CVRD

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Lower Chemainus Watershed

FLOODPLAIN MANAGEMENT PLAN

May 31, 2023

NHC Reference No: 3006373

Credits

Project Partners:

Cowichan Valley Regional District

Municipality of North Cowichan

Penelakut Tribe

Halalt First Nation

Project Funding:

National Disaster Mitigation Program

Infrastructure Canada

Emergency Management BC

Cowichan Valley Regional District

Municipality of North Cowichan

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May 29, 2023

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We respectfully acknowledge that the Chemainus River, its tributaries, watershed, and estuary lie within the traditional, unceded territories of the Coast Salish Peoples.

The study area falls within the territory of the Hul'qumi'num speaking First Nations peoples, including Cowichan, Halalt, Stz'Uminus, Penelakut, and Lyackson Nations.

Executive Summary

The Chemainus River Flood Mapping Program (project) was conducted by Northwest Hydraulic Consultants (NHC) on behalf of the Cowichan Valley Regional District (CVRD) and its partners. The project is divided into two phases: Part 1, Floodplain Mapping, assessed flood and erosion hazards and updated floodplain maps. This document, the Floodplain Management Plan, presents Part 2 of the project and provides a high level assessment of strategies for reducing flood damages on the lower Chemainus River and portions of Bonsall Creek. The overall objectives of the plan are as follows:

- Enhancing public safety;
- Protecting public infrastructure;
- Protecting and enhancing the environment;
- Inform and support community preparedness and recovery.

NHC conducted a vulnerability (flood risk) assessment using the hydraulic modelling results presented in the report summarizing Part 1 of the project. The team also used land use data, which characterized the infrastructure and buildings exposed to flooding in the project study area.

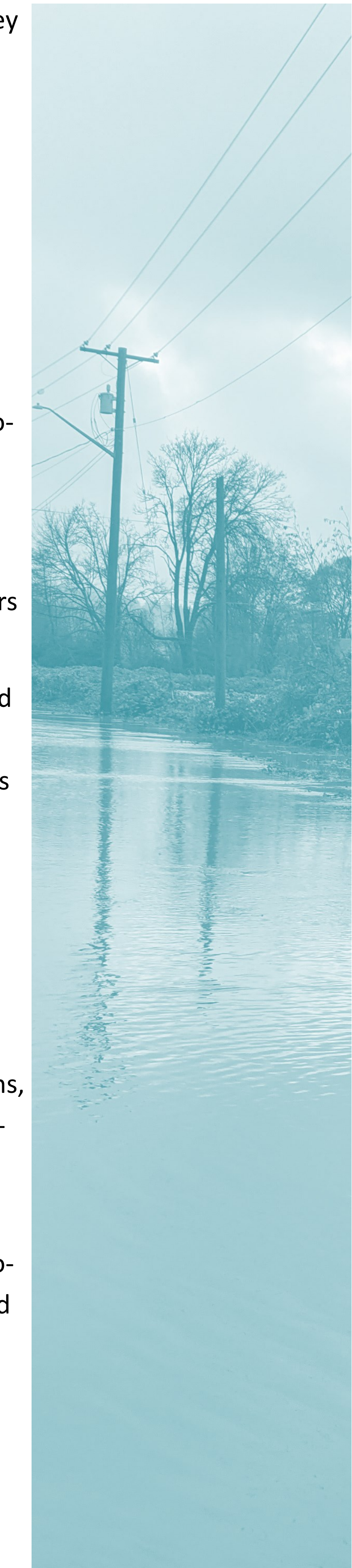
A Project Advisory Group (PAG) was convened by the CVRD as the work progressed to provide input and feedback at various stages of the investigations. Members of the PAG included representatives from the Municipality of North Cowichan, Halalt First Nation, Mosaic Forest Management Corporation, Emergency Management BC (EMBC), Ministry of Transportation and Infrastructure (MOTI), Island Corridor Foundation, and members of flood-affected communities. In addition, separate public consultation meetings were held on three occasions between July 18 and 20, 2022.

The strategies identified during these meetings included land use management, emergency response planning, flood proofing, and structural flood control measures such as flood dikes and gravel removal programs. Not all strategies and suggested measures were found to be technically feasible. The effectiveness and impacts of each option were assessed using the flood and erosion hazard information developed in Part 1. These results were then used to identify the strengths, weaknesses, opportunities, and threats associated with each strategy. The strategies were evaluated in terms of their effectiveness under a 200 year flood condition, accounting for future climate change and sea level. This approach is consistent with current regulatory guidelines and is intended to ensure that the adopted strategies will provide long-term protection against flooding.

NHC's recommended strategies include a mix of primarily non-structural flood mitigation methods, including land use management (Strategy 1), emergency preparedness and response (Strategy 2), floodproofing (Strategy 3), and gravel removal and debris control (Strategy 4—5) as the core strategies for reducing future flood damage. Permanent flood proofing and house raising (Strategy 3) can be implemented on both new and existing buildings. These measures can address both short-term and long-term flood hazards without the need for large-scale structural interventions, such as flood dikes. NHC recommends engaging a qualified professional to carry out site specific investigations to assess the need for erosion mitigation counter measures.

Due to the expected adverse impacts, building continuous dikes (Strategy 4—1 and 4—2) cannot be recommended. Continuous dikes along the Chemainus River will protect some areas but the confinement effect will raise flood levels significantly, which will increase flooding at other unprotected communities. The confinement effect of dikes will also raise flood construction levels over large areas of the floodplain, increasing the need to further elevate new homes and future infrastructure.

During the public consultation meetings held for the project, gravel removal and debris control (Strategy 4—5) was identified and can be a potentially useful measure for maintaining a more stable river channel. NHC expects the effect of gravel removal on flood levels will be minor (less than 0.3 metres) for extreme floods. The team recommends conducting additional technical and environmental studies to prepare a long-term gravel removal and channel management program for the Chemainus River. An essential component of this work is to develop a sediment budget to assess the long-term rates of aggradation or gravel buildup in the river.



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1. Introduction

1.1 Project Snapshot

1.2 Project Timeline

PROJECT SNAPSHOT: Chemainus River Flood Mapping Program

Part 1: Floodplain Mapping Report *(Completed Spring 2022)*

In 2022, NHC produced a floodplain mapping report to document Part 1 of this two-part project. In this report, NHC developed floodplain maps and also provided a high-level overview of Part 2 of the project, describing the methods used to complete flood and geomorphic hazard mapping for the Chemainus River basin. Report details include an overview of the Chemainus watershed, a description of the surveys completed by NHC, and an overview of the hydrology and geomorphology of the floodplain. The report also includes a description of NHC's hydraulic modelling methods, provides details on the coastal assessment, wave modelling, flood maps, and geomorphic hazards, and recommended next steps. Additional technical information describing the detailed hydrological, hydraulic, and geomorphic investigations that have been carried out is summarized and presented in appendices posted online (See here). The following technical reports are provided as appendices to the flood mapping report:

Appendix A: Surveys

Appendix B: hydrology

Appendix C: Geomorphic Atlas

Appendix D: Hydraulic Modelling

Appendix E: Coastal Modelling

Appendix F: Flood Mapping Methodology

Appendix G: Flood Depth and Velocity Hazard Maps

Appendix H Designated Floodplain Map

Appendix I: Geomorphic Hazard Map

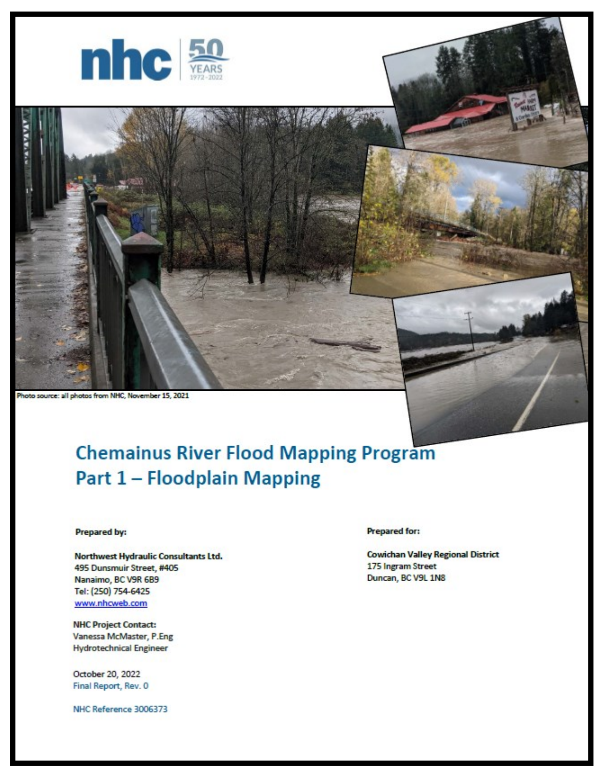

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Photo source: all photos from NHC, November 15, 2021

