:

- Identified as FC1 on the sensitive areas map, the first option discusses regarding the roadway at the intersection of Comox Avenue and the Old Island Highway "*so that floodwaters that flow across Lewis Park are directed under Old Island Highway and across the natural floodplain on other side"*

- Option FC2 is described as an *“opportunity to reconnect some of the river water to the floodplain through a pipeline or creating a channel along low lying areas across Lewis Park to the farmland on other side of Highway 19A, possible utilizing Marina Slough at Simms”*.

Both options are founded on utilization of the agricultural fields within the lower floodplain to relieve flooding upstream, and enhance natural processes that would occur from time to time during higher flood stages.

3 HISTORY OF FLOODING IN COURTENAY

3.1 THE WATERSHED

The Courtenay River begins at the confluence of the Puntledge and Tsolum Rivers and flows 3.1 km through the City of Courtenay to Comox Bay. The total drainage area of the Courtenay River is 868 km^2, including the 598 km^2 Puntledge River catchment area and the 266 km^2 Tsolum River catchment area. The watershed includes numerous tributary streams such as the Cruickshank River, Browns River, Perseverance Creek, Morrison Creek in the Puntledge River watershed and Murex Creek, Headquarters Creek, Dove Creek and Portuguese Creek in the Tsolum River watershed. There are also a number of lakes in the Courtenay River watershed, Comox Lake being the largest, with a surface area of approximately 16.2 km^2. An overview of the watershed is shown on Figure 3.1.

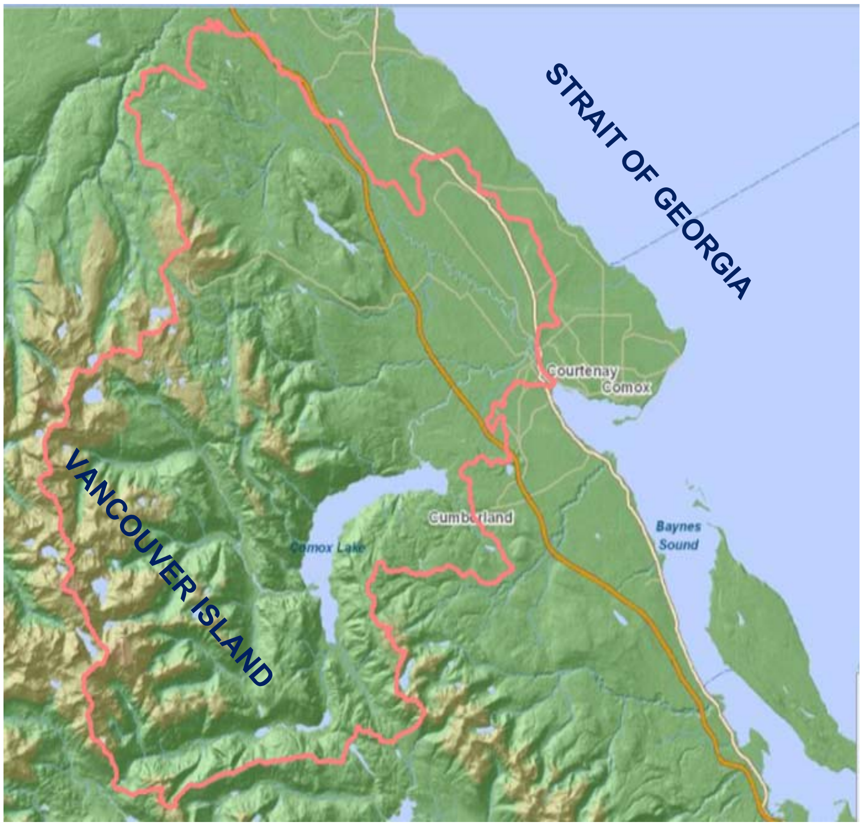


Figure 3.1: Courtenay River Watershed

Most of the Puntledge River watershed lies at relatively high elevations with the majority above 200 metres, ranging up to 2,134 m at Mount George V. The western boundary of the watershed is defined by the Vancouver Island Range which contains a number of glaciers and lakes within Strathcona Provincial Park. The Puntledge River flows from Comox Lake in a predominantly north-eastern direction to join with the Tsolum River upstream of the City of Courtenay. Flow in the Puntledge River is regulated by the dam operated by BC Hydro at the outlet of Comox Lake.

The Tsolum River watershed contains relatively low lying topography with half of the watershed area below an elevation of 300 m. Conversely, areas in the headwaters of some of the tributaries streams are much higher, reaching 1,590 m at Mount Washington. The Tsolum River flows predominantly south-east to join with the Puntledge River upstream of the City of Courtenay to form the Courtenay River.

Significant snow pack can accumulate in both the Puntledge and Tsolum River watersheds at higher elevations during the winter months. However, peak discharges as a result of spring snowmelt are generally smaller than those peak flows associated with heavy rainfall events, during large frontal storms from the Pacific Ocean. Often these frontal storms result in low pressure systems and high winds which can cause storm surge and wave set-up in Comox Bay. As a result, flooding in the Courtenay River system occurs most frequently between October and February when higher tides and higher precipitation are prevalent.

3.2 FLOODS ON RECORD

The Courtenay River floodplain has flooded many times since 1900. The dates of more significant floods and a brief commentary are listed in Table 3.1.

Table 3.1: Historical Flood Events[3]

Date	Comments
October 13, 1905	As documented in the Colonist newspaper, Victoria, BC
February 1, 1935	Flow records indicate that a moderate flood occurred on the Puntledge River; however newspaper accounts stated that this was the largest flood in the preceding 40 to 60 years.
November 15, 1939	Flood waters rose rapidly during the night of the 14th, and peaked on the 15th just before a high tide of 1.32 m geodetic, which crested at 11:00am. Southeast gale-force winds accompanied the heavy rain, which set a precipitation record of 83mm in 24 hours on the 15th. Newspapers reported that residents found this flood to be more severe than the 1935 flood
December 8, 1939	A second flood in 3 weeks occurred along the Courtenay River, however the maximum stage did not reach the levels attained in the November flood
November 13, 1953	A total of 229 mm of rain in 5 days was measured at Courtenay, with 57 mm falling on the 13th. The storm was accompanied by a 59 km/h southeast wind. From the newspaper accounts, it appears that the 1953 flood was not as high as the 1939 flood. A new dike around Lewis Park was credited for reducing the extent of damage to the Park in comparison to effects of the 1935 and 1939 floods.
November 13, 1975	Flood waters caused considerable damage in the Rye Road area, entering homes and businesses in the lowlands north of Ryan Road. Some residents expressed the opinion that the construction of Ryan Road caused higher flood levels in this area. Flooding also occurred along the approaches to the Condensory Road Bridge. Puntledge Park and Lewis Park were heavily inundated. The Courtenay Flats received some flood waters from the rivers, but were not filled as they had been in earlier floods.
December 26, 1980	Several days of record warm temperatures and heavy rain resulted in very high discharges, especially in the Puntledge basin. The highest

[3] Adapted from Ker, Priestman & Associates Ltd., Floodplain Mapping Program: Courtenay, Puntledge and Tsolum Rivers, January 1990

	record peak inflow to Comox Lake occurred with this event; however the high flows were not sustained over a long period of time. The peak instantaneous flow for the Puntledge River also set a record. The Tsolum River flows, however, were not as extreme.
October 25, 1982	This was not a large flood but it was associated with a high inflow to Comox Lake
February 11, 1983	Warm temperature, high winds and heavy rains of 80.2 mm, caused flooding along the Tsolum and Courtenay Rivers. In contrast to the 1980 and 1982 flood events, this flood was more extreme in the Tsolum River than in the Puntledge and was similar in some respects to the 1975 event. Dove Creek Road, near its crossing of the Tsolum River, was overtopped by flood waters. The Old Island Highway near Ryan Road and the Rye Road area where flooded once again. Water did not, however, inundate the Courtenay Flats on this occasion. The tide was very low at the time when the Tsolum and Puntledge Rivers peaked.

More recently, high flows in Puntledge and Tsolum River combined with large tides in Comox Bay, resulted in flooding in the City of Courtenay on November 12 to 19, 2009 and January 14 to 16, 2010, with a lesser flood occurring later in December of 2010 (Dec. 21-29). Maximum Courtenay River water levels recorded at the 5th Street Bridge of 3.154 m, 3.096 m and 3.002 m (see Table 3.3) were recorded for the November 2009, January 2010 and the December 2010 events, respectively. This compares with estimated 20-year return period water level of 3.14 m, 50-year return period water level of 3.48 m, and 200-year water level of 3.87 m. Flood extents for the November 2009 event, as recorded by McElhanney staff, are shown on top of the 2012 aerial photography on Figure 3.2 (overleaf).

Relative timing and magnitude of the peak flows in the Puntledge River and Tsolum River in comparison with high tide in Comox Bay plays an important role in the peak water levels along the Courtenay River. For example, the high water levels during the January 2009 event are a result of high discharge in the Puntledge River and Tsolum River combined with high tide in Comox Bay whereas the January 2010 event is the result of higher discharge in the Puntledge River during low tide with low Tsolum River flows. The peak flows in the Tsolum River for the January 2009 and December 2010 events both occurred near high tide and were roughly the same magnitude; however the peak water levels in the Courtenay River were lower because of lower Puntledge River flows.

Table 3.2 outlines recorded water levels and discharges during the 2009 and 2010 flood events.

Table 3.2: Recent 2009 and 2010 Flood Event Peak Discharges and Water Levels

Flood Event	Peak Water Levels (m-GSC)			Peak Flows (m^3/s)			
	Courtenay River at 5th Street Bridge	Comox Bay		Puntledge River		Tsolum River	
		Measured Peak	Coincident Peak	Measured Peak	Coincident Peak	Measured Peak	Coincident Peak
Dec 2009	3.154	1.93 m 1 hr before	1.65	372 3 hrs after	339	277 1 hr before	276
Jan 2010	3.096	2.15 m 8 hrs after	- 1.75	525 1 hr before	433	50.2 50 hrs before	24.8
Dec 2010	3.002	2.53 1 hr before	2.43	206 18 hrs after	114	277 8 hrs after	257

Note: Times shown for peak water levels and flows are in relation to peak Courtenay River at 5th Street Bridge water levels.

Figure 3.2: Extent of Flooding in November 2009

3.3 THE EFFECT OF CLIMATE CHANGE, SEA LEVEL RISE AND LAND USE ON FLOODING

In 2011, the City of Courtenay, the Comox Valley Regional District and the TimberWest Company co-sponsored an investigation the Tsolum River Flood Hydrology[4]. The study focused on causes for recent flooding on the Tsolum River near Courtenay, including a literature review of climate variability and the hydrology of similar watersheds. Trends in peak flows and high intensity rainfall events across the region were assessed and it was determined that the recent increase in the magnitude of peak flood flows is closely associated with increased frequency and magnitude of high intensity rainfall events.

The study also examined the effect of forest harvesting on peak flows, the general conclusion being that larger watersheds on Vancouver Island (10-600 km^2) are not subject to the same sensitivity to flooding from forest harvesting as smaller watersheds. Northwest Hydraulic Consultants (NHC) cited a 2003 study by Chapman[5], which concluded *"that land use effects were overwhelmed by very high precipitation rates on Vancouver Island and that logging effects on peak flows in large, rain dominated Vancouver Island watersheds appears to be small*". Thus, it was concluded that land use changes over the last century within the Tsolum River watershed are not likely to have contributed largely to the flooding experienced within Courtenay, but rather the past, present and future weather patterns dictate the extent of flooding within the watershed.

Moreover, the 2011 study emphasized *"that Floods in Courtenay are governed by timing and magnitude in the Puntledge River and Tsolum River as well as the level of the Tide in Comox Bay. The most severe flooding will occur when extreme peak flows coincide along with extreme high tides"*. This is supported by the historical evidence provided, demonstrating variability of flooding and describing the causes.

Changes in average sea level and the magnitude of storm surge are likely to have had an impact, over time, on flood levels in the study area. Water level records at Comox Bay have not been collected for a long enough period to clearly assess historical trends. However, recent analysis of tide level data from the Point Atkinson Tide gauge near Vancouver indicates increased trend in average sea level as well as extreme sea level over the past 50-years (Thomson et. al.[6], 2008 and Dilumie[7], 2010). They also indicate that climatic variability, such as El Niño/La Niña events, plays an important role in the occurrence of extreme sea levels. Higher peak water levels tend to occur during El Niño years with average sea level about 0.1 m above average background levels during these years. An assessment of potential impacts on flood profile in the Courtenay River as a result of sea level rise has been considered in more detail, presented in Section 5.7 below.

---

[4] Northwest Hydraulic Consultants, Tsolum River Flood Hydrology Investigation, June 2011

[5] Chapman, A. 2003. Long-Term Effects of Forest Harvest on Peak Streamflow Rates in Coastal BC Rivers. Report for Forestry Innovation Investment, Forintek Canada Corporation, March 31, 2003. 57pp.

[6] Thomson, R.E., B.D. Bornhold and S. Mazzotti. An Examination of the Factors Affecting Relative and Absolute Sea Level in British Columbia. Canadian Technical Report of Hydrography and Ocean Sciences 260. Prepared by Fisheries and Oceans Canada and BC Ministry of Environment. 2008

[7] Dilumie, S.A. Climate Variability and Change Impacts on Coastal Environmental Variables in British Columbia Canada. Dissertation Submitted in Partial Fulfillment of PhD. Department of Geography. University of Victoria. 2010

3.4 THE RIVER CHANGES WITHIN THE FLOODPLAIN

A review of recent changes in channel geometry of the Tsolum, Puntledge and Courtenay Rivers was completed as part of the study. This fluvial geomorphology assessment included characterization of channel geometry changes over time, sediment accumulation or erosion and a high-level review of the governing stream processes on the three rivers.

Findings from the high level review indicate that the lower Tsolum River continues to undergo a moderate level of morphological changes (channel widening, aggradation) due to the extensive logging and agricultural activities that have occurred over the last 90 years (Gooding 2010). A comparison of surveyed river cross section from 1988 with those collected in 2012 indicate some channel widening and possible degradation has been occurring in the lower Tsolum. In addition, a review of available historical air photographs from 1931 to 1996 indicate that significant planform changes have occurred along the lower Tsolum River, including: a large meander cut-off creating a new confluence location with the Puntledge River (between 1951 and 1957), the current confluence location has elongated to the north and will eventually create a new meander cut-off in the next 50-100 years should this trend continue, and the large ‘Oxbow’ upstream of Dove Creek Road has migrated up valley and elongated to the northeast.

The high level review for the Puntledge River suggests that the limited activity/disturbance in the watershed (forestry, agriculture), the construction of a dam at the outlet of Comox Lake in 1912, and the presence of bedrock outcrops along the river have been the dominant controls along the lower reach over the last 90 years. Apart from some minor morphological changes within each cross-section, it does not appear that there has been a net gain or reduction in the volume of sediment between 1988 and 2012 in the lower reach of the Puntledge River. In addition, very little changes to the planform shape have occurred on the lower reach of the Puntledge River. This is likely the result of the Comox Lake reservoir and dam that has limited the peak flows and sediment throughput. The only notable planform change that has occurred between 1931 and 1996 is the northeast migration (~ 120 m) of a meander bend immediately upstream of the confluence with the Tsolum River.