Chemainus River Flood Mapping Program
Part 1 – Floodplain Mapping

Prepared by:

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October 20, 2022
Final Report, Rev. 0

NHC Reference 3006373

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Part 2: Floodplain Management Plan

Study Area: Lower Chemainus River including Bonsall Creek and Whitehouse Creek that are part of the Chemainus Floodplain on Vancouver Island, British Columbia

Agency: Cowichan Valley Regional District

Funding: National Disaster Mitigation Program (NDMP)

Objectives: Develop an flood management plan for the lower Chemainus Floodplain. More specifically,

- To provide a strong foundation for future flood mitigation and adaptation.
- Identify and assess potential strategies that communities could adopt to reduce future flood damages.
- Outline recommendations and provide a framework for going forward to implementation.
- Mitigate the losses, costs, and human suffering caused by flooding.
- Protect the natural and beneficial functions of the floodplain.

Approach: Collaborative, including partner communities and public consultation

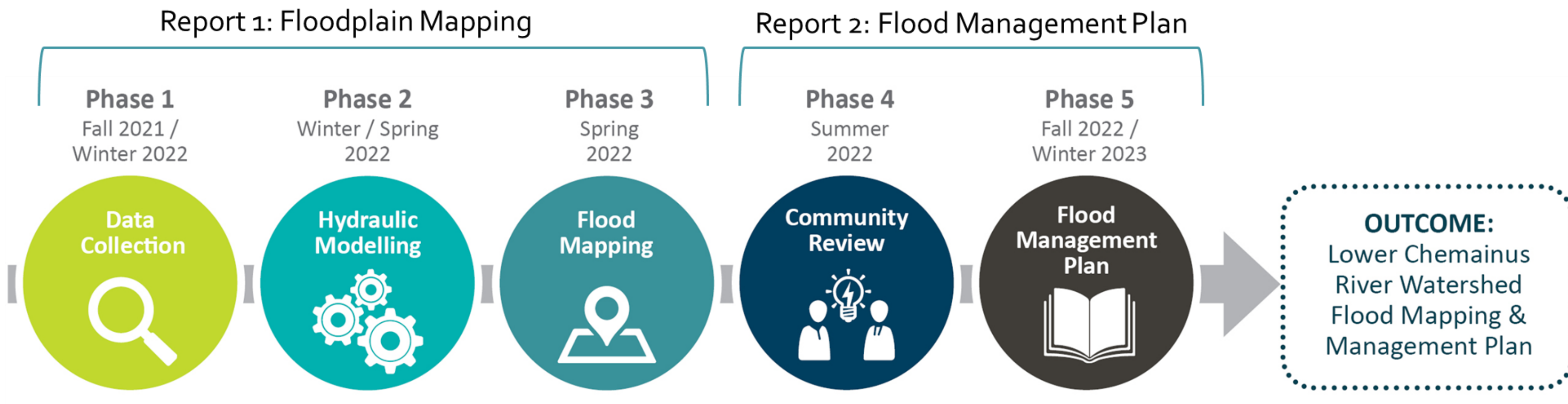
Timeline: May 25, 2021—March 31, 2023

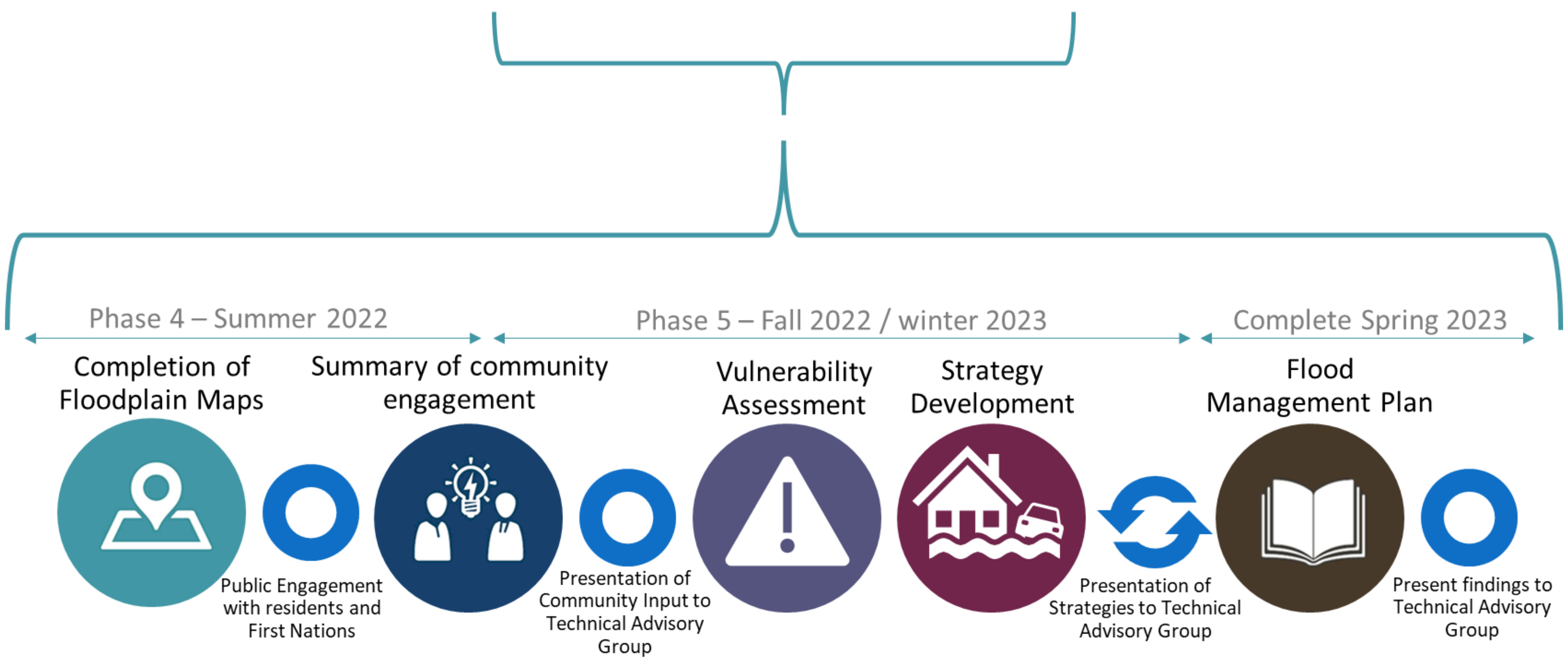
Summary:

Part 2 of the project is development of the Floodplain Management Plan and presentation of strategic flood management options for communities to withstand a 200-year flood on the Chemainus floodplain. This document also summarizes the floodplain management strategies for structural and non-structural mitigations and presents land use management, emergency planning, flood proofing, and structural mitigation options and recommendations. In addition, this report presents conceptual structural strategies, describes the assessment of each strategy's strengths, weaknesses, opportunities, and threats (SWOT), presents the scoring criteria and results, and summarizes recommendations.

Timeline

The two-part project involves five phases, as shown in the diagrams below. Part 1 of the project, the Flood Mapping report, was delivered in spring of 2022 and involved 3 phases, which are summarized below. Part 2 of the project includes phases 4 and 5 and was completed in spring of 2023.





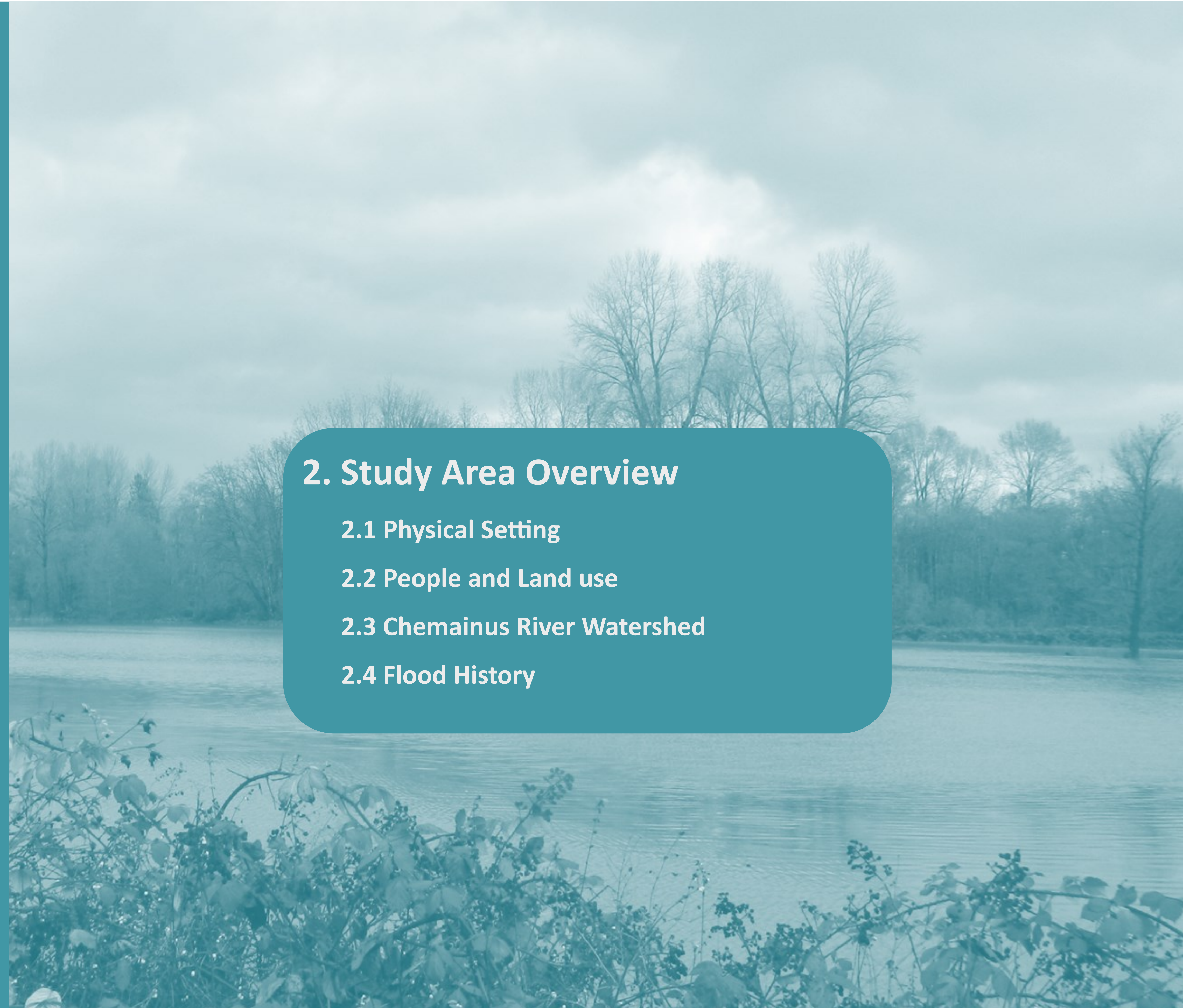
Effective floodplain Management is an iterative process that requires input from the project partners, community-based technical committees, and concerned members of the public. Participants help identify, refine, and improve options during each review, providing critical feedback that helps improve floodplain management while meeting the needs of everyone living in the floodplain.

The CVRD convened a Technical Advisory Group (TAG) from its partner organizations at the start of the project to provide input and advice during various stages of the investigations. During Part 1 (Flood Mapping), the TAG members included representatives from the Municipality of North Cowichan, Halalt First Nations, and Mosaic Forest Management Corporation.

As the project moved to Part 2 (Flood Management Planning), the TAG was expanded to a broader Project Advisory Group (PAG) including representatives from EMBC, MOTI, Island Corridor Foundation and from members of flood-affected communities. During the flood management strategy phase of the study, the PAG met on June 20, 2022, October 21, 2022, January 26, 2023 (TAG only), February 7, 2023 (TAG only) and March 16, 2023.

In addition, separate public consultation meetings were held on three occasions between July 18-20, 2022. The flood management strategies and options that were subsequently assessed in the study reflect the input and advice from these meetings.

1. Introduction
2. Study Area Overview
3. Part 1 Floodplain Mapping
4. Introduction to Integrated Flood Management
5. Flood Management Strategies
6. Evaluation of Flood Management Strategies
7. Recommendations