The high level review for the Courtenay River shows that the channelization (date unknown, occurred prior to 1931), dredging activity (dates and frequency unknown), and tidal action are the governing geomorphic processes in this river. The cross-section comparison revealed that significant channel morphology changes have occurred between two sets of surveys; however, this is likely the result of dredging activity rather than natural stream processes. The only notable planform change that has occurred between 1931 and 1996 on the Courtenay River is the initiation of a small meander downstream of the Courtenay Airport.

3.5 THE TSOLUM RIVER FLOODWALL

In response to recent flood events, the City of Courtenay applied for grant funding from Emergency Management BC (EMBC) to design and build a floodwall along the Old Tsolum Channel. The wall was expected not only to protect the adjacent property in the commercial area of Ryan Road, but also to keep transportation links open to Courtenay residents. The original application featured a conceptual design of the floodwall, which is attached as MCSL Drawing 2221-47143-0 FIG-3. The design concept was viewed as a permanent enhancement to the existing, emergency traffic barrier / sandbag wall now in place.

The intent was to register the floodwall with the Diking Authority at the Ministry of Forest, Lands and Natural Resource Operations (MFLNRO), Water Management Branch.

4 FLOODPLAIN MANAGEMENT TOOLS

4.1 MUNICIPAL LEVEL

The study area includes lands within the City of Courtenay, the Comox Valley Regional District and the K'ómoks First Nation. Generally, floodplain management is provided by a combination of Floodplain Bylaws, Zoning Regulations, and Official Community Plans (municipalities) or Comprehensive Community Plans (First Nations).

4.1.1 City of Courtenay Floodplain Bylaw

The City of Courtenay Bylaw No. 1743 (1994) regulates building and development within the floodplain. Enacted in 1994, the current bylaw is based on the results of the 1990 floodplain mapping. In general, no person shall construct any building or structure contrary to the provisions of the bylaw. The bylaw, with its accompanying maps, designates 'Flood Construction Levels', which generally increase in elevation moving up-river from the Courtenay Estuary. The bylaw requires that areas 'used for dwelling purposes, business, or the storage of goods which are susceptible to damage by floodwater shall be above the Flood Construction Level'. Landfill or structural support is allowed to elevate the underside of a floor system above the Flood Construction Level.

The bylaw also requires minimum setbacks from the natural boundary of watercourses or the sea. For the Courtenay, Puntledge and Tsolum Rivers, this is 30m. Structural fill is not allowed within the setback areas.

4.1.2 City of Courtenay Official Community Plan

The City of Courtenay Official Community Plan (Bylaw No. 2387, 2005) provides a land use and infrastructure policy framework to guide development in the City. Policies and content of significance in a Floodplain context include:

- Greenways designations along the majority of the shoreline of the Courtenay, Tsolum and Puntledge Rivers. This designation also extends around the periphery of the agricultural area in the lower floodplain.
- Significant parks and recreation land use designations (existing and proposed) along the waterfront. Large parcels with this designation include Airpark Lagoon, Standard Park, Lewis Park, Simms Millennium Park, Puntledge Park, and several natural areas along the Puntledge and Courtenay River banks.
- A large agricultural area that extends across Courtenay, Comox and K'ómoks First Nation areas.
- The CVRD Exhibition Grounds site on the Tsolum River, and adjacent Suburban Residential.
- On the west side of the Courtenay River, a mixture of higher uses ranging from commercial through mixed use and multi-family residential. A small pocket of urban residential remains in a single family area of the riverfront.
- On the east side of the Courtenay River, outside the parks designations, there are land use areas designated as industrial (some vacant at present), commercial, and mixed use.
- The areas of Old Island Highway and Ryan Road include a shopping center commercial designation.
- The Puntledge Indian Reserve No. 2 is K'ómoks First Nation land base outside the City boundary on the north side of the Puntledge River.

- A third bridge crossing of the Courtenay River is anticipated, with two potential locations shown in the OCP. In addition, major arterial connections include Cliffe, 17^{th}, 5^{th}, Comox Road / Island Highway, Old Island Highway and Ryan Roads.

On a land area basis, as shown on the attached Zoning and Floodplain Map, the great majority of the floodplain is designated agricultural, parks and recreation, and similar uses that adapt reasonably well to infrequent flooding events.

Building developments in the floodplain study area are required to be raised to flood construction levels with (structure or fill) to minimize the flooding risk at the structure. Roads and parking areas, however, may still be subject to flooding.

As sea level rise occurs over the long term, the designated flood construction level may need adjustment upward.

4.1.3 City of Courtenay Zoning Bylaw

The City of Courtenay Zoning Bylaw No. 250 identifies more specific land use zones and regulations. The zoning designations in the floodplain study area closely follow the land use framework in the Official Community Plan.

The zoning and study area limits are shown on the attached Zoning and Floodplain Map. The relationship between this land use and flood levels (existing conditions, Year 2100 and Year 2200) is discussed in Section 9.4.

4.2 PROVINCIAL LEVEL

The Environmental Management Act provides the Ministry of Forest, Lands and Natural Resource Operations (FLRNO) with broad powers to establish guidelines, regulations, and hazard management plans with respect to flood protection, dikes and the development of land subject to flooding.

Through the Act, FLNRO has established the Integrated Flood Hazard Management Program. The objective of the program is to reduce the impacts of flooding on people, communities and infrastructure, though development of policies, guidelines, and information to assist local governments. The program provides guidance in three primary areas:

1. Managing land use within the floodplain;
2. Managing flood protection systems; and
3. Preparing for and responding to emergencies.

Effective flood management practice integrates all three of these components (see Figure 1.1). Although flood protection works such as dikes provide protection from flood damage, they require on-going maintenance and periodic upgrades to be effective over-time. It is, typically, not cost effective to rely solely on constructed flood protection works to control the threat of flooding. It has been shown that appropriate land use management and flood mitigation are the most practical and cost effective ways to reduce flood damage. Finally, communities having an effective emergency planning and response program can reduce the risk of loss of life and trauma as well as improve recovery times, in the event that flooding does occur.

4.2.1 Floodplain Land Use Management

The provincial Flood Hazard Area Land Use Management Guidelines (MWLAP, 2004) provide guidance for local government, land-use managers and approving officers to develop and implement land use management plans and subdivision approvals for floodplain areas.

Land Use Management Policies

The guidelines suggest that general land use policy statements regarding flood hazard management, and maps showing areas of flood hazard, should be included in Official Community Plans. The guide provides general examples of policy statements. Under sections of the Local Government Act, local governments may incorporate requirements for flood protection measures, or restrictions on floodplain development through floodplain bylaws, land use bylaws, and development permit bylaws. The guideline provides example bylaws that local government can use.

During the subdivision approval process for lands that are deemed subject to flooding or erosion, the approving officer can require an engineering certification that the land may be used safely for its intended purpose. The provincial government has prepared a guide to selecting qualified professionals for preparation of flood hazard assessment reports. The Association of Professional Engineers and Geoscientists of BC (APEGBC) have recently prepared Professional Practice Guidelines for Legislated Flood Assessments in a Changing Climate in BC (APEGBC, 2012) which provides qualified professionals with guidance on flood standards and methodologies to use when reviewing flood hazards for land development.

Where land may be subject to flood hazard beyond what is considered safe for the intended use, a restrictive covenant can be used to restrict development within all or part of the land parcel. The guidelines provide a summary of specific conditions that should be included in a restrictive covenant for flood hazard management, as well as examples.

Floodplain Mapping

Local governments must consider relevant floodplain mapping in development of flood hazard bylaws and other land use management policies. Floodplain maps show the route and limits of water courses, surrounding features, ground elevations, flood levels and floodplain limits. One of the primary purposes of the Courtenay River Integrated Flood Management Study has been to update the floodplain mapping for purposes of land management planning.

The impacts of Climate Change and Sea Level Rise must now be considered in the preparation of floodplain mapping. Recently the Provincial Government has developed Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use (MoE, 2011a) as well as Coastal Floodplain Mapping Guidelines (MoE, 2011b). These guidelines recommend that a1.0 m increase in average sea level should be used for planning purposes, for the Year 2100 timeline.

Recommended Minimum Flood Hazard Reduction Requirements

The Flood Hazard Area Land Use Management Guidelines also provide a list of minimum requirements for higher flood risk areas, where detailed floodplain mapping has not yet been prepared. Some of these requirements include:

- Floodplain setbacks to be established, ensuring development is kept away from areas of potential erosion and to avoid restriction of flow capacity. The minimum recommended setback for rivers is 30 m.
- Flood Construction Levels (FCL) are used to keep living spaces and areas used to store goods that could be damaged by flooding above the established flood levels. The minimum recommended FCL is either 0.6 m above the designated flood water level or 3.0 m above the natural ground level adjacent to the water course if no flood levels have been established.
- Designated Flood is the flood having an average recurrence interval of 200 years or that has an average likelihood of occurring 0.5% in any given year.

The guidelines also provide suggestions intended to reduce flood hazards by land-use type, as well as recommendations on access and egress requirements from the floodplain during flood events.

Legislated Flood Assessment Guidelines

The Association of Professional Engineers and Geoscientists in conjunction with Provincial Ministry of Forest, Lands and Natural Resource Operations as well as Natural Resources Canada have developed a professional practice guideline for “Legislated Flood Assessments in a Changing Climate in BC”, published in June 2012. The purposes of this guideline is to provide a framework for communities and professionals to define the roles and scope of flood assessments required for building permits, subdivision approvals and other land development activities that are reviewed by Approving Authorities. The scope of the guidelines provides recommendations on how to:

- undertake flood assessments consistently and transparently;
- provide for appropriate consultation with approving authorities;
- use a level of effort and approach appropriate for the nature of the
- elements at risk;
- standardize the flood assessments to make them directly comparable
- le within BC;
- consider existing regulations and the level of protection provided by
- structural mitigation works;
- increasingly consider risk management” and “adaptation” as opposed to solely “protection”
- and “defense”;
- consider a broader range of issues and broader range of analytical techniques to help
- achieve improved social and environmental outcomes as part of development;
- include predicted changes in the hydroclimate as well as natural and anthropogenic
- changes to channel morphology and watersheds in the flood assessment; and
- identify situations that require expert input

Although the guidelines have been primarily developed as a tool for qualified flood assessment professionals, the document also provides guidance on how local governments can better define flood assessment requirements as part of their land development approval processes.

4.2.2 Dike Safety Management

The responsibility for construction and maintenance of dikes lies with local government or other diking authorities such as regional districts, first nations or other public authority designated by the provincial minister. The provincial government has responsibility for general supervision relative to construction and maintenance of dikes, including administering the Dike Maintenance Act, setting dike design and maintenance standards, as well as monitoring and auditing functions.

Under the Integrated Flood Hazard Management Program, the provincial government has prepared guidelines and policies for local government and other diking authorities to use to meet the requirements of the Dike Maintenance Act. These include the:

- Dike Design and Construction Guide: Best Management Practices for British Columbia (MoE, 2003);
- Riprap Design and Construction Guide (MoE, 2000)
- Seismic Design Guidelines for Dikes (MFLRNO, 2011)

These provide recommendations on preferred design approaches and best management practices, as well as specific detailed design criteria that dikes must meet to be considered a “Standard Dike”.

4.2.3 Flood Emergency Management

Emergency Management BC (EMBC) is the primary provincial government agency responsible for coordinating flood response. This said, emergency planning and response should be coordinated from the household level through local government to higher levels of government. Through the Integrated Flood Management Program the provincial government has prepared several guidance documents to help local governments and households prepare for flood emergencies, these include:

- British Columbia Flood Plan, 2012
- Flood Planning and Response Guide for British Columbia
- Flood Precautions;
- Local Authority Planning Guide;
- BC Tsunami Warning Plan; and
- Other Hazard Specific Plans

The BC Flood Plan provides specific recommendations and guidelines to assist in preparing for flood emergencies, both at local and provincial level. It identifies some of the specific issues associated with flood events including:

- Flash flooding without warning can be extremely hazardous and pose significant risk to infrastructure and loss of life;

- Flooding can occur across wide geographic area or at several locations across the province at the same time, which can overwhelm provincial and local resources;
- Health risks associated with flooded sewage systems or other hazardous waste and contaminated drinking water supplies;
- River Forecasting can allow for advanced planning in locations where snowmelt dominates the flood process; and issues advisories and warnings;
- Dike authorities (such as local government) should actively monitor flood protection works;
- Waterways should be monitored for hazardous materials and debris;
- There may be the need to implement site specific flood protection measures such as sand bags or other temporary structures.

4.3 FEDERAL LEVEL

4.3.1 Flood Damage Reduction Program

Under the Canadian Constitution, floodplain management falls under the jurisdiction of the provinces. However, the federal government's role is to reduce major disruptions to regional economies and to reduce disaster assistance payments through the Flood Damage Reduction Program. Generally, this program has provided funding of flood protection works, such as the recent partial funding of the provincial Flood Protection Program, which has provided funding to upgrade and construct new flood protection works across BC. In addition, specific programs are supported federally such as the Provincial-Federal Floodplain Mapping Program carried out from the 1987 to 1998.

4.3.2 Public Safety

Under the Emergency Management Act (EMA), the Federal Government provides overarching Emergency Management Planning and Disaster Mitigation support in the event of disasters of national importance and to protect critical infrastructure. As emergencies most often have the greatest impact at the local level, the Act provides clear guidance on working collaboratively and sharing information with provincial and local emergency management agencies. Public Safety Canada who administers the EMA has developed high level emergency planning and recovery policies and guidance for provincial and local governments.

4.3.3 Other Relevant Federal Legislation

Often flood protection works require alterations of stream channels or construction near watercourses that could have impacts to fish habitat. Under the Federal Fisheries Act, administered by the Department of Fisheries and Oceans (DFO), any potential harmful alteration disruption or destruction (HADD) of fish habitat requires prior approval from DFO. Should DFO determine that proposed flood protection works result in HADD, compensation is typically required in the form of construction of habitat enhancement works. During design and planning of flood protection works, opportunities for potential habitat enhancement should be identified, to compensate for HADD.

In addition to the Fisheries Act, the approvals under the following legislation may also be required for flood protection works:

- Navigation Protection Act, should works impact navigability of waterways
- Environmental Assessment Act, if works are partially funded through Federal Grants
- Species at Risk Act, if works could impact species identified on the list of wildlife species at risk

It should be noted that the Federal Government has recently enacted new legislation (Bill C-38 and C-45), which have imposed changes to the Environmental Assessment Act, the Fisheries Act and the Navigation Protection Act which will impact the way that works carried near waterways are approved in the future.

4.4 FLOOD MANAGEMENT PRACTICES AND STRATEGIES

The "solution space" for flood management moves from a "hard" engineering solution, where the risks and impacts of flooding are high, to "soft" solutions where risks are lower. The current practice is to integrate the planning function for long-term land use with the long-term risks to flooding. Worldwide, alternate solutions to classic flood protection structures are being sought and practiced, to allow floodplains to function in a more natural manner. Only where no viable relocation alternative exists for land uses within existing floodplain areas should flood mitigation be considered as a long-term strategy.

To this end, the following sections provide brief summaries for both conventional and more recently adopted practices in flood mitigation, as they pertain to the Courtenay Floodplain situation.