2. Study Area Overview

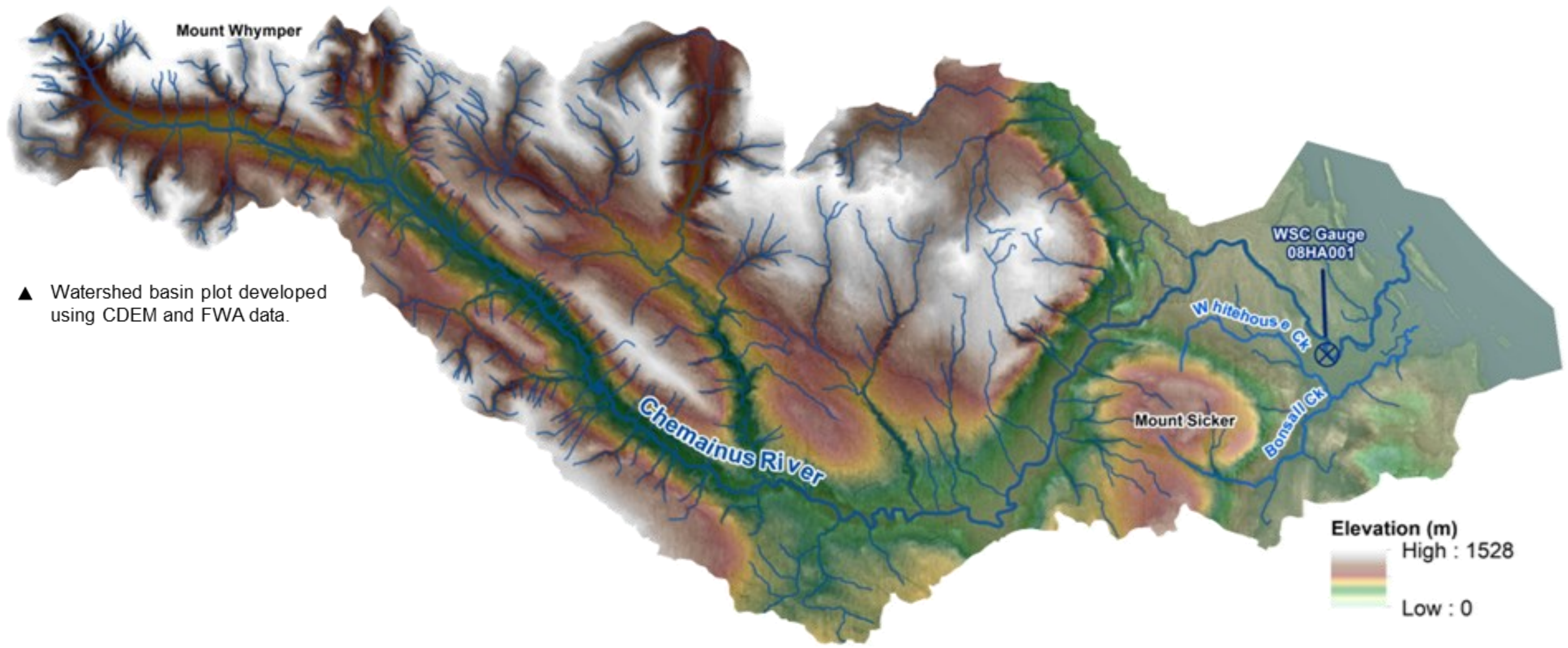
2.1 Physical Setting

2.2 People and Land use

2.3 Chemainus River Watershed

2.4 Flood History

Physical Setting



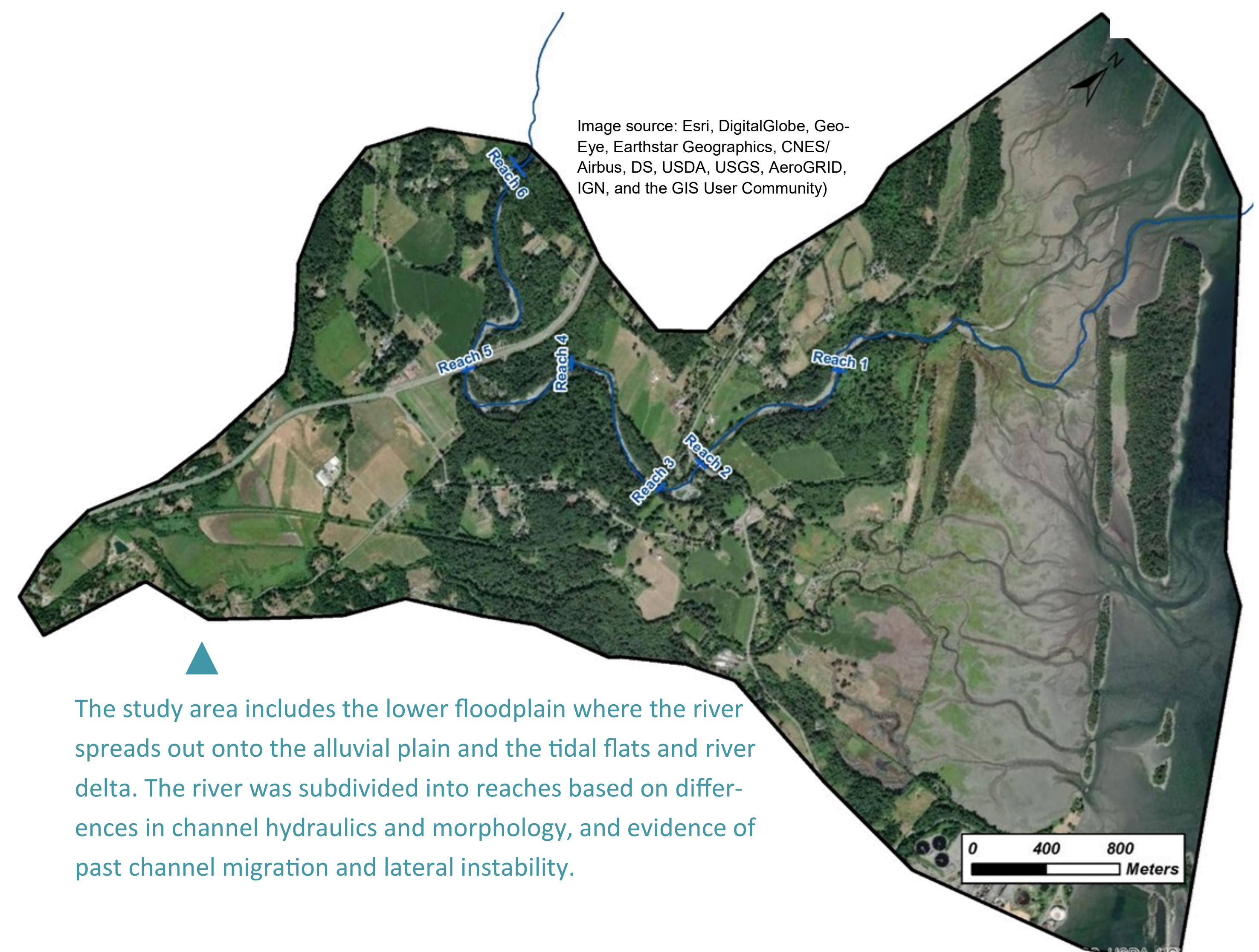
▲ Watershed basin plot developed using CDEM and FWA data.

The Chemainus River is located on the east coast of Vancouver Island. At 1500 m above sea level, Mount Wymper is the highest point in the watershed. The slope in the upper watershed is steep and confined by tall channel banks. As the river erodes the toe of these banks, steeper sections become prone to failures and sediment and debris is added to the channel. The Chemainus River exits a confined canyon and spreads out onto a broad, low gradient alluvial plain. The river has formed extensive tidal flats and delta at its downstream end and eventually flows into the Strait of Georgia.

Geomorphic response to European settlers

European settlement has dramatically altered the Chemainus River, and its watershed, floodplain, estuary, and coastline. This includes:

- Altered sediment yield and timing and frequency of peak flood events associated with historical mining activities and legacy forestry.
- Altered drainage patterns and potential for hillslope instabilities and sedimentation associated with the legacy road deactivation practices and development of cutblocks and road and rail networks in the watershed. Ongoing forestry practices in the watershed have not been evaluated for this study.
- Altered sediment deposition patterns, and channel planform and profile changes associated with channel hydraulics at road and railway bridge crossings.
- Encroachment into historical channel migration zones.
- Concentration of channel flow during food events associated with the earthen berm constructed along the southern bank of the floodplain upstream of Highway 1.
- Altered channel flow pathways and floodplain flow resistance associated with land clearing and landscaping in support of agriculture and other intensive land uses on the floodplain.
- Altered rates and patterns of deposition of sediment and LWD in the low gradient channel reaches, in the distributary channel zone and in the estuary (Chief James Thomas, pers. comm. 7 October 2021).
- Altered tidal and wave processes in the estuary associated with the construction of the causeway to the pulp and paper mill.

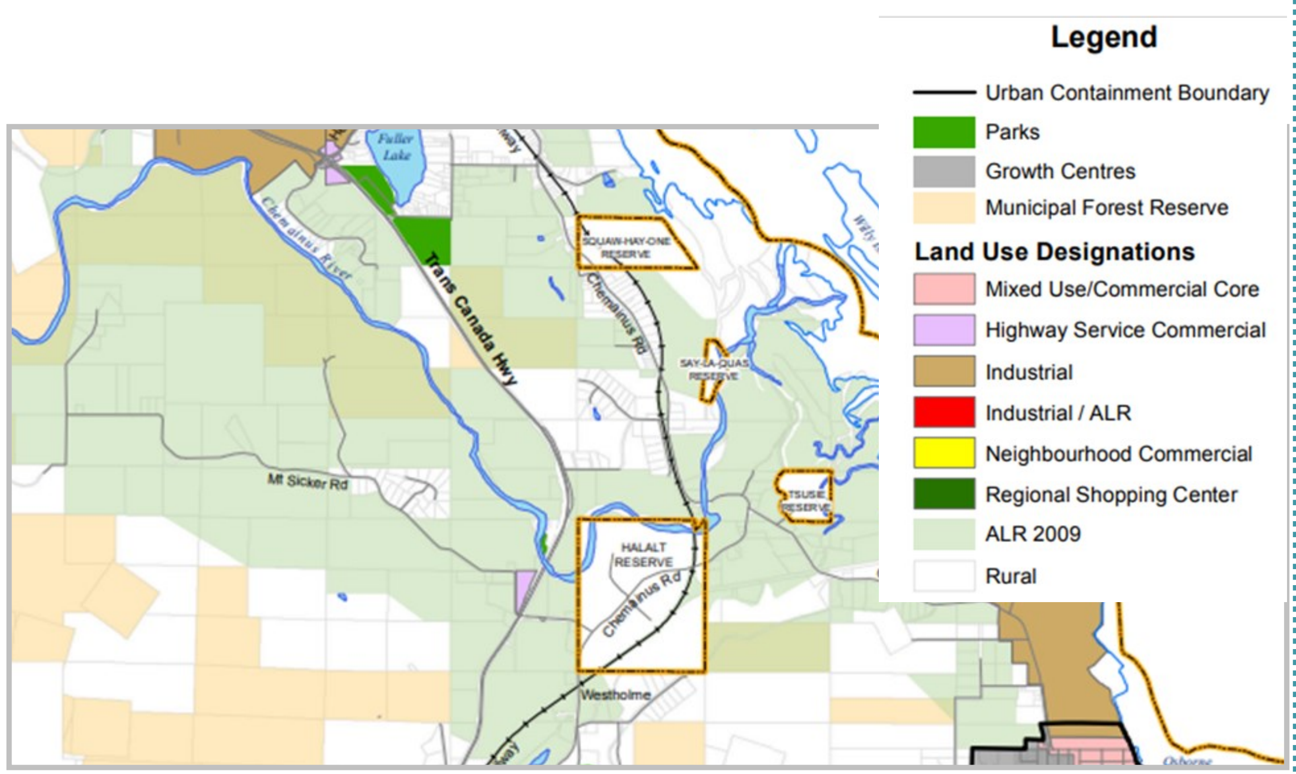


▲ The study area includes the lower floodplain where the river spreads out onto the alluvial plain and the tidal flats and river delta. The river was subdivided into reaches based on differences in channel hydraulics and morphology, and evidence of past channel migration and lateral instability.