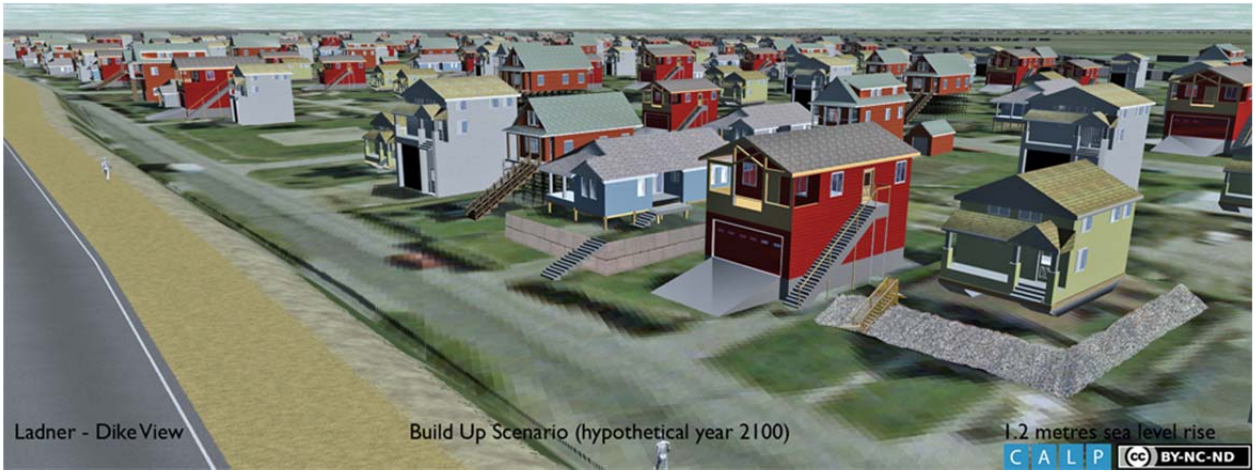
4.4.1 Dikes and Levees

The conventional method of protecting private and public assets is to provide an engineered solution such as dikes and levees. As described above, there are regulations for the development of these structures, and typically other constraints such as costs and environmental impacts, which need to be considered.

The above image shows the existing dike structure along the Courtenay River upstream of the 5th Street Bridge. Structures like these will continue to require maintenance if continued the near bank land use and managing risks to property are of consequence to the City.

4.4.2 Flood Proofing of Buildings

In accordance with City bylaws, existing structures and new buildings need to be built to a set "Flood Construction Level". The bylaw allows for filling of land to achieve this elevation. As sea levels rise, it may be necessary to raise the living areas of buildings further as depicted on the image below, which shows some buildings on raised "pads" of earth, and some with raised habitable areas above flood levels. These techniques are considered as methods for "flood proofing" buildings within floodplain areas.



4.4.3 Managed Retreat

From a longer term perspective, adaptation to increased flood risks is a preferred approach, and the solutions for flood mitigation tend to move away from the engineered flood protection structures such as dikes and levees. A balance needs to be achieved between the uses of the land today and future uses, which include assessment of environmental and socio-economic values, potentially returning the land to a more natural state. Termed "managed retreat", the mitigation strategy involves zoning and land use designations to be "downgraded" as properties are brought forward for re-development, preventing re-development of the land. The land is effectively returned to the City and managed as a natural floodplain area, or for more flood tolerant uses such as agriculture.

Each of the above strategies was reported to the various stakeholders and were further considered when determining flood mitigation strategies for Courtenay, which follow in Section 7 below.

5 HYDROLOGIC AND HYDRAULIC MODELING

5.1 HYDROLOGIC ASSESSMENT

The provincial Floodplain Mapping Guidelines are based on an estimated 200-year return period peak water levels to determine floodplain mapping levels (or flood construction levels). The 200-year return period event is also used in developing flood protection options and assessing upstream and downstream impacts.

Flood hydrology of the Courtenay River basin is dependent on a complex number of variables. These combine to influence the magnitude of stream flow experienced during a flood event. Development of design floods for the mandated 200-year return period requires an assessment of flows within the tributary streams, an assessment of the timing of tributary peak flows relative to each other, and the magnitude and timing of tide levels in Comox Bay.

A detailed hydrologic assessment was completed by KWL, relating available hydrometric data to the timing of peak flows and tide levels, arriving at predicted design discharges and hydrographs. This information was then used as input to the development of flood profiles in the river and floodplain. The results of their hydrologic assessment are provided in Appendix C and are summarized below.

5.1.1 Available Hydrologic Data

Six Water Survey of Canada (WSC) hydrometric stations are located within the Courtenay River watershed, providing stream flow and water level data. These stations include:

- Puntledge River at Courtenay (08HB006)
- Puntledge River below Diversion (08HB084)
- Tsolum River near Courtenay (08HB011)
- Browns River near Courtenay (08HB025)
- Cruickshank River near the mouth (08HB074)
- Courtenay River at 5th Street Bridge (08HB083)
- Comox Bay near Comox (08HB087)

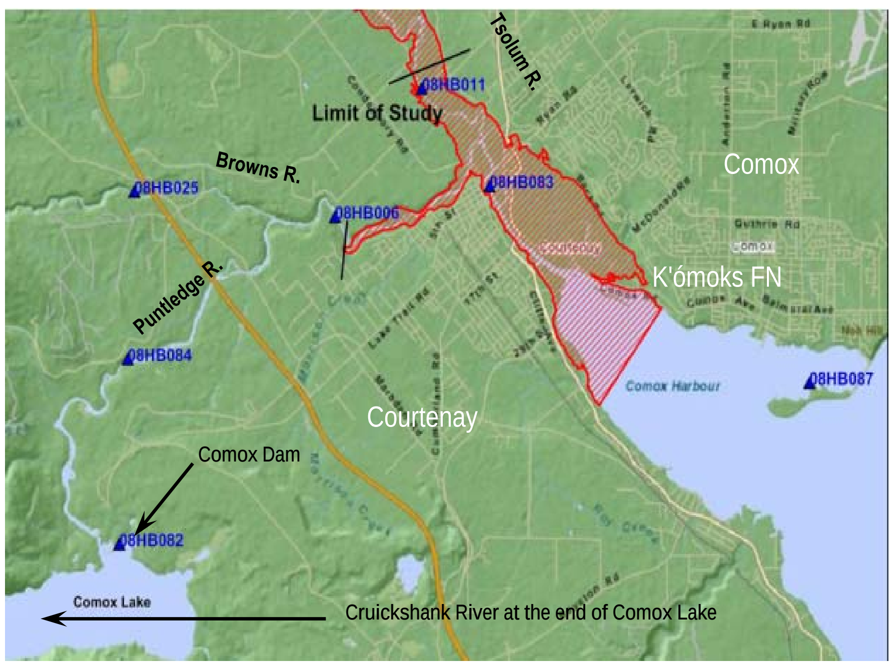


Figure 5.1: Hydrometric Stations

In addition to the Water Survey of Canada records, BC Hydro also maintains a daily record of inflow to Comox Lake which is back calculated based on the recorded Comox Lake levels and controlled outflows into the Puntledge River at the Comox Lake Dam. The locations of the hydrometric gauges are shown on Figure 5.1.

The magnitude of the peak design flows for the Courtenay, Puntledge and Tsolum Rivers have been estimated through a regional flood frequency analysis. This analysis uses peak flood records from hydrometric stations from watersheds across the region, having similar physical characteristics and similar statistical peak flood characteristics as those for the study watersheds.

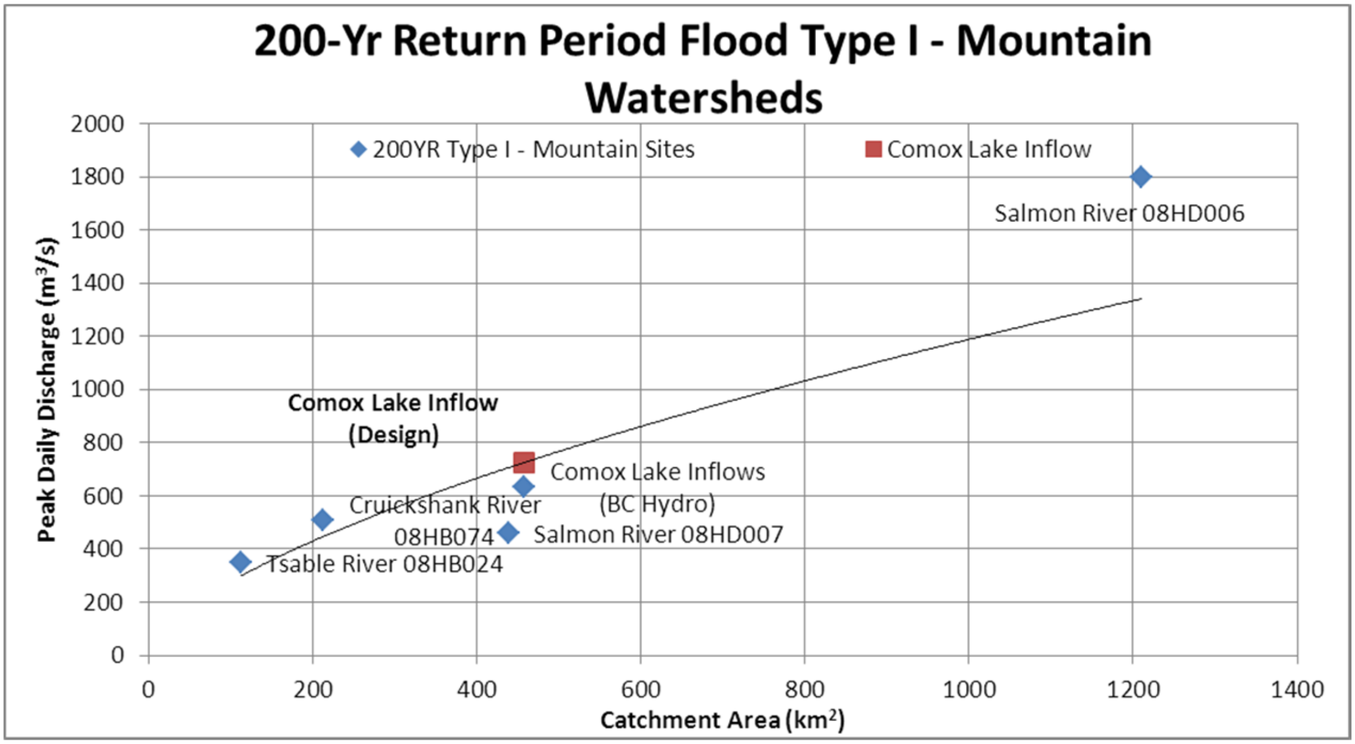
Screening of regional hydrometric stations was carried out to identify watersheds with similar characteristics as the Puntledge and Tsolum Rivers. Regional stations selected to estimate peak flood flows for the Puntledge River, Comox Lake Inflow and Browns River where based on watersheds with higher elevation mountainous watersheds. For the Tsolum River, watersheds with lower average elevation and lower elevation mountain watersheds were selected.

Regional flood frequency involves calculating the 200-year return period peak daily discharges for each of the selected regional stations. These peak flood estimates are then plotted against watershed area to develop a regional flood frequency curve for each of the watershed types, high mountainous watersheds and lower mountain and lowland watersheds. A copy of the regional flood frequency curves for the high mountain and lower mountain watersheds are included in Figures 5.2 and 5.3, respectively.

The results of the regional analysis indicate that the estimate of the daily 200-year inflow to Comox Lake would be marginally higher, about 10% greater, than what would be estimated using the BC Hydro inflow records alone. This is shown as the difference between the blue diamond labeled Comox Inflows (BC Hydro) and the red square labeled Comox Inflow (Design) in Figure 5.2. For the Tsolum River, the regional 200-year return period peak daily flow is about 30% higher than the 200-year return period estimate based on the annual daily peak record from the Tsolum River near Courtenay (WSC 08HB011) gauge. The suitability of both the regional estimate and the single station estimates were carefully considered for adoption as the design value for the assessment. Ultimately, discussions held with the Inspector of Dykes during development of the study, led to using the more conservative regional estimate due to the uncertainty in estimating peak flood flows based on a single station.

Instantaneous peak flow estimates for each of the rivers has been estimated using the results of the regional analysis, by applying an average instantaneous to daily peaking factor based on the over-lapping period of record for the daily and instantaneous flows.

Figure 5.2 – Regional Flood Frequency Curves for Mountain Watersheds

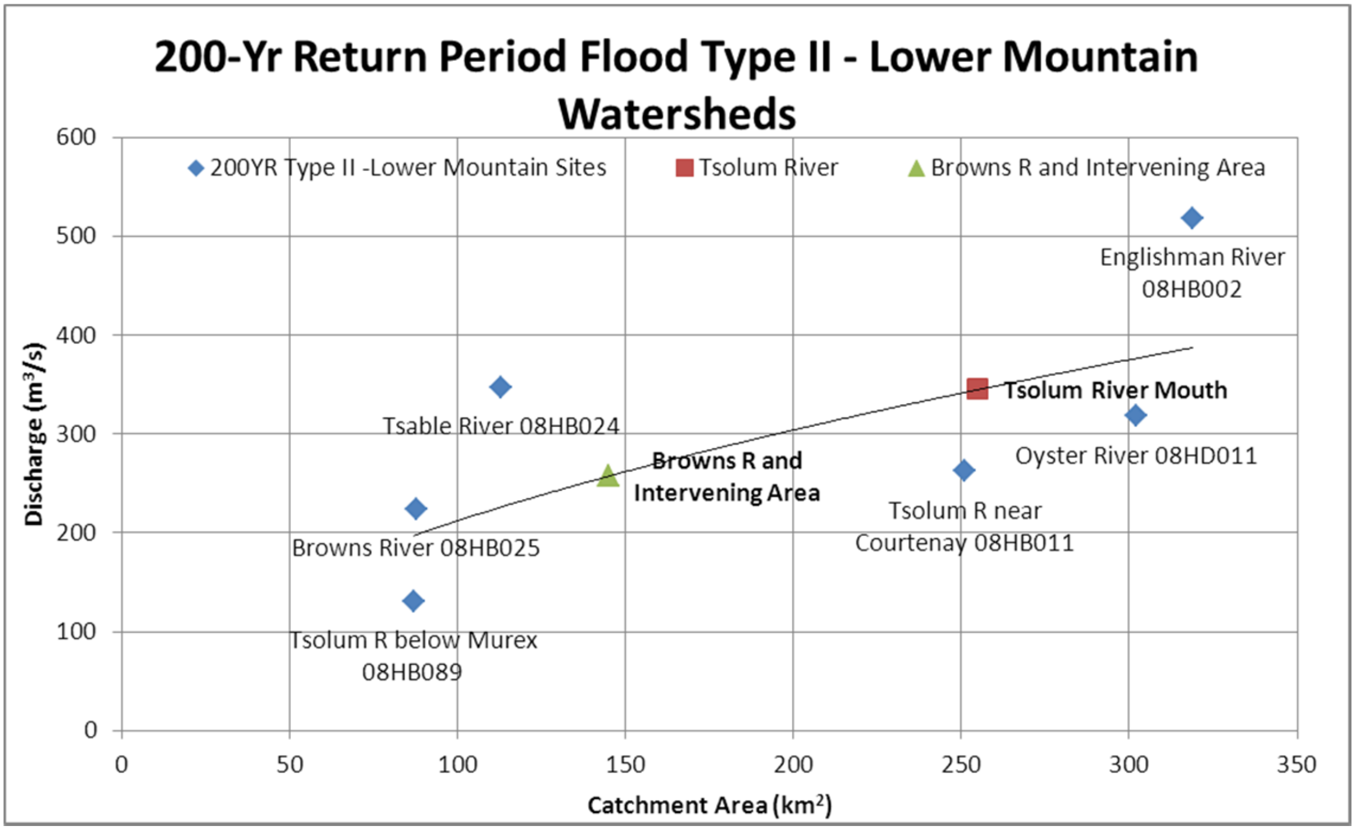


Since discharge in the Puntledge River is strongly influenced by operation of the Comox Lake dam, a frequency analysis of the recorded flows at the Puntledge River gauge does not provide a good indication of the river discharge conditions under the design flood event. For the IFMS study, frequency analysis was performed for Comox Lake inflows (back calculated by BC Hydro), together with the Browns River flows, to determine respective peak design flows. The design return period Puntledge flows were then calculated by adding the following three components:

1. The estimated Comox Lake inflow being routed via the lake and the control dam
2. The estimated Browns River flow
3. The design flow from the additional intervening area of 47 km^2 between Comox Lake and Courtenay River (excluding the Browns River, based on the Browns River design flow).

A reservoir operation model was developed, based on BC Hydro's Operating Orders, to simulate discharges from Comox Lake. This model incorporated the current Operating Orders which outline how the dam is to be operated under flood conditions. Under the orders, flow releases from the dam are to be reduced during high tide periods, to limit the potential for flooding; however, this is limited by the storage capacity of Comox Lake.

Figure 5.3 – Regional Flood Frequency Curve for Lower Watersheds



The model assumes that the Comox Lake water level is at the spillway crest level at the start of the 200-year return period flood event, at El. 135.33 m. Typically, BC Hydro operates the dam to control water levels below this level. However, per discussions with the Provincial Authorities, for the 200-year return period event, it has been assumed that water levels in the lake have been raised to the limit of control, as a result of high inflow to the lake prior to the start of the 200-year return period flood event. Therefore, flow is released from Comox Lake uncontrolled from the start of the 200-year return period event until such time as the reservoir level falls below the spillway crest and the operating orders can resume.

Once the magnitude of peak flows for each of the tributaries to the Courtenay River was estimated, the distribution of flow over time (hydrograph shape) and relative timing of flows had to be established for the design event. Both hydrograph shape and relative timing were based on review of recent flood events. The design event hydrograph shapes were selected to have a single peak, cover typical flood event durations and produce larger than average total volume. The historical events were then scaled up to the magnitude of the design events, by multiplying the ratio of the design event peak flow and the recorded peak flow to hourly data points from the historical recorded flood event. The historical flood events used to develop hydrograph shapes for the Tsolum River and Browns River are based on recorded events from November 4 to 16, 2004, and from November 12 to 19, 2011, respectively. The design Comox Lake Inflow hydrograph is based on hourly records from the Cruickshank River gauge, located at the headwaters of Comox Lake, for an event recorded in November 10th to 20th, 2004.

Relative timing of the peak floods was based on a review of historical flood events. These indicate that for those storm events which produce large flood peaks on all tributary streams, the Browns River tends to peak prior to that of Comox Lake inflow, while Tsolum River tends to peak after the peak of the Comox Lake Inflow. The timing of the peak flows between Comox Lake Inflow and the Browns River and Tsolum River were found to occur 1 hour before and 4 hours after, respectively. This combination produces a peak flow at the mouth of the Puntledge River that is coincident with the peak flow on the Tsolum River. A summary of the design peak flood discharges at various locations in the study area is shown in Table 5.1. Plots of the 200-year return period flood event hydrographs are shown on Figure 5.4.

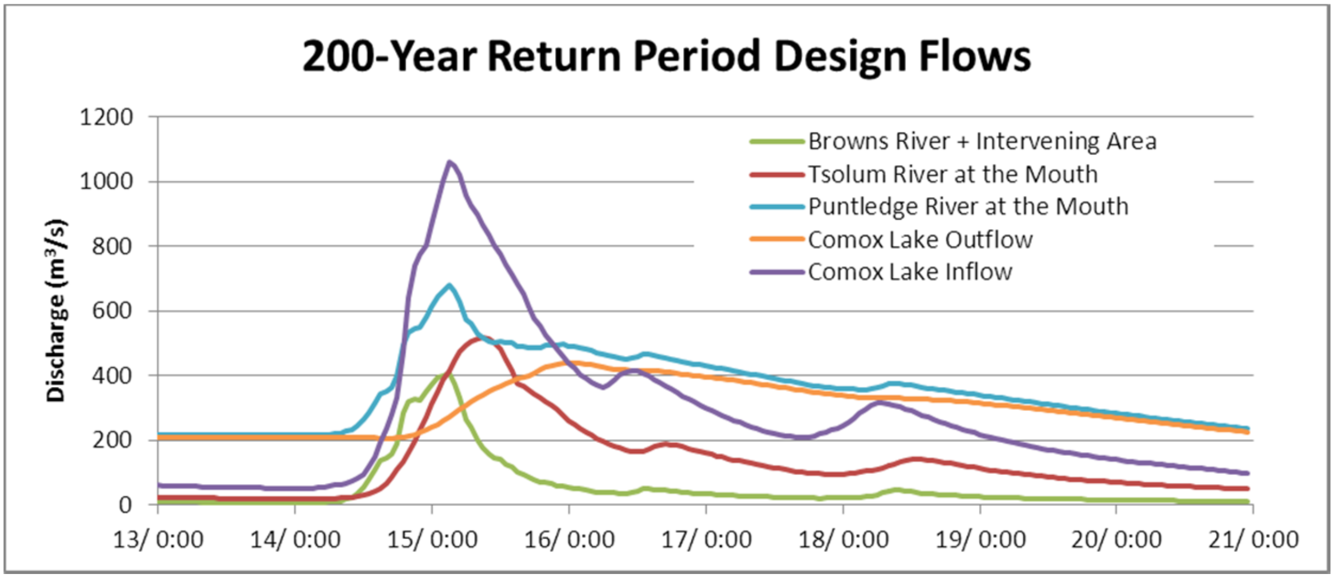
A sensitivity analysis was carried out to assess the influence of relative timing of the Comox Lake inflow peak and the Tsolum River peak flow. Due to the routing effect of Comox Lake and the flattening of the Puntledge River peak, it was found that adjusting the relative timing of the peaks had very little influence on the magnitude of peak flows in the Courtenay River.

Table 5.1: 200-year Return Period Design Storm Event Values

River	Peak Instantaneous Discharge (m^3/s)
Comox Lake Inflow	1059
Comox Lake Discharge[1]	439
Puntledge River at the Mouth	679
Tsolum River at Mouth	516
Courtenay River[3]	1105

Note: 1 – Table shows magnitude of instantaneous flood peaks but not the relative timing of the peaks. The peak discharges in the contributing watersheds do not occur at the same time which is reflected in the peak flow estimates for Puntledge River at the mouth and Courtenay River.
2 – Comox Lake Discharge is based on controlled outflows using the Operating Rules until lake levels rise above free overflow spillway at which point flows are assumed to be uncontrolled.
3 – Contribution to peak flow from intervening area between Comox Lake Dam and Puntledge River mouth not including Browns River.
4- Peak Courtenay River Discharge is estimated by adding Puntledge River and Tsolum River hydrographs which provides an estimate of total peak flow in the river channel and across the floodplain.

Figure 5.4: 200-Year Design Flood Event



5.2 HYDRAULIC MODEL DEVELOPMENT

MIKE FLOOD is a hydrodynamic computer modeling software developed by Danish Hydraulic Institute (DHI) for flood modeling. It is an integrated tool for river channel, floodplain, and coastal flood studies. The MIKE FLOOD model for the Courtenay River watershed is a combination of the MIKE 11 one-dimensional hydrodynamic model used to model flows and water levels in the main river channels and the MIKE 21 two-dimensional model in the floodplain area and coastal areas. The MIKE 21 Flexible Mesh module was used to allow for variations in the grid sizes in the floodplain and therefore to increase topographic detail in critical overflow areas while allowing for reduced topographic detail in areas of ponding or areas outside the flood extents, thereby limiting model size and run times. The model covers the following extents:

- Courtenay River from tide water at Comox Bay to the confluence of the Old Tsolum River Channel and Puntledge River;
- Puntledge River from the confluence with the Courtenay River to the Puntledge River at Courtenay Gauge (WSC 08HB006) downstream of the BC Hydro Puntledge Powerhouse;
- Tsolum River from the confluence with the Puntledge River to a point approximately 300 m upstream of the Dove Creek Road bridge; and
- Old Tsolum River Channel adjacent to Headquarters Road, the Old Island Highway and Lewis Park.

The limits of the model are shown on Figure 2.1, and are consistent with the limits of the Study Area.

The physical geometry of the modeled area was represented by channel cross sections, based on bathymetric surveys completed in May and June of 2012. Floodplain topography is based in LiDAR data collected in May 2012.

5.3 COASTAL MODELING

As outlined above, coastal modeling was performed to develop downstream water level hydrograph boundary data for the river model, considering the impacts of the geometry of the Comox Bay, storm surge and wind set-up. A coastal MIKE 21 HD model of Comox Bay was established roughly between the tip of Goose Spit and the mouth of the Trent River in Royston and is based on bathymetric data collected by Canadian Hydrographic Service.

The High High Water Level Tide (HHWLT) for Comox Bay is 2.19 m, geodetic while the average high tide level that occurs two to three times a year is estimated to be 2.10 m, geodetic. An extreme value analysis of the difference between recorded tide levels and predicted astronomic tide levels was used to estimate peak design storm surge values. Wind shear and wind set up were simulated within the coastal model by including the estimated 200-year wind speed for the south east wind direction to the coastal model.

The estimated storm surge and peak water levels at Comox Bay are outlined in Table 5.2.

Table 5.2: Coastal Flood Water Levels and River Flood Levels at Comox Bay - Current Conditions.

	200-year Return Period Coastal Flood Level
Astronomic Tide (m_GSC)	2.19
200-year Return Period Storm Surge	1.19
200-year Wind Setup	0.07
Peak Comox Bay Still Water Level (m)	3.45

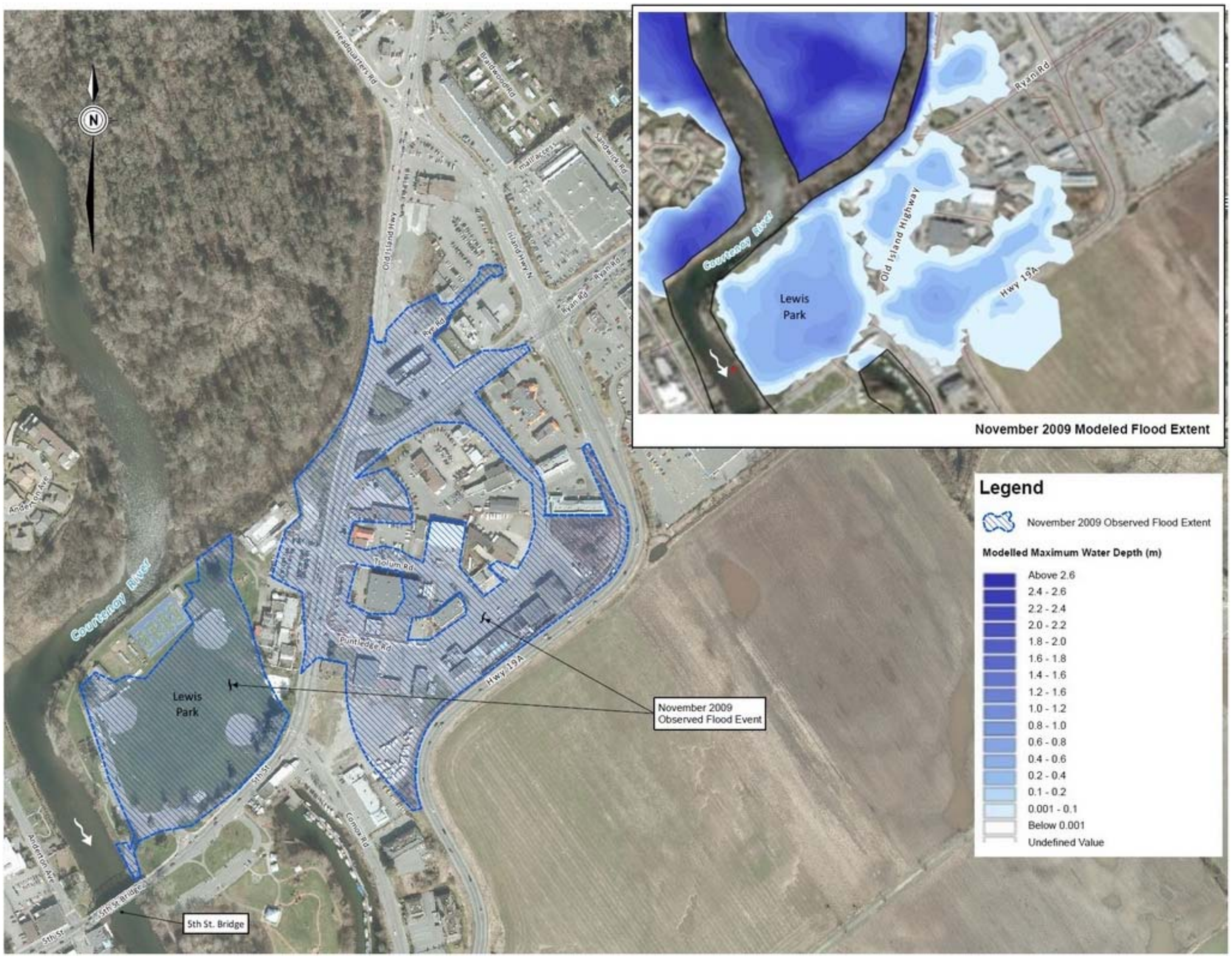
Note: Still peak water levels do not include waves or freeboard allowance. Site specific design will be required to establish Flood Control Levels (FCL) for development along coastal areas. All elevations are geodetic.

5.4 MODEL CALIBRATION AND VERIFICATION

The hydrodynamic model for the river system was calibrated and verified using the 2009 and 2010 flood events, respectively. Recorded hourly discharge data of the Tsolum River at Courtenay gauge (WSC 08HB011), the Puntledge River at Courtenay gauge (WSC 08HB006) and the tide level data for the Comox Harbour gauge (08HB087) was used as boundary conditions of the MIKE FLOOD river model, to simulate the recorded flood events. The model results were compared with water levels recorded at the Courtenay River 5th Street Bridge gauge (WSC 08HB083) and the observed 2009 flood extent in the Lewis Park area of the City of Courtenay. The channel and floodplain roughness coefficients used in the model were adjusted until simulated water levels compared well with recorded levels for the 2009 flood event.

Calibration results indicate that the model is calibrated well, matching the observed flood levels at the Courtenay River gauge in both the 2009 and 2010 events (within 3 mm). A comparison of the modeled and observed flood extents in the 2009 flood also indicates reasonable accuracy in overflow and inundated land coverage during this event (see Figure 5.5).