The People

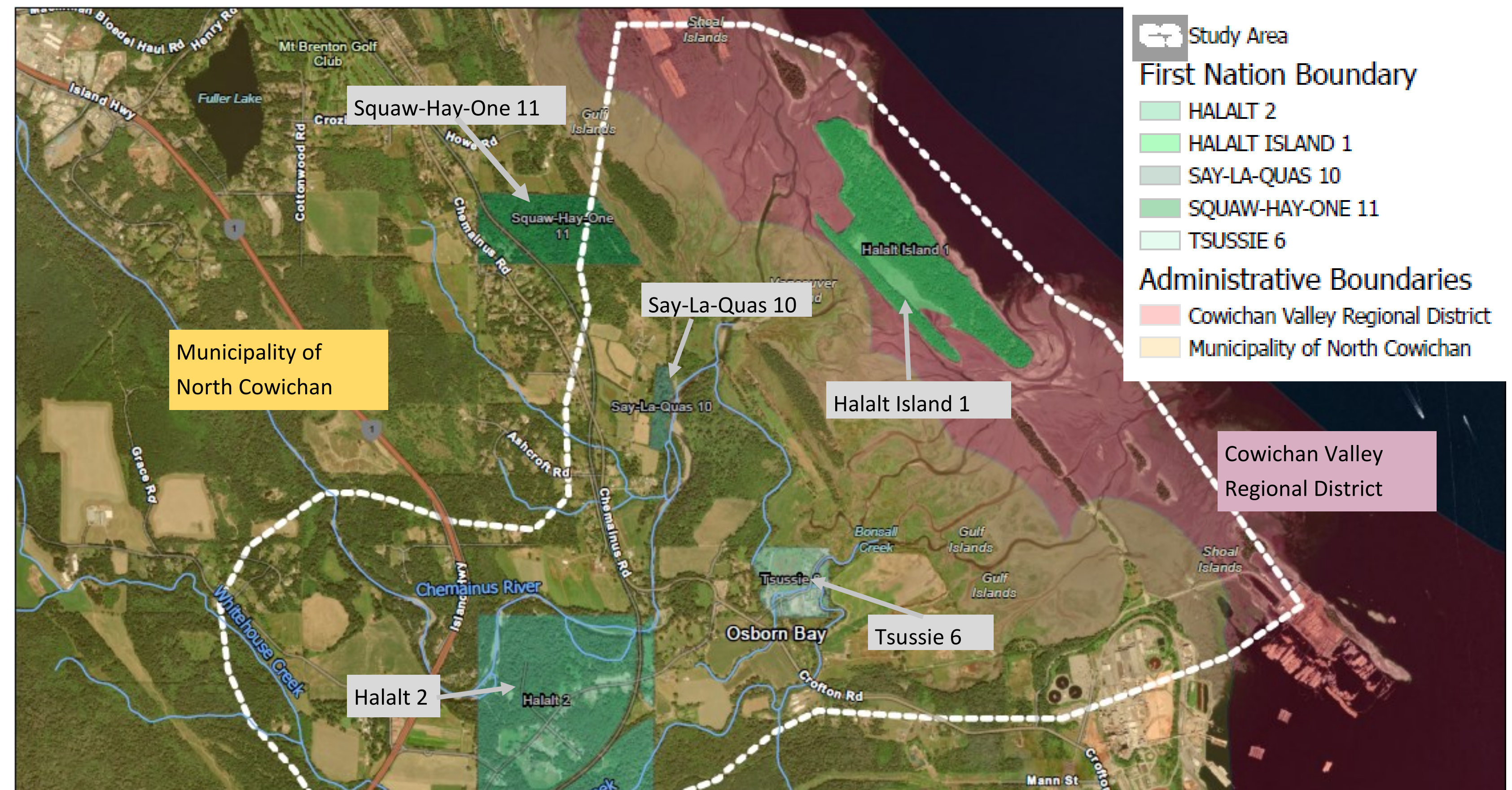
The Chemainus River floodplain, its watershed, estuary, and surrounding islands have been used since time immemorial by First Nation peoples for village sites, hunting, fishing, trapping, harvesting, and other cultural and sacred purposes (Rozen DL, 1985; Arthur Jim, Stz'Uminus First Nation Band Council member and cultural consultant, pers. comm. 18 March 2022). Halalt No. 2 (Halalt First Nation), Say-La Quas No. 10 (Stz'uminus First Nation), and Tussie No 6 (Penelakut Tribe) federal administrative boundaries are all located within the floodplain.

In 1849, colonization of the region began under the Hudson's Bay Company (L.M. Bell and R.J. Kallman, 1976), after which the landscape started to drastically change. The Trans-Canada Highway, Chemainus Road-Crofton Road, and Island Corridor Foundation (ICF) Rail line also cross the floodplain in the study area. Today the Chemainus River floodplain includes variety of land-uses, with agriculture being an important component.



Jurisdictions in the Chemainus River and Bonsall Creek floodplain

Portions of the floodplain lie within the boundaries of the Municipality of North Cowichan and the Cowichan Valley Regional District. Several First Nations communities also reside in the floodplain. Area and percent of floodplain of various jurisdictions that have boundaries in the Chemainus River and Bonsall Creek floodplain is shown in the image and table below. There are approximately 130 buildings in the floodplain and 1 major highway bisecting the floodplain as well as several local roads.



Jurisdiction	Area of floodplain (m^2)	Percentage of floodplain
HALALT 2	1,110,087	14.4
HALALT ISLAND 1	117,786	1.5
SAY-LA-QUAS 10	35,398	0.5
SQUAW-HAY-ONE 11	4,793	0.1
TSUSSIE 6	144,301	1.9
MNC	6,191,780	80.5
CVRD	83,933	1.1