Figure 5.5: Comparison of Modeled and Observed Flood Extents (Nov 2009 Event)



5.5 200-YEAR RETURN PERIOD DESIGN FLOOD ANALYSIS

Flooding in the City of Courtenay has two primary contributing factors, high river flows and high tides. Not surprisingly, flooding in the upper part of the study area is mainly controlled by peak flows; flooding in the lower section of the study area is due to high tide levels; while flooding in the middle sections of the study area are a result of the combined effects of high flows and high tides. To develop a design flood event model with the expected return period (e.g. 200-year return period) for the entire study area, both the design river flows and tide data (with the desired return period) were used.

Peak downstream water level at Comox Bay for the 200-year river flood event was assumed to be the combination of the 200-year return period storm surge and wind setup occurring on top of the high tide level which occurs two or three times a year on average. The 200-year return period tide and river flows, under current climate and sea level conditions, were modeled to determine the floodplain mapping levels of the Courtenay River system. The coastal model results for the coastal flood levels and the river model results for the river levels have been combined by selecting the higher of the two results to establish the 200-year return period peak flood profile. The profiles are shown on Figure 7 of the attached technical memorandum in Appendix C.

5.6 FLOODPLAIN MAPPING

Based on direction from the Provincial Inspector of Dikes, , a freeboard of 0.6 m was added on top of the simulated peak 200-year return period instantaneous water levels to establish flood construction levels (FCLs). The recommended freeboard provides an allowance to reflect other factors such as river surface waves, changes in bed geometry over time and uncertainty in the model results. The updated 200-year return period floodplain maps show the FCL contours throughout the entire floodplain areas, as shown on the attached Maps 1 through 3.

Table 5.3 provides a summary of peak 200-year return period flood levels and flood construction levels at key locations along the rivers. These are based on existing conditions in the floodplain and do <u>not</u> include potential impacts of flood protection works or future development in the floodplain.

Table 5.3 also lists the flood control levels established in the 1990 Floodplain Mapping Study. In general, the updated FCLs are higher than those developed in the 1990s. This is partially due to increased peak flow estimates for the Puntledge River, as well as increase freeboard allowance requirements from 0.3 m in 1990 to 0.6 m in the current study.

Table 5.3: Estimated Peak Design Water Levels

Location	200-Year Return Period Flood Level (m-GSC)*	Flood Construction Level (m-GSC)	1990 Floodplain Level (m-GSC)
Courtenay River			
Courtenay River at Comox Bay	3.45	4.05	3.7
Upstream Side of the 17th Street Bridge	3.74	4.34	3.7
Upstream Side of the 5th Street Bridge	4.32	4.92	4.5
Downstream end of Old Tsolum Channel	4.84	5.44	4.75
Puntledge River			
Confluence with the Tsolum River	5.34	5.94	5.3
Upstream Side of the Condensory Road Bridge	5.84	6.44	6.0
Old Tsolum Channel			
Adjacent to Headquarters Road and Old Island Highway Intersection	5.08	5.68	5.15
Tsolum River			
Maple Pool Camp Site	5.34	5.94	5.5
Upstream Side of the Dove Creek Road Bridge	7.45	8.05	8.0

*m-GSC equals metres above geodetic datum

5.7 CLIMATE CHANGE IMPACT ANALYSIS

Global temperature records indicate a warming trend over the Earth's surface since the beginning of the 20th century, with more rapid acceleration of warming in recent decades. Over the past century, global average surface temperature increased by approximately 0.6° C. Coincident with the temperature increase, climate change impacts related to sea levels and precipitation are generally accepted to be occurring.

While the mechanisms causing sea level rise (SLR) are well understood, the expected magnitude of changes in sea-level is highly uncertain. SLR 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. Estimated sea level rise rates have recently been assessed for BC. In the province's Coastal Floodplain Mapping – Guidelines and Specifications (June 2011), the recommended sea level rise allowance to be used for coastal floodplain mapping studies was specified as follows:

- Year 2100 – Increased mean sea level by 1 m over the Year 2000 sea level
- Year 2200 – Increased mean sea level by 2 m over the Year 2000 sea level

Tide level increases of 1 m and 2 m over the estimated existing climate condition tide data were assumed in this study, to reflect climate change impacts on sea level for Year 2100 and Year 2200 respectively.

In order to forecast future 200-year flood levels, both changes in storm surge levels and changes in ground levels (as a result of uplift or subsidence) must be taken into account. Based on the analysis, 200-year return period peak "still water" levels in Comox Bay are forecast to be about 1.1 m and 2.4 m higher than current levels, by the year 2100 and 2200, respectively. They are outlined in Table 5.4 below. It should be noted that model results are based on still water levels; site specific design will be required to estimate the height of surface waves, to plan for coastal development and upgrades to existing infrastructure.

Prediction of climate change impacts on future precipitation is not as certain as the potential for SLR. The magnitudes of the change cannot be well-defined on a watershed basis. For this study, it was assumed that a 15% increases to the storm surge peaks and the river runoff data will occur by Year 2100 and another 15% increases by Year 2200. This assumption is based on the recent climate modeling results of the Pacific Climate Impacts Consortium for the BC area.

Model results show significant increased flood levels in the lower reaches of the Courtenay River, reducing upstream as the influence of tide levels on peak river levels decreases. By the year 2100, peak 200-year return flood levels in the Courtenay River are likely to be about 1 m higher at the 17th Street Bridge while peak levels are likely to be about 0.5 m higher at the downstream end of the Old Tsolum Channel near Lewis Park. Forecast increase in peak water levels in the Puntledge River and Tsolum River upstream of the confluence are likely to be less, with model results indicating increases of between 0.5 to 0.3 m by the year 2100.

With an increase of 2 m in average sea level by the year 2200 in Comox Bay, it is likely that Comox Road between the 17th Avenue Bridge and K'ómoks First Nation would be overtopped regularly during storm events, producing storm surge from south east winds. Although the specific return period, which would cause road overtopping, was not estimated, a comparison of the typical road crest elevation (El. 3.5 m to El. 4.0 m) with future higher high tide levels (3.19 m by year 2100 and 4.19 by year 2200) shows that even relatively small storm surge and waves (~ 0.3 m) could result in roadway inundation.

A listing of the peak flood levels estimated under future climate conditions is shown on Table 5.4. The water levels are based on existing conditions in the floodplain and do not include potential impacts of flood protection works or other development in the floodplain.

Table 5.4: Comparison of Current Flood Construction Levels future planning Flood Levels due to SLR and Climate Change

Location	Existing Climate Flood Construction Level (m-GSC)	2100 Climate Planning Flood Level (m-GSC)	2200 Climate Planning Flood Level (m-GSC)
Courtenay River			
Courtenay River at Comox Bay	4.05	4.49	5.72
Upstream Side of the 17th Street Bridge	4.34	4.70	5.88
Upstream Side of the 5th Street Bridge	4.92	5.03	5.95
Downstream end of Old Tsolum Channel	5.44	5.37	6.16
Puntledge River			
Confluence with the Tsolum River	5.34	5.79	6.40
Upstream Side of the Condensory Road Bridge	5.84	6.28	6.73
Old Tsolum Channel			
Adjacent to Headquarters Road and Old Island Highway Intersection	5.08	5.52	6.21
Tsolum River			
Maple Pool Camp Site	5.34	5.74	6.24
Upstream Side of the Dove Creek Road Bridge	7.45	7.65	7.91

5.8 BRIDGE CLEARANCES

Typical standards require that 1 m of clearance is allowed between the 200-year return period flood and the underside of bridge deck, to allow for passage of debris and for uncertainty in modeling. A summary of the clearance for current climate and sea level conditions as well as forecast conditions for year 2100 and 2200 are shown in Table 5.5.

Table 5.5: Estimated Bridge Clearances

Bridge	Bridge Deck Soffit Elev. (m)	200-Year Return Period Condition					
		Year 2013		Year 2100		Year 2200	
		Peak WL (m)	Clearance (m)	Peak WL (m)	Clearance (m)	Peak WL (m)	Clearance (m)
17th Street Bridge	6.02	3.74	2.28	4.70	1.32	5.88	0.14
5th Street Bridge	5.55	4.32	1.23	5.03	0.52	5.95	0.00
Condensory Bridge	5.98	5.81	0.17	6.25	0.00	6.71	0.00
Dove Creek Road Bridge	7.81	7.43	0.38	7.63	0.18	7.89	0.00

Note: Cells highlighted in Yellow indicate bridges with clearance less than 1 m under 200-year return period conditions and cells highlighted in Red indicate bridges with no clearance under 200-year return period flood conditions.

6 ISSUES AND CHALLENGES

Addressing flood risk and viable mitigation options requires both a technical understanding and an appreciation of stakeholder values.

6.1 ISSUES FROM THE PUBLIC ENGAGEMENT PROCESS

The following is a summary of dominant themes stemming from the public engagement meeting dated November 15, 2012:

Support further study and costing of the following *short term* improvement:

Construct a Floodwall to provide protection for smaller more frequent events (20 year). Ryan Road area will continue to flood during extreme (200 year) events.

42.0%	Support	No consensus established
18.0%	Support with refinements	
40.0%	Don't Support	

Support further study and costing of the following *long term* improvements:

The strongest support was for the following two ideas:

1. Avoid further flooding risks by discouraging further up-zoning or subdivision in the floodplain, outside dikes, that would result in increased need for flood protection of that new use.

82.7%	Support	Consensus demonstrated
5.8%	Support with refinements	
11.5%	Don't Support	

2. Pursue 'managed retreat' from public lands (existing or purchased) in the floodplain, outside dikes, by removing uses that cannot be adapted to flooding.

69.2%	Support	Majority demonstrated
7.7%	Support with refinements	
23.1%	Don't Support	

Public response was mixed on the following two ideas:

3. Construct a Dike along both sides of Courtenay/Lower Tsolum Rivers, by raising Old Island Highway, Comox Road, and riverside dikes to 200 Year Levels.

20.4%	Support	No consensus established
20.4%	Support with refinements	
59.2%	Don't Support	

4. Construct a Dike Ring by raising Old Island Highway and Hwy 19A to improve flood protection to Ryan Road area.

22.0% Support
36.0% Support with refinements
42.0% Don't Support

No consensus established

Sea Level Rise

The strongest support expressed for the further study and cost-benefit analysis related to SLR was provided for the following two ideas:

1. Review land use applications and public capital works in SLR Planning Areas to ensure the proposals anticipate how to adapt to the potential changes in flood levels. Avoid projects that are not adaptable with reasonable cost-benefit.

80.0% Support
16.4% Support with refinements
3.6% Don't Support

Consensus demonstrated

2. Create Sea Level Rise (SLR) Planning Areas for Year 2100 and Year 2200 including all lands that would potentially face inundation due to the combination of rising seas and river flood levels.

75.5% Support
15.1% Support with refinements
9.4% Don't Support

Majority demonstrated

In short, it is clear from the above, and from other public input events and letters, that respondents generally favour 'soft' solutions to flood management, as opposed to extensive diking along the Courtenay River.

Opinions on floodwall or limited diking in the Old Island Highway / Ryan Road areas are more mixed, based on the sample of the Public from whom an opinion on this issue was sought. We would add that land owners specifically affected by flooding, who would benefit directly from diking, were not singled out as a group.

6.2 TECHNICAL ISSUES AND CHALLENGES

The two documents referred to for the construction of dikes in the Province of British Columbia are:

- Dike Design and Construction Guide: Best Management Practices for British Columbia, Ministry of Forests, Lands and Natural Resource Operations, Flood Safety Section, July 2003
- Seismic Design Guidelines for Dikes, Ministry of Forests, Lands and Natural Resource Operations, Flood Safety Section, August 2011

Options for community based flood protection, whether considered interim or long-term, should meet the criteria for registration as a Provincial Dike. These criteria include the following:

- Minimum flood protection is 200 year return period.
- Designed to withstand the seismic events according to the Seismic Design Guidelines for Dikes in BC.
- Be constructed in a manner where access to the dikes can be maintained permanently for routine and emergency maintenance. This includes provision for suitable land tenure by the Operator of the Dike, in this case, the City of Courtenay.
- Be constructed of materials in such a manner that they meet all stability requirements including:
    - The crest of the dike follows the profile of the design flood, and includes freeboard for hydraulic and hydrologic uncertainty;
    - Recommended minimum crest width is 3.66m (12 feet) to allow for emergency access;
    - Landside slope stability due to steady seepage;
    - Waterside slope stability due to draw down;
    - Surface erosion of slopes, and stream/wave erosion of the waterside slopes;
    - Seepage, uplift, and piping through or under the dike and structures;
    - Internal drainage, and provision for dealing with structures in and through dikes;
    - Consideration for climate change and SLR.

The above criteria need to be considered in conjunction with constraints imposed by existing and future development, especially as it relates to the key area requiring protection: the Ryan Road commercial area. Any flood protection work needs, therefore, to consider the following technical constraints.

- Corridors, Land Tenure and Easements need to be either respected or established.
- Geotechnical assessments of sub-surface soils need to be completed, to ensure stability under various hydraulic conditions and potential earthquake resistance.
- Diking structures need to be adaptable, and amendable to height increases as the Courtenay River Basin experiences the potential Sea Level Rise and/or greater river flows, due to climate change.

In addition, construction must not harm the environment both in the short and long-term. Alternatively, compensation mechanisms need to be in place to offset any unavoidable harm occurring as a consequence of constructing a flood protection structure. Other regulatory requirements include the need for Archaeological assessments, to ensure any Heritage Resources are properly accounted for. Lastly, funding constraints require the construction of flood protection works within available budgets and limits imposed by external funding sources.

The above is not intended as an exhaustive list or summary of stakeholder and technical issues. Rather, it is assumed that issues raised here will serve as guidelines, later revisited and potentially added to, upon finalization of the preferred flood mitigation solution for Courtenay.

7 FLOOD MITIGATION ALTERNATIVES

Three options for flood mitigation were developed based on consultations with the City, various stakeholders and the public. It needs to be emphasized that the options do not each afford the same level of flood protection or area of protection.

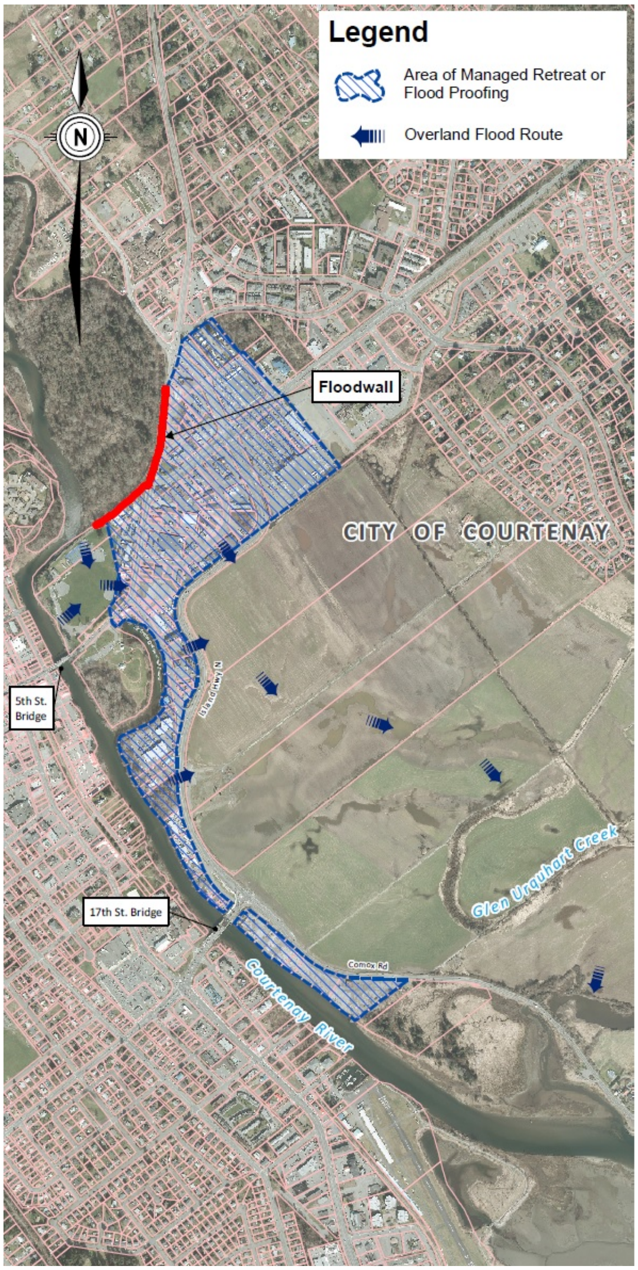


Figure 7.1: The Tsolum River Floodwall

7.1 THE TSOLUM RIVER FLOODWALL – OPTION 1

Option 1 proposes a floodwall along the Old Island Highway abutting the Old Tsolum Channel bank. The City expected the floodwall to be a portion of an overall flood protection plan, meant to protect the most vulnerable area, which is subject to more frequent flooding, property damage and transportation closures. This solution required a review of the entire floodplain hydrology and hydraulics (i.e. this IFMS) to ensure that allocated funds would be applied to a 200-year flood protection.

Based on the models produced for this report, the floodwall Option 1 would not provide the standard 200-year return period criteria recommended in the Provincial Flood Protection guidelines. Rather, it would be intended to prevent flooding resulting from smaller and more frequent flood events such as the 2009 and 2010 events. If a floodwall was to be constructed to the 200-year return period standard along the Old Island Highway alignment, it would not prevent flooding of the Ryan Road/Old Island Highway area during extreme events greater than the 2009 and 2010 water levels, since backwater from Lewis Park and Courtenay Slough would overtop Old Island Highway near 5th Street and Comox Road. In order to provide flood protection to the 200-year standard, a full ring dyke would have to be constructed as discussed in the analysis of Options 2 and 3, in the following sections.

In order to prevent flooding of properties during extreme events under Option 1, properties would need to be flood proofed or raised to the 200-year return period flood construction level, presumably best undertaken over time, as redevelopment occurs. Properties with existing buildings (within the blue hatched area of Figure 7.1) were artificially raised within the model (i.e., the model surface was altered to represent flood proofing areas), to simulate required future “flood proofing” for the assessment.

The proposed floodwall option, Option 1, would provide some level of protection to the commercial/ industrial area east of Old Island Highway and north of South Island Highway. Under the 2009 flood condition, the proposed floodwall would result in slight increases of the peak flood levels by up to 0.08 m in the Old Tsolum Channel adjacent to the proposed floodwall, and by up to 0.03 m, 0.04 m and 0.02 m in the Courtenay River, Puntledge River and Tsolum River, respectively during an event equivalent.

Under the 200-year return period flood conditions, the proposed floodwall would slightly reduce the flood levels in the Ryan Road/Old Island Highway commercial/industrial area, but this area would still be inundated. However, this option would result in increases of peak flood levels respectively by up to 0.23 m in the Old Tsolum Channel, 0.10 m in the Courtenay River, 0.10 m in the Puntledge River and 0.08 m in the Tsolum River, in comparison with the 200-year return period water levels under current conditions without the floodwall.

The Floodwall Concept needs to be considered as part of a broader, more comprehensive flood mitigation strategy, if protection for the 200-year flood is to be achieved.

7.2 COMMERCIAL AREA RING DIKE – OPTION 2

Public concern regarding a full dike down both sides of the Courtenay River, coupled with a low requirement for protection on the west side, led to a compromise solution: diking only around the Ryan Road commercial area. This smaller area represents roughly $40 million of private and public property and includes portions of major transportation corridors, connecting the west and east parts of the city.

Option 2 (Figure 7.2) proposes the development of dike structures along the Old Island Highway north of Ryan Road, building a new dike or raising the existing dike along the Old Tsolum Channel bank (west of Old Island Highway then along the east

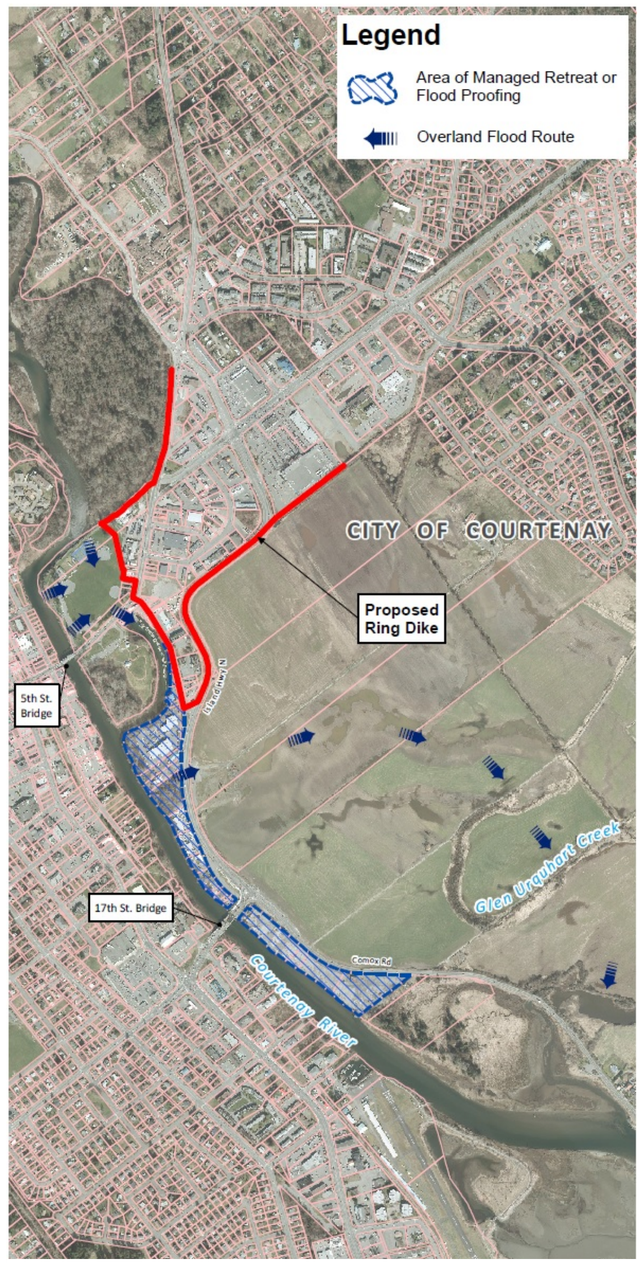


Figure 7.2: Option 2 – Commercial Area Ring Dike

boundary of Lewis Park), raising Comox Road adjacent to the Courtenay Slough and a section of South Island Highway, and constructing a dike along the south-east boundary (behind SuperStore) of the commercial development area. This option then provides a ring dike to protect the commercial/industrial properties in the Ryan Road/Old Island Highway area. Lewis Park and Centennial Park would be allowed to be flooded and, thus, provide flood relief. Properties in flood risk areas adjacent to the Courtenay River banks, not protected by the ring dikes, would be flood proofed with added fills under this scenario.

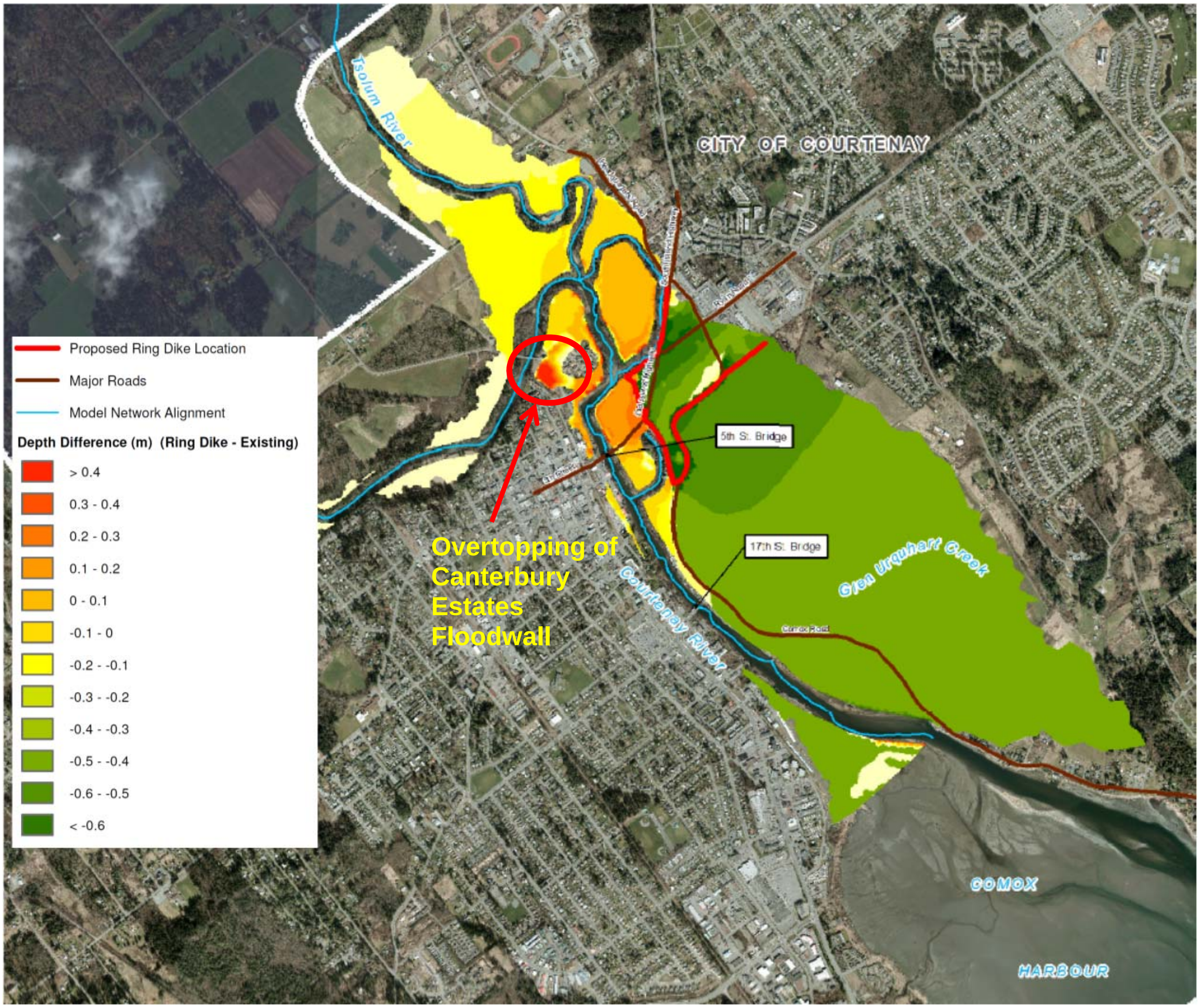
The intent of this option is to expand upon Option 1 – Tsolum River Floodwall Concept, providing full flood protection to the adjacent commercial area up to and including the 200-year flood. This option would integrate the Tsolum River Floodwall, or a differing dike structure along the same corridor. This option allows greater protection of transportation links across the 5th Street Bridge, maintaining connectivity during emergency flood conditions. Existing overland flood paths to the agricultural fields would be reduced under this option, but they would continue to receive floodwaters across Comox Road upstream and downstream of the 17th Street Bridge.

Modeling result for the 200-year event with the ring dike option (with all other properties within the blue hatched area being flood proofed) shows more significant effects on flood levels both upstream and downstream. This is to be expected, because the ring dike serves to promote greater channelization of the Courtenay River during the major events. Figure 7.3 shows the difference in flood levels on a thematic map. The calculated difference, as indicated, is that expected during a 200-year flood event with and without the ring dike.

The proposed full ring dike along the Ryan Road/Old Island Highway commercial/industrial area would protect the diked area from flooding up to 200-year return period events and would also reduce the flood levels by up to approximately 0.4 m in the agricultural fields area. However, this option would result in up to 0.65, 0.64, 0.41 and 0.32 m increases to the peak 200-year return period flood levels in the Old Tsolum Channel, the Courtenay River, the Puntledge River, and the Tsolum River, respectively.

The modelled upstream impacts during the estimated 200 year return period flood are considered to be significant. For instance, increased water levels near the Puntledge River and Tsolum River confluence would likely result in over-topping of the existing floodwall at the Canterbury Estates located at 20 Anderton Avenue to the south-east of the Condensory Road Bridge. In addition, construction of the ring dike as proposed in Option 2 would result in significant increase (greater than 0.1 m) in flood levels in the unprotected floodplain along the Tsolum River as far upstream as the Dove Creek Bridge. This area includes both private properties within the City of Courtenay Boundary as well as K'omox First Nation lands.

Figure 7.3: Flood Level Comparison for Option 2



7.3 PARTIAL RING DIKE WITH FLOODWAY – OPTION 3

Option 3 proposes raising Old Island Highway north of Ryan Road, building a dike along the Old Tsolum Channel bank west of Old Island Highway and along the east boundary of Lewis Park and then from the Old Island Highway and Comox Road across the vacant private property at 498 Old Island Highway (Old Courtenay Hotel property)to South Island Highway, raising the section of South Island Highway east of the new dike and building a dike to tie into the high ground along the south-east boundary of the commercial/industrial development area. This dike alignment and extents is depicted on Figure 7.4.