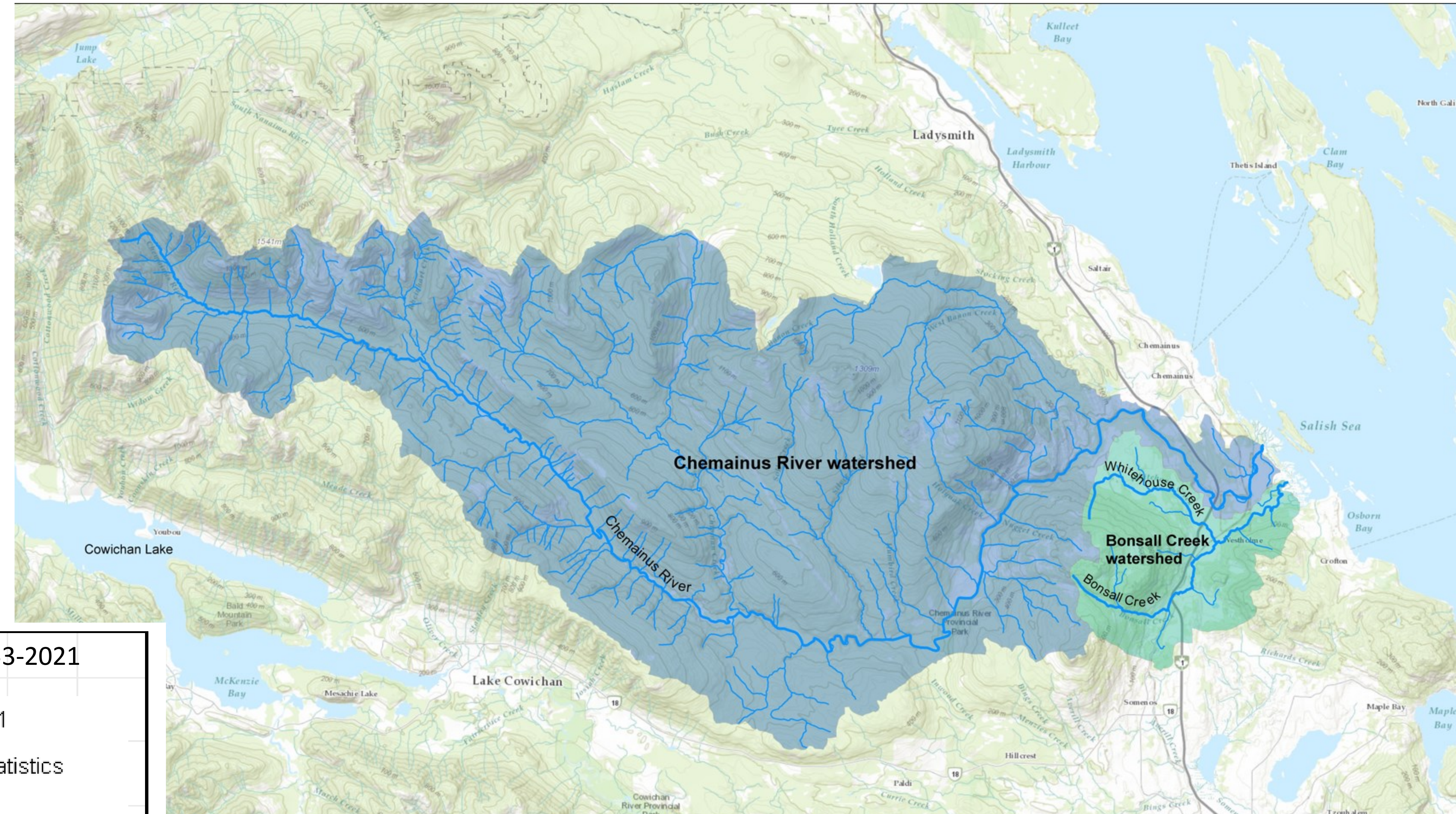
Chemainus River Watershed

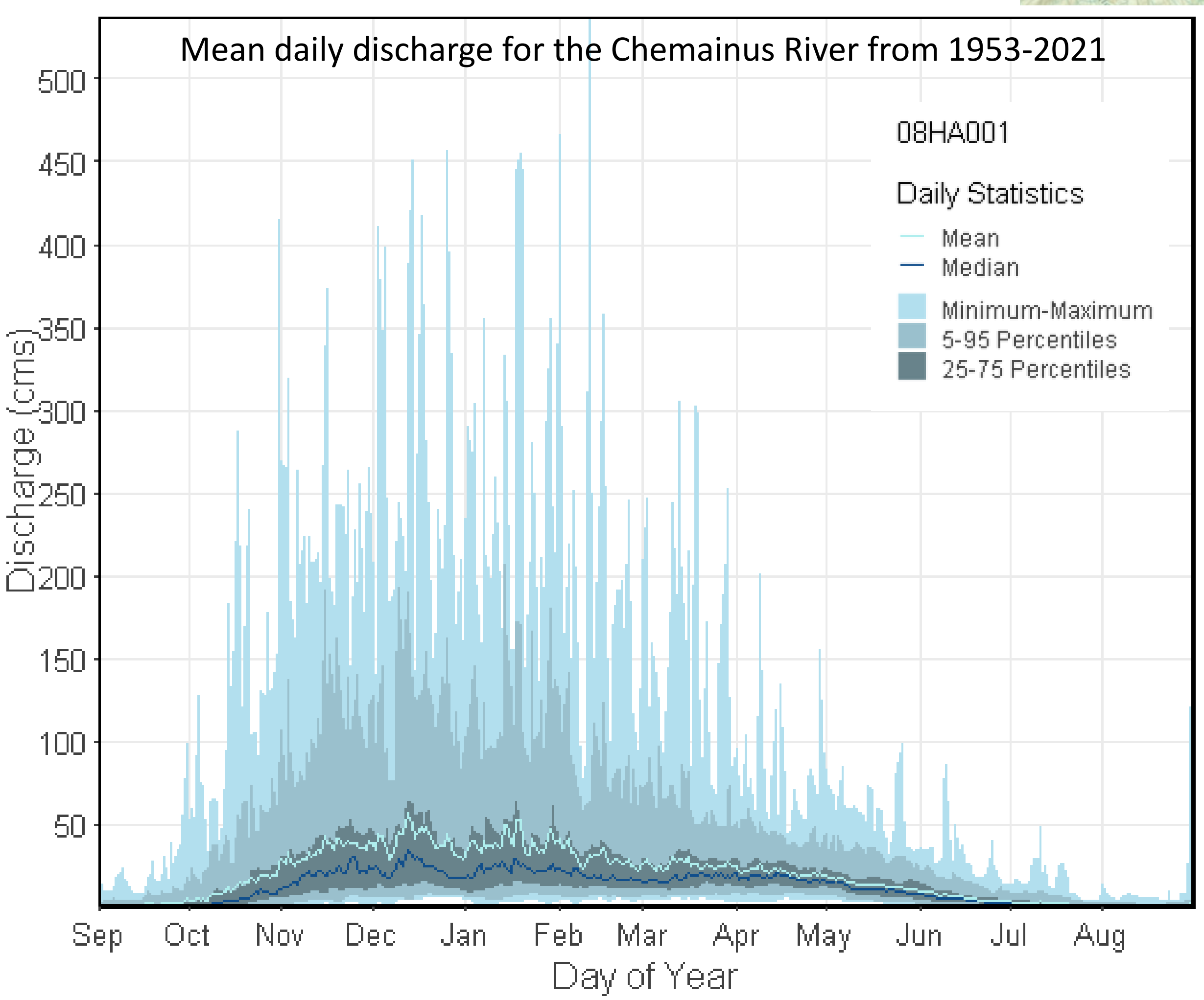
The Chemainus River drains 355 km^2 of forested uplands and mountains. The highest point in the basin in on the peak of Mount Whymper at an elevation of 1,540 m.

The majority of the river flows in a structurally controlled valley (i.e. rock). At Westholme, the river transitions to an irregularly meandering channel flowing over a broad, flat valley. The river enters the estuary tidal flats and drains into the Stuart Channel.

Bonsall Creek Watershed

Bonsall Creek drains 36 km^2 and flows from the slopes of Sicker Mountain. The lower portion of Bonsall Creek crosses an alluvial plain in an incised, irregular meandering channel. The creek splits into a series of distributary channels and flows over the tidal flats into the Stuart Channel.





Flood Hydrology

The Chemainus River and Bonsall Creek have a rainfall dominated regime. The period between November and March is time in which the region experiences higher river flows driven by winter storm events.

Extreme flooding in the Chemainus floodplain typically occurs from a series of Pacific low-pressure frontal systems generated off the West Coast of Vancouver Island. These storms, referred to as atmospheric rivers, bring large precipitation cells to the region that can lead to flooding. The extent of flooding brought on by these winter storms depends on both the current watershed conditions (e.g. how saturated the ground is) and coinciding tide levels. The extent of the tidal influence extends from the estuary to the Chemainus Road bridge.

By the end of this century, the 200-year event could be substantially different as the magnitude, and frequency of flood events may be influenced by changes in climate (i.e., global climate change) or changes in vegetation and landcover within the watershed.

Flooding and Watershed History

LEGEND

- SIGNIFICANT FLOOD EVENTS
- INDUSTRIAL ACTIVITY AND SIGNIFICANT LAND-USE CHANGES
- FLOOD MITIGATION ACTIVITIES
- POLICY & GUIDELINES

time immemorial
The region was used by multiple Indigenous Groups.

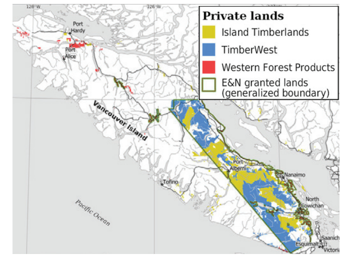
1850
The logging industry in the Chemainus Valley was underway in 1850 introduction of road building in the watershed (Chemainus Valley Courier, 2017).

1858
November
First homestead in the area was bought known as *Grahames Prairie or Rainbow Ranch* (Chemainus Valley Courier, 2017).

1873
Highway between Nanaimo and Victoria constructed.

1884-1886
Construction of the E&N Railway altering the flow across the floodplain.

1884
Settler-colonial land grants established 853,050 hectares of private land on the unceded Indigenous territory of the Kwakwaka'wakw, Coast Salish, and Nuu-chah-nulth people for construction of the Esquimalt and Nanaimo (E&N) Railway (Ekers et al., 2020). Indigenous people constrained to reserve lands. Mosaic Forest Management own over 500,000 hectares of this land as of July 2020.



1888
The Federal Government enacted fish licensing regulations.

1912
The provincial Forest Act was established to regulate logging rates and harvesting operations (Plowright, n.d.).

1913
Department of Fisheries and Oceans had forcibly removed all First Nations fishing weirs from the Cowichan and Chemainus Rivers altering fisheries managment (NHC, 2022).

1920s – 1930s
Ownership of cars begins to significantly increase in the 1920s, inspiring considerable efforts for paving surfaces in towns in the 1930s (MOTI, n.d.).

The Malahat in 1918

1951
January 20-25
Heavy rain and high tides led to flooding on the Chemainus River threatening many homes in Chemainus and Westholme.

1949
Highway 1 bridge constructed.

1947
December 22-23
Chemainus River overflowed its banks. Island Highway near Westholme flooded. Dozens of homes were surrounded by water.

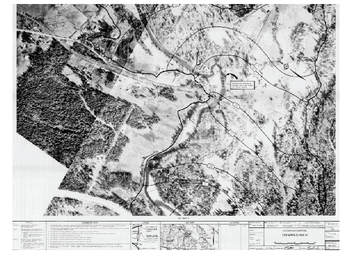
1958
Development of the Crofton pulp mill in 1958 has closed off the southern opening to the estuary between Vancouver Island and Shoal Island (NHC, 2022).

1963
December 22-23
Heavy rain caused flooding in Chemainus. A garage, restaurant and several homes around Pinson's Corner were under 4 ft (1.2 m) of water. Just south of Westholme the rail line was fl ooded.


Rivers, creeks overflow due to Christmas rains

1946–1968
Gravel extractions between Highway 1 and Chemainus Road took place between 1946 and 1968, which may be the cause of river bank widening between the E&N railroad and Chemainus Road (KWL, 2021).

1991
September 20
BC Ministry of Environment releases floodplain mapping for lower Chemainus River watershed.

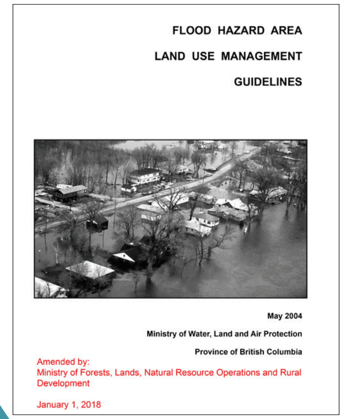


1983
February 11
Following this flood event, in September 1984 a petition was signed by 24 residents and land owners to express concern over frequent flood damage and disruption of the road access along the lower Chemainus River (NHC, 1990).

1972
December 25-26
A high tide on Christmas night led to flooding in Chemainus floodplain. Approximately 10 homes were flooded. Croft on Road was flooded with 5 ft .
(1.5 m)
of water.

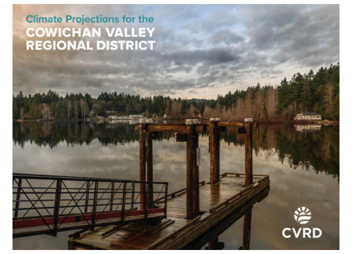
1997
March 18
Following heavy rain, the Chemainus River overflowed its banks and flood Pinson's Corner.

2004
May
Provincial Government releases flood hazard guidelines to help local authorities implement management plans for flood prone areas. The Province places the responsibility of floodplain mapping on local governments.


FLOOD HAZARD AREA
LAND USE MANAGEMENT
GUIDELINES

May 2004
Ministry of Water, Land and Air Protection
Province of British Columbia
Amended by:
Ministry of Forests, Lands, Natural Resource Operations and Rural Development
January 1, 2018

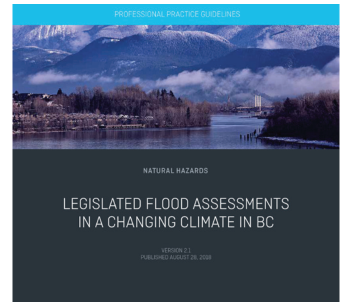
2017
CVRD New Normal Cowichan – Phase 1 Report released "Climate projections for the Cowichan Valley Regional District".



2011
June
Provincial Government releases coastal floodplain mapping guidelines.

2007
August to September
Gravel removal between Highway 1 and Chemainus Road, undertaken by the District of North Cowichan and Halalt First Nation (Clough, 2007). Debris jambs were also cleared in the area as a preventative measure for the next flood season.

2018
August
EGBC releases flood assessment guidelines that incorporate climate change.



2019
January 3
The Chemainus River spilled its banks. Pinson's Corner flooded. WSC Chemainus River flow 512 m^3/s.

2021
Summer
Halalt First Nation completed sediment removal between Highway 1 and Chemainus Road to increase channel conveyance, and installed wattle fencing to protect against bank erosion (NHC, 2022).

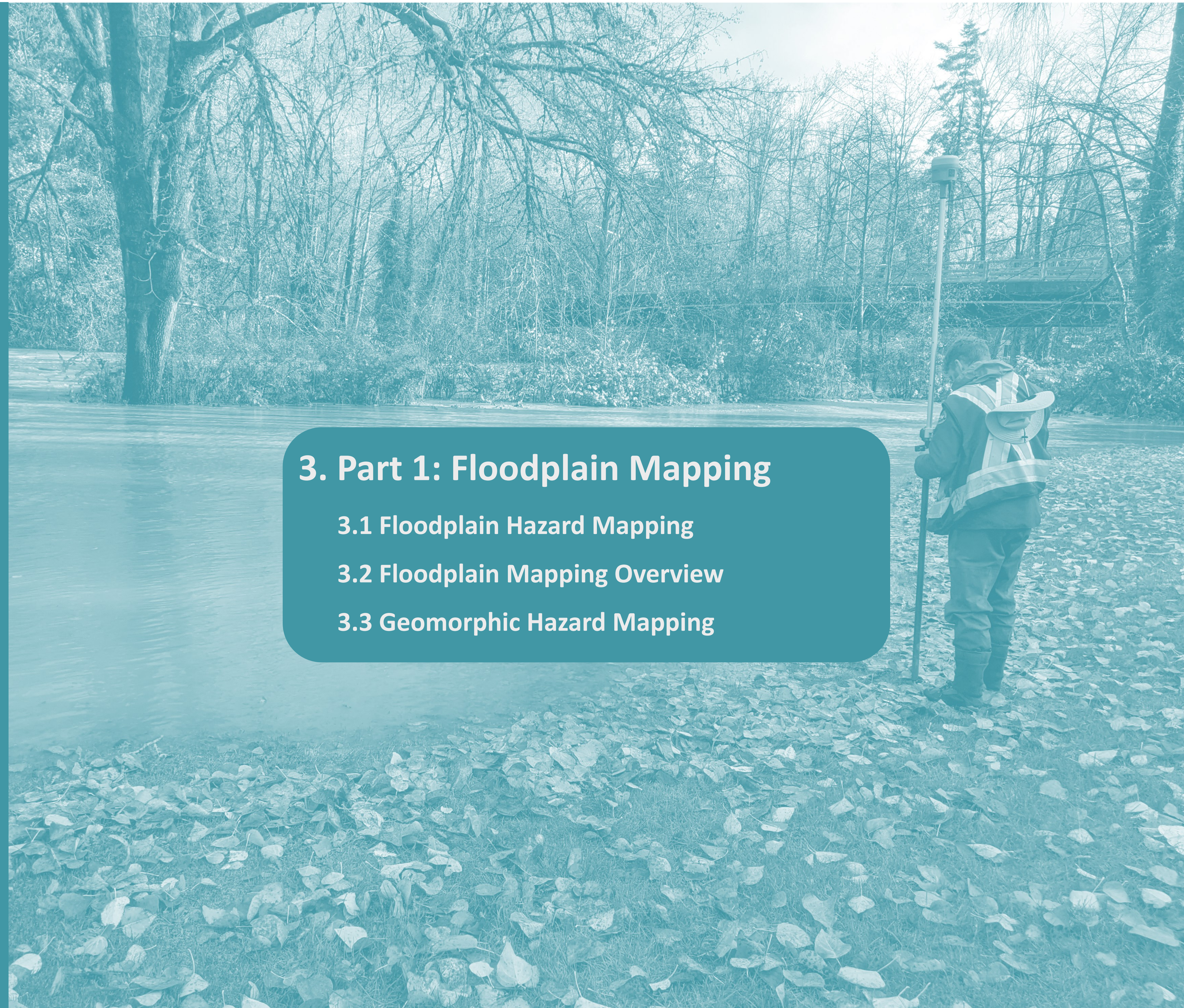
2020
February 1
Flooding closed Highway 1 and Pinson's Corner. Russel's Farm and several parts of the lower floodplain were flooded. WSC Chemainus River flow 729 m^3/s.