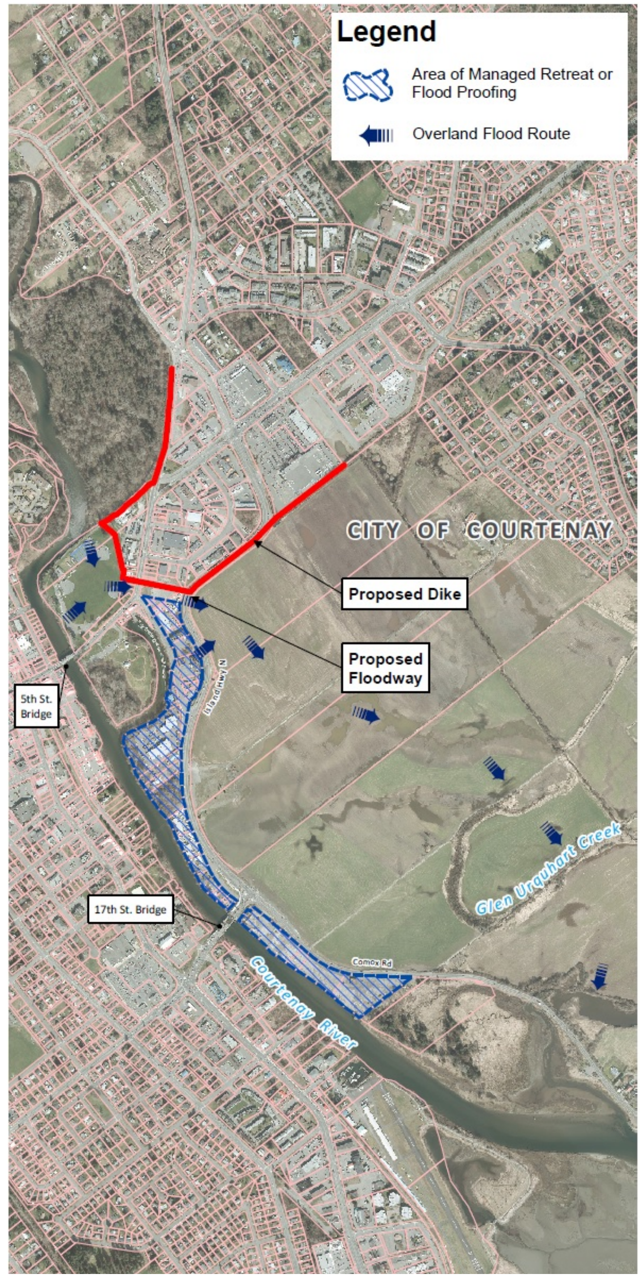


Figure 7.4: Option 3 – Partial Ring Dike with Floodway

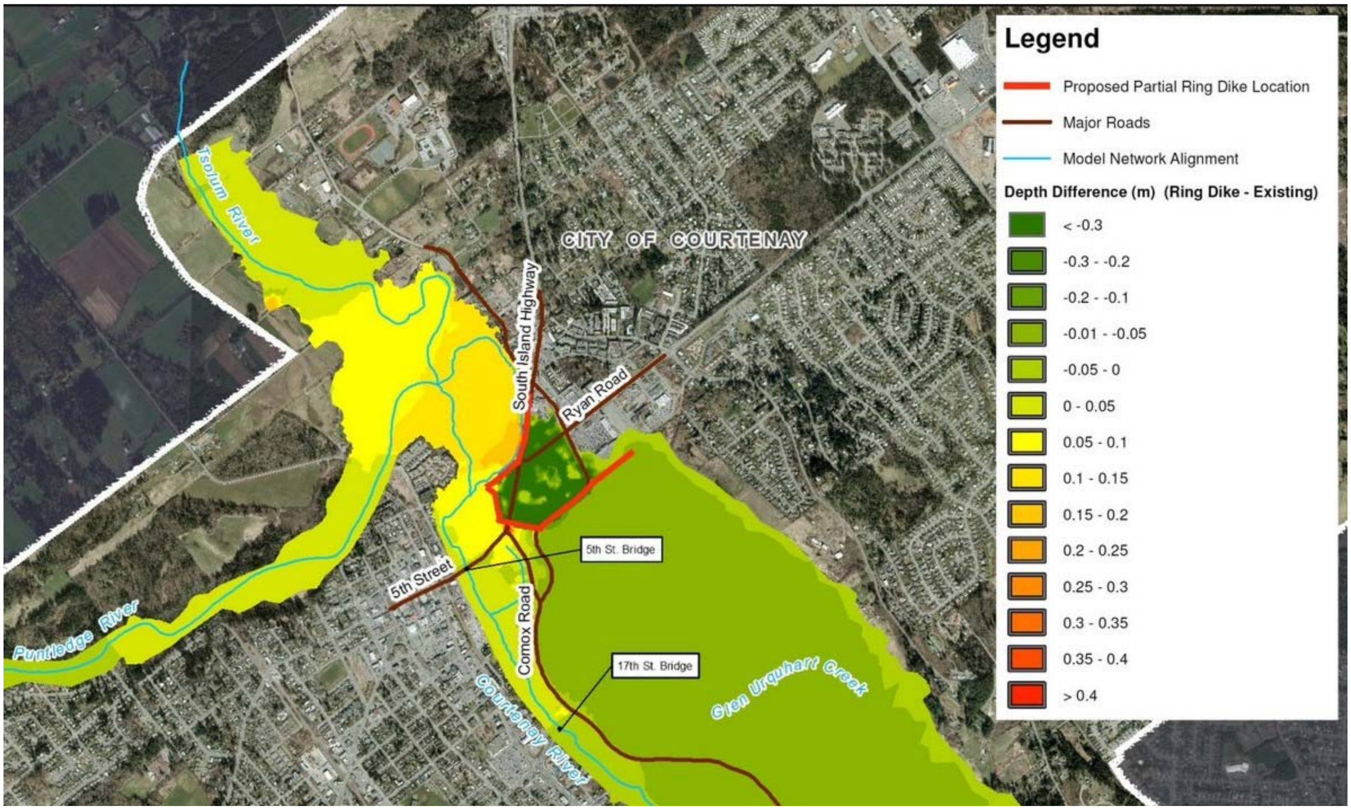
This option provides a partial ring dike to protect the majority of the commercial/industrial area near the Ryan Road/Old Island Highway intersection, but eliminates the need to raise Comox Road and the southern section of South Island Highway. This option also proposes a 30 m wide floodway route through the developed ground between the Old Island Highway and Comox Road intersection to South Island Highway.

The floodway would start at the intersection of the Old Island Highway and Comox Road with an invert elevation of 3.0 m-GSC, providing flood relief from Lewis Park into the agricultural area in Courtenay Flats.

Drainage structures would be required under the Old Island Highway and Highway 19A to provide flood passage, while maintaining transportation links. Similar to Option 2, properties in the flood risk areas outside of the ring dike adjacent to the Courtenay River banks, not protected by the dikes, would either require to be flood proofed and raised to the FCL or considered under a managed retreat policy. However, unlike Option 2 the properties along Comox Road between the Old Island Highway and Highway 19A would <u>not</u> be protected. This includes both the Provincial Offices and the Regional District Offices located on Comox Road.

The above scenario was configured within MIKE FLOOD, and the 200-year event was simulated to define calculated peak water levels throughout the floodplain. As with Option 2, the results were compared to current conditions (with no flood protection in place). As expected, by promoting or allowing more water to be conveyed to the agricultural fields during more significant flood events, the upstream peak flood level increases would be reduced. Figure 7.5 provides thematic mapping of the difference in peak flood levels for comparison.

Figure 7.5: Flood Level Comparison for Option 3



Similar to Option 2, the proposed partial dike would protect the diked Ryan Road/Old Island Highway commercial/industrial area from flooding up to the 200-year return period event, and would reduce flood levels in the Courtenay Flats area by up to approximately 0.2 m, compared with the peak flood levels under the existing (no flood management) scenario.

Table 7.1 below lists the model results where proposed Option 3 causes up to 0.34, 0.34, 0.30 and 0.22 m increases to the peak 200-year return period flood levels in the Old Tsolum Channel, the Courtenay River, the Puntledge River, and the Tsolum River, respectively. This is between 0.26 m and 0.1 m <u>less</u> than the water level increases resulting from Option 2.

Although the upstream impacts are still significant under Option 3, the model indicates that peak water levels would not overtop the Canterbury Estates floodwall. This said, the floodwall would still likely have to be raised to provide sufficient freeboard allowance above 200-year return period flood levels. Under Option 3, significant increases in water levels greater than 0.1 m would only extend upstream as far as the property at 4795 Headquarters Road.

Table 7.1: Comparison of Peak Flood Levels among Alternative Mitigation Strategies

Location	Peak Flood Level 200-Year Event (m)	Change in Peak Flood Level (m)		
		Option 1 Floodwall	Option 2 Ring Dike	Option 3 Ring Dike/Floodway
Comox Bay	3.45	0	0	0
Upstream of 17th Street Bridge	3.74	0.04	0.16	0.07
Upstream of 5th Street Bridge	4.32	0.14	0.64	0.31
Puntledge and Tsolum River Confluence	5.34	0.10	0.41	0.30
Old Tsolum River Channel near Old Island Highway and Headquarters Road	5.08	0.12	0.50	0.34
Upstream of Condensory Bridge (Puntledge River)	5.84	0.08	0.23	0.19
Upstream of Dove Creek Road Bridge (Tsolum River)	7.45	0	0.02	0.01

The magnitude of impacts to water levels outlined in this section is influenced by the conservative nature of the design flood estimate for the Puntledge and Tsolum Rivers. An analysis was carried out during development of the options to check potential changes in water levels as a result of the flood protection options using 200-year peak flow estimates for the Tsolum River and Puntledge River that were 30% lower and 10% lower respectively. These changes were based on the results of the single station frequency analysis rather than the regional flood frequency analysis. The results indicate that the lower peak design flows result in changes in water levels upstream of less than 0.1 m for all the options.

Noting the sensitivity of the backwater effect to the design storm, selection of the preferred flood mitigation option needs to include a more detailed assessment of the sensitivity of upstream water level impacts on changes in design flows and downstream boundary conditions. Better definition of the magnitude and frequency of potential changes in upstream water levels is needed, together with additional correspondence with the Provincial Diking Authority in this regard.

All three options include a flood protection alignment along the Old Tsolum River Channel, including Option 1, the “Floodwall Concept”. We believe the concept of a flood protection structure along the proposed floodwall alignment is a valid interim solution, which will protect the immediate area for all floods between the 20-year and 50-year return period event, until it is integrated into the broader flood protection scheme.

8 COSTS AND BENEFITS

8.1 ESTIMATED COSTS FOR CONSTRUCTION

Cost estimates for the three options have been prepared at a conceptual level for this study without the benefit of detailed engineering. They include a 25% contingency for uncertainty of both scope and price. A breakdown of estimates for the three options is provided in Appendix D, summarized on Table 8.1 below.

Table 8.1: Summary of Estimate Construction Costs

Alternative Mitigation Measure	Construction*	Soft Costs**	Total
Option 1 - Floodwall	450,000	300,000***	$750,000
Option 2 – Ring Dike	5,161,000	690,000	5,851,000
Option 3 – Partial Dike with Floodway	4,811,000	645,000	5,456,000

* Construction includes a 25% Contingency
** Costs include engineering, environmental approvals, administration and financing
*** Includes costs for this Integrated Flood Management Study
Note: Estimate does not include additional capital or other costs related to mitigation of upstream/downstream impacts.

As originally envisioned, the floodwall concept (Option 1) is estimated to cost about $450,000 for design and construction of the cast-in-place concrete structure. Subsequent assessments of geotechnical conditions have indicated that subsurface soils are poor, requiring mitigation to meet seismic design requirements. The costs of seismic improvements and full flood protection structures are indicated for Option 2 and 3. Since Option 1 does not provide comprehensive flood mitigation to the 200 year flood return period, the true comparison when deciding on a "preferred" option can only be made between Options 2 and 3.

Less protection is afforded by option 3 for roughly the same cost of construction. However, additional benefits (such as lower backwater effects, etc.,) arising from either option must be considered, over and above the level of flood protection afforded. The following sections provide further discussion regarding other potential costs and/or benefits associated with each option, beyond the direct costs and benefits mentioned above.

8.2 OTHER MITIGATION/COMPENSATION COSTS

Each of the three options has an effect on flood levels in the both the upstream and downstream directions, which will likely be considered to have negative impacts to those property owners not protected by new flood protection infrastructure. Considering Option 2, for example, property owners in the valley outside the proposed ring dike area will be affected by increased water levels between 0.15 and 0.65 metres during the estimated 1:200 year flood. This increase in water levels, however temporary, could give rise to increased damages to property. Assessment of these impacts is not easily quantified at this level of study, as the analysis must look at what the incremental impact is rather than just what the total damage may be. It requires a detailed assessment of each property, and a negotiated value with the affected property Owner. The agreements for compensation should be registered on as caveats or covenants to ensure that the negotiated values are maintained in perpetuity with the land. Even if the negotiated values for compensation are zero, legal covenants indemnifying the City from future claims need to be considered. As is evident from the described process, there could be significant legal costs associated with the negotiations and registrations of legal documents on property titles. All these costs need to be identified, quantified and considered when deciding whether or not to proceed with an individual flood mitigation project that has effects to adjacent properties.

One alternative to compensation is additional mitigation, meaning more “flood proofing” to adjacent properties. Throughout the public consultation process, wide spread flood mitigation (diking, etc.,) along the Courtenay River was indicated by the public as <u>not</u> a preferred option. We can predict, essentially with certainty, that more extensive flood proofing will give rise to yet further increases in river backwater effects. As agreed with the City, a comprehensive flood mitigation option covering the entirety of the study area has not been considered as part of this study.

Another alternative is the purchase affected properties. This can occur over time, as they are marketed for sale, or negotiated agreements for assumed ownership over time can be formulated, perhaps on the basis of reduced or no property taxes as payment for eventual ownership or even reduced claims for incremental flood damage. There are several mechanisms to transfer the ownership of the land to the public domain, but a detailed assessment of such is considered to be beyond the scope of this assignment.

8.3 ENVIRONMENTAL COSTS

Ecofish reviewed each of the three options, with consideration for the increase/decrease in water levels, discharges and durations of flooding. Ecofish also examined the potential for short-term impacts during construction. In general, the changes resulting from the construction of any of the options would <u>not</u> have a substantive effect on fish or fish habitat within, or beyond, the study area. The assessment, which can be found in full in Appendix B, also states that the three options do not appear to represent any meaningful encroachment into the wetted width of the adjacent streams or riparian habitat; however, this will clearly need to be confirmed at the time of final design. In summary, the options are expected to have no substantive environmental impact, as long as construction adjacent to the sensitive areas is completed following applicable best management practices, with appropriate Erosion and Sediment Controls; thereby protecting the environment during short-term construction. In addition, work windows (scheduling) for construction adjacent to or within sensitive areas should be respected. On this basis, all three options are viewed as having negligible environmental costs to implement them.

8.4 BENEFITS

Financial benefits from flood protection schemes are most often measured via assessment of saving what would otherwise be flood damage costs. Direct costs to the City during the most recent flooding in 2009 and 2010, amounted to about $160,000. Considering private property damage to businesses affected by the interruption, and that of upstream land owners, together with disruption to transportation and other emergency services, the cost are higher. Although there are no total hard costs available, it would not be unreasonable to conclude that hard costs could easily reach $500,000 per occurrence of flood magnitude similar to events of 2009 and 2010.

The total assessed value of properties subject to flooding at the 200-year flood level approaches $40M, just within the Ryan Road commercial area. Considering the two major retailers in the area, restaurants, auto service businesses and other commercial ventures, a flood of the magnitude of 200-year event would be expected to cause considerable building, property and inventory damage. A detailed cost-benefit analysis is not within the scope of this study, but the importance of flood mitigation in the area is clearly emphasized by the base cost of the assets to be protected. In addition, the City has just completed a multi-million dollar addition to the Lewis Center, which, during an emergency, could serve as a place of refuge. Protecting these assets is a significant reason for building the flood protection in the neighbourhood.

Option 2 provides more protection than Option 3, at about the same capital cost. The most significant difference between the two options is that Option 2 – the full ring dike option – creates higher upstream water levels during the 200 year return period flood, which will, in turn, require that other existing dikes (Canterbury Lane) be upgraded. Upgrades to these same dikes would also need to be considered under Option 3, as the increased water levels under this scenario infringe upon the required 600mm freeboard allowance.

Both Options 2 and 3 will ensure that major transportation links between west Courtenay and East Courtenay are maintained via the Old Island Highway and Ryan Road. Highway 19A will be susceptible to breaching both north and south of the 17th Street Bridge, noting its current surface level of construction. From an emergency traffic access perspective, neither option provides a material benefit over the other, in the long-term.

Both Options 2 and 3 provide reasonable opportunity for adaptation due to SLR, but this aspect of planning should be looked at in more detail as the science and our collective experience become more refined, and the socio-economic impacts of land use changes can be better understood. On this basis, long-term planning should include a cost-benefit assessment of managed retreat options covering larger portions of the floodplain.

8.5 REVIEW OF OPTIONS

Table 8.2 is intended to summarize the spectrum of criteria used when deciding which of the options may be best to be pursued further, as a flood mitigation strategy.

Table 8.2: Summary Review of Mitigation Options

Review Criteria	Option 1 Floodwall	Option 2 Ring Dike	Option 3 Ring Dike/Floodway
200-Year Flood Levels Upstream Changes*	0.10 m	0.41 m	0.30 m
Other Mitigate / Compensation Costs	Low	High	Moderate-High
Level of Flood Protection for Old Island Highway/Ryan Road	Between 20-year and 50-year return period	200-year Return Period	200-year Return Period**
Relative Capital Cost	Low	Moderate-High	Moderate-High
Land Use Benefits	Low	Moderate-High	Moderate
Habitat Impacts	Low	Low	Low
Emergency Response Benefits	Low	Moderate-High	Moderate-High
Adaptability to Climate Change	Low	Moderate	Moderate
Public Response	Moderate-High	Low-Moderate	Moderate
Cost Sharing Potential	To be determined	To be determined	To be determined

* As calculated at the confluence of the Tsolum and Puntledge Rivers
** Does not include the properties along Comox Road between Old Island Highway and Highway 19A.

In regard to cost sharing potential, the senior funding agencies have retracted funding for Option 1, as it has, through the outcome of this IFMS update, been shown not to meet the criteria as a registered dike with the Provincial Diking Authority. There may be future opportunity to pursue all options with senior levels of government, but Option 1, if pursued, will likely need to be funded locally, either entirely by the City, or through some funding arrangement shared with specific beneficiaries of the proposed floodwall scheme.

9 RECOMMENDATIONS

9.1 GUIDING PRINCIPLES

Based on the combination of technical analysis and community engagement, the following broad recommendations to Council are provided.

1) Continue to protect the majority of the floodplain, imposing compatible land uses that will accommodate floods over the long-term (Managed Retreat 2100 and beyond):

   - Avoid new dikes along the Courtenay River where existing natural environment remains.
   - Adapt, but do not raise, the Comox Road Dike in recognition that it will be overtopped in large events, as is the existing situation.
   - Discourage new dikes on the Puntledge and Tsolum Rivers, except in limited areas where proposed below.
   - Encourage continued agriculture / wildlife /recreation management uses in the majority of the floodplain. Work with such landowners to recognize the need for any related structures to be designed to withstand occasional flooding.

2) Consider the Tsolum River Floodwall Concept (Option 1) as an interim solution to an overall flood mitigation strategy.

   - Determine a suitable cost-sharing arrangement with benefitting land owners.
   - Subject to satisfactory environmental review and permitting.
   - Subject to legal review pertaining to flood protection to levels less than the 200-year return period standard, and agreements with adjacent land owners affected by the work, but not protected by it.
   - With careful attention to the visual appearance of the wall. Consider a planter and plantings and wall colour / texture to avoid creating a target for paint vandalism.
   - To anticipate future integration of larger flood protection dikes with the floodwall.

3) Review Emergency Plans for Today, Year 2100 and 2200

   - Review key emergency routes, to analyze how these routes might need to be raised to avoid flooding in today's climate and subject to Year 2100 and Year 2200 potential flood levels, and to identify potential land requirements and cost.
   - Make recommendations to Council to refine emergency routes and related adaptation / evacuation strategies.
     - Emergency routes may also act as dikes.
     - To act as dikes, raise critical emergency routes to 600mm (2 ft.) above predicted flood level complete with conveyance culverts as may be deemed necessary.

4) Identify where and when additional diking might be warranted for consideration, subject to the general direction in item 1 above, such that diking along the watercourses will be very limited in area and scope:

- Option 2 and 3 are potential dike alignments – identify if there are other highly localized areas within the floodplain that might be considered for small-scale diking eventually e.g. K'ómoks FN built-up area, Millard Road area.
- Compare plans, and compile a final set of options for diking, together with the anticipated year such diking might be required.

5) Evaluate diking options including financial / cost sharing analysis

- Investigate scale, land requirements, habitat compensation, capital cost and other mitigation/compensation costs required for diking (beyond the notion of emergency transportation routes) – consider climate change implications on future investment required.
- Summarize joint funding opportunities, including a mix of senior government, property owner (development cost charge or special levy) and local government finance.
- Review the public cost-benefit of each option considering all of the above, as well as the relative current and build-out assessed value of the area to be protected for each option.
- Undergo public review and City Council deliberations, which might include a mix of limited dike areas, combined with more broad and general strategies of flood proofing and managed retreat.

9.2 FLOOD MITIGATION

In the short-term, the City should pursue the construction of flood protection infrastructure along the Old Tsolum River Channel. This section is the first area of breach for more frequent flooding, and adequate flood protection is warranted, presuming the infrastructure built can be integrated in a broader medium-term flood mitigation strategy, consistent with the guiding principles listed above.

In looking at the medium term (prior to the next turn of Century), the existing commercial enterprises in the Ryan Road area are of relatively new construction, and are high value properties. Taking into account these properties will have useful serviceable lives of perhaps another 50 years, and the fact that this area includes key transportation links between West and East Courtenay; it is recommended that the City pursue a flood mitigation strategy to protect these assets. Based on the assessment of the hydraulic modelling, cost–benefit and environmental impacts, it appears that either Options 2 or 3 could be considered for protecting this area over the short to medium term, and as long as high valued assets exist within this corridor. Each option has different costs, benefits and impacts as outlined, which need to be evaluated by the City from the perspective of overall community needs and impacts.

The City should begin to incorporate sea level rise and climate change into its long range flood mitigation strategy. This long-term planning should focus on methods and strategies (including bylaw and OCP changes) to return the floodplain to a more natural state, employing land use policies that are more tolerant of infrequent flooding (parks, agriculture and/or environmental reserves).

9.3 PUBLIC OUTREACH AND EDUCATION

Ongoing public outreach is advised to help landowners and the community understand the evolving flood risk, in particular related to Sea Level Rise and to potential increase in river flow due to heavier rainfall, both related to climate change. This knowledge will allow the public and landowners to be prepared for emergency evacuation if necessary, and also to plan their land use and structures with knowledge of the risk and how to mitigate its impacts.

Key themes of public education should include:

- Major areas of the floodplain should continue to flood in large events (50 – 200 year) – these areas would remain in agriculture, recreation, and environmental uses.
- New structures would need to be designed to suit gradually rising flood levels (rising by Year 2100, continuing to Year 2200 and beyond).
- Current BC policy is that new or replaced buildings would need to meet Flood Construction Levels for habitable floors – including within ring dikes.
- Non-habitable areas, if not raised to flood proof levels, could be constructed of flood resistant building materials.
- Where not raised, local roads and parking would be flooded during design storm events.

9.4 CITY BYLAW AND POLICY REVISIONS

Section 4.1 of this report introduces existing municipal tools to manage flood risk and related land use / transportation and infrastructure regulations/guidelines. Section 9.4 describes how the new floodplain level information herein, including climate change risks, could lead to refinements to those municipal tools.

9.4.1 Official Community Plan and Zoning Bylaw

The land use and transportation framework in the Official Community Plan and the Zoning Bylaw, for the most part, establishes policies that encourage flood-compatible uses in the great majority of the floodplain. For existing conditions, there is no change required in the OCP or Zoning to mitigate flood risk, provided that flood proofing requirements of the Floodplain Bylaw are followed for new development.

More fundamental decisions will need to be made in the next review of the Official Community Plan, specific to localized areas along the Courtenay River, where Sea Level Rise puts these areas at risk.

The attached flood plain maps show the floodplain boundaries based on existing climate conditions, and also those approximated for Year 2100 and Year 2200. There are some low lying areas along the Courtenay River and Estuary which may be at an increased risk of occasional flooding in extreme events, as Sea Level Rise occurs. Generally the change in floodplain extents is small in area, but where these extents effect existing developed properties, the concern will be increasingly pronounced.

Notable areas where special attention will be required include parts of Cliffe Avenue and areas seaward that may be at flood risk (near Driftwood Mall), as well as localized flood risks close to the Courtenay River and the Condensory Bridge.

It is these localized areas that will be newly at flood risk in Year 2100 and 2200, where new consideration of flood mitigation strategies will be warranted as OCP and Zoning Bylaws are updated. Options to be considered include:

- Accepting flood risk and focusing on evacuation plans for rare events.
- Reviewing land use types to allow commercial (low risk to life) rather than residential uses (higher risk to life) on properties with higher flooding risk.
- Localized filling and diking to protect flood risk sites.
- Flood proofing of proposed buildings only, with parking/driveways allowed to flood occasionally
- Flood proofing by raising key roads and emergency routes (e.g. Cliffe Ave) in the local areas where it is at risk.
- Public sector or Non-government organization purchase of lands at risk for public use (parks, recreation, agriculture or environment).

The above options are best discussed in the context of broader land use, emergency preparedness, and policy plans, where the multi-variant aspects of these decisions can be weighed in a thorough public process.

Three points are very important in addressing these climate change concerns:

1. Sea Level Rise will be very slow (averaging 1 cm per year), and therefore it is not urgent to move higher – there is time to adapt, to the extent that in most cases adaptation could be allowed to occur at the end of life of a building (at the time of redevelopment).
2. However, it is important to recognize the need to establish Sea Level Rise Planning Areas that include the areas potentially at flood risk both in Year 2100 and Year 2200. Within these SLR Planning Areas, land use decisions should include an acceptable strategy to either avoid flood risk impacts or adapt proposed land uses to the evolving risk, at reasonable benefit to cost ratios.
3. It is very important that land use decisions be made with a full awareness of the evolving flood risk, so that there are adequate mechanisms in place to balance life and safety, environmental, economic and public/private investment responsibility. Applications for land use change in the floodplain should provide a clear flood mitigation strategy prior to being formally considered by City Council. Any additional flood risk assessment carried out as part of land development applications should follow the APEGBC Legislated Flood Assessment Guidelines, where appropriate.

The flood risk information in this report provides scientific and societal values information to allow land use decisions to be made, and avoid without passing large flood mitigation costs onto future generations in Courtenay and the Region.

9.4.2 Floodplain Bylaw

The existing Courtenay Flood Control Requirements in Bylaw No 1743 are adequate to address the risk of flooding from existing climate conditions. These requirements include:

- Existing Bylaw Buildings Setback: min 30m from the Puntledge River, Tsolum River and Courtenay River.
- Existing Bylaw Building Elevations:
  - All habitable space above Flood Construction Level
  - Parking may be below Flood Construction Level

At present, the Province of BC has created guidelines for public discussion on Land Use in Coastal Flood Hazard areas. It would be premature to alter Flood Construction Bylaws in Courtenay until the discussion around these guidelines concluded, and they are finalized and adopted as Provincial Policy. It is expected that some form of these guidelines will be published in the next few years. Ongoing science investment is also expected toward more refined predictions of sea level rise and other related climate change processes. As such, there will be a need for ongoing amendments to the Flood Construction Levels.

- At time of reconstruction, buildings would be constructed above a new minimum elevation (this will rise as SLR continues – therefore the Flood Construction Levels in the bylaw will need to be monitored and potentially altered periodically).
- The Flood Construction Level needs to anticipate where flood levels might be at the END OF BUILDING LIFE. The Building Life may vary depending on the type of building e.g. a modular home typically has a life of 50 years or less, whereas a concrete building may have a 100 year life. Generally speaking, a 75 year building life prediction could be considered average in west coast BC.
- Site elements (parking, driveways, and landscape areas) would still flood if not raised, if dikes fail, or if rainfall exceeds drainage capacity.

New construction within the floodplain should be assessed using the hydraulic model, prepared as part of this study, to ensure that the proposed development does not have any significant effects on neighbouring properties. Impacts due to the magnitude of the 1:200 year return period flood are likely to occur on neighboring properties, especially if the proposed development is of substantial size (big box store developments for example).

10 IMPLEMENTATION

Public entity adaptation to climate change in British Columbia is only just upon us. However, it is time to become aware, and to prepare. It is especially important that the City to not make uniformed land use decisions that would otherwise render flood risks and consequences worse than existing conditions, given the growing knowledge of Sea Level Rise. Three general actions are recommended below.

10.1 REVIEW OF THE FLOODPLAIN BYLAW

The Floodplain Bylaw should be formally reviewed, with new minimum Flood Construction Levels that anticipate Sea Level Rise, within a year of the Province of BC formalizing its Land Use Guidelines for Coastal Flood Hazard Areas, or equivalent document.

As an interim policy, the City, Region and First Nation are encouraged to require any application for significant land use change or transportation/infrastructure investment within the floodplain to include a mitigation and adaptation strategy which addresses Sea Level Rise and peak flood climate change risks for Year 2100 and Year 2200. Recommendations by qualified professionals as to how these risks would be addressed by the application should become part of the typical approval process. Any additional flood assessments should be guided by the APEGBC Flood Assessment guidelines. A key determinant of approval would be assurance and certification that future generations are not faced with high flood mitigation costs or risks due to developments proposed.

10.2 INTEGRATION OF LAND USE CLIMATE ADAPTATION INTO ON-GOING PLANNING REVIEWS

Where the City, Region or First Nation instigate planning reviews, e.g. Official Community Plans, Zoning Bylaw, Transportation or Infrastructure Plans, it is recommended that evolving Flood risks be carefully considered in these plans. It is recognized that many objectives are balanced in these planning initiatives, but it is strongly encouraged that a clear strategy for adapting to the evolving flood risk is incorporated into policy and financial planning programs over time.

10.3 MONITORING AND ADAPTIVE MANAGEMENT

This Courtenay Integrated Flood Management Study is a first step toward local government adaptation to Sea Level Rise and climate-change flood risk analysis and planning. We expect much greater certainty and understanding of risks and, perhaps, adaptation strategies will become evident as our society undertakes further research.

The scale of the Sea Level Rise and climate change impacts around the world will mean that society in general, all levels of government and the private sector, will need to refine programs and undertake adaptive strategies.

Given this gradually evolving challenge, it is appropriate to begin planning now, to minimize local consequences, risks and costs.

At the same time, it would be prudent not to react too quickly to issues of Sea Level Rise, but rather, to monitor the evolving senior government programs and overall body of scientific understanding on the issue, setting the stage for focused adaptations. There remains time to discuss and refine a long-term strategy, prior to major investments by Courtenay. In the meantime, immediate attention should focus on beginning local flood protection works (such as the Tsolum River Floodwall) to mitigate the flood impacts on existing development.