2020
Flood mapping project initiated for the Chemainus River and Bonsal Creek floodplains.

2021
November 15
Historic rainfall records were broken as an atmospheric river storm event impacted British Columbia. Flooding closed Highway 1 and Pinson's Corner. Russel's Farm was fl ooded. Residents in the lower fl oodplain were evacuated. WSC Chemainus River flow 652 m^3/s.

2022
Flood mapping for the Chemainus River and Bonsal Creek floodplains is completed.

2022-2023
Lower Chemainus watershed floodplain management plan initiated. Public input sought. Flood management plan completed May 2023.

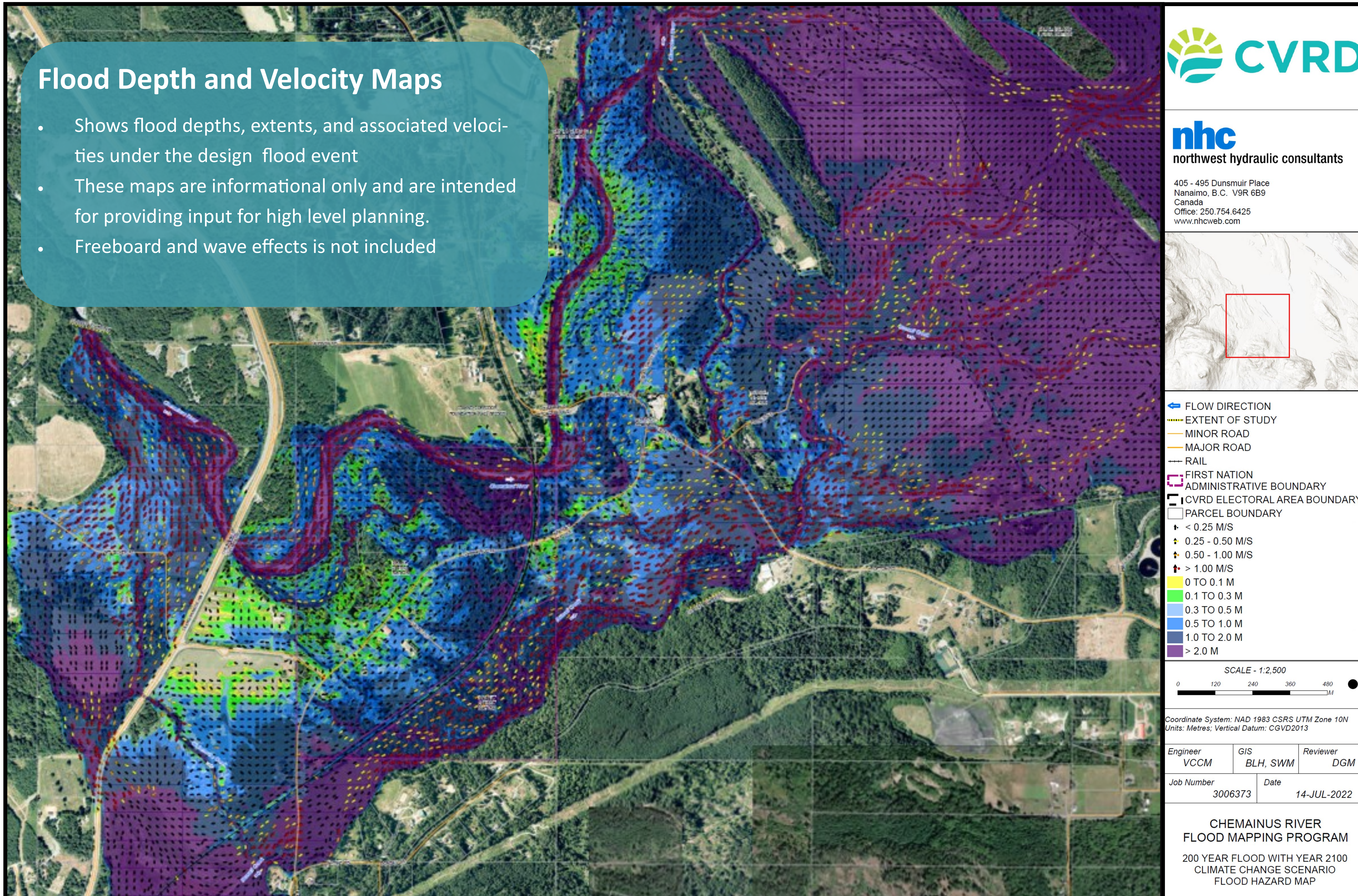


3. Part 1: Floodplain Mapping

Floodplain Hazard Mapping

Flood Depth and Velocity Maps

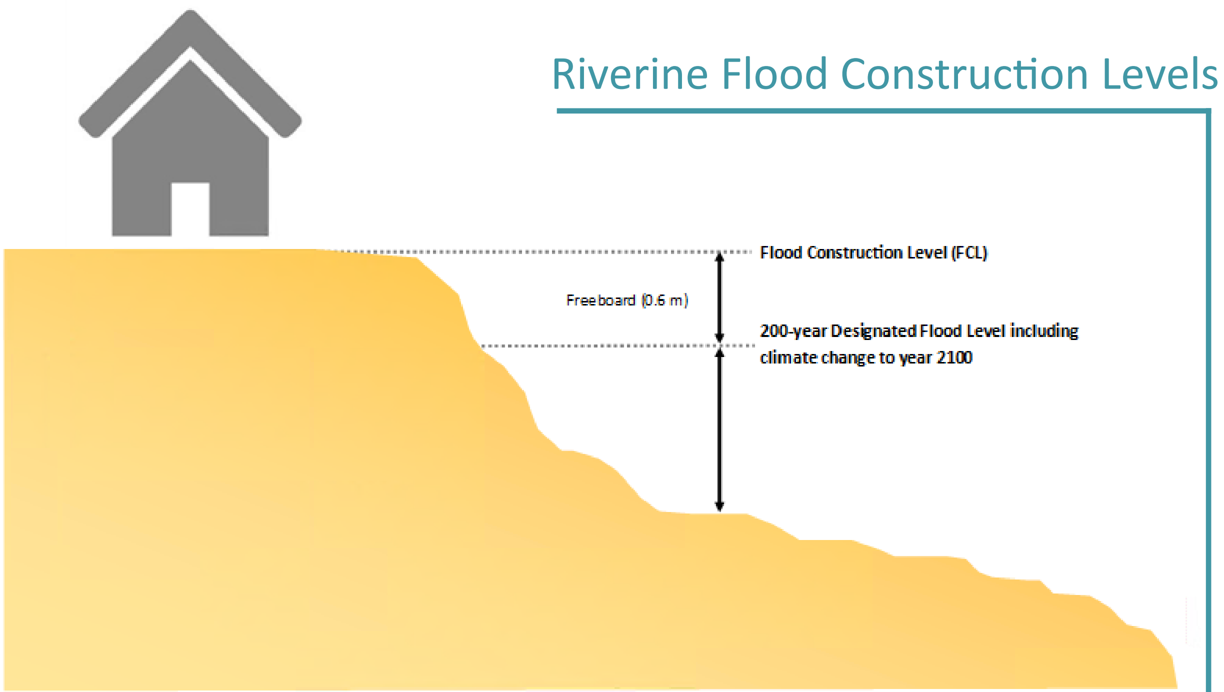
- Shows flood depths, extents, and associated velocities under the design flood event
- These maps are informational only and are intended for providing input for high level planning.
- Freeboard and wave effects is not included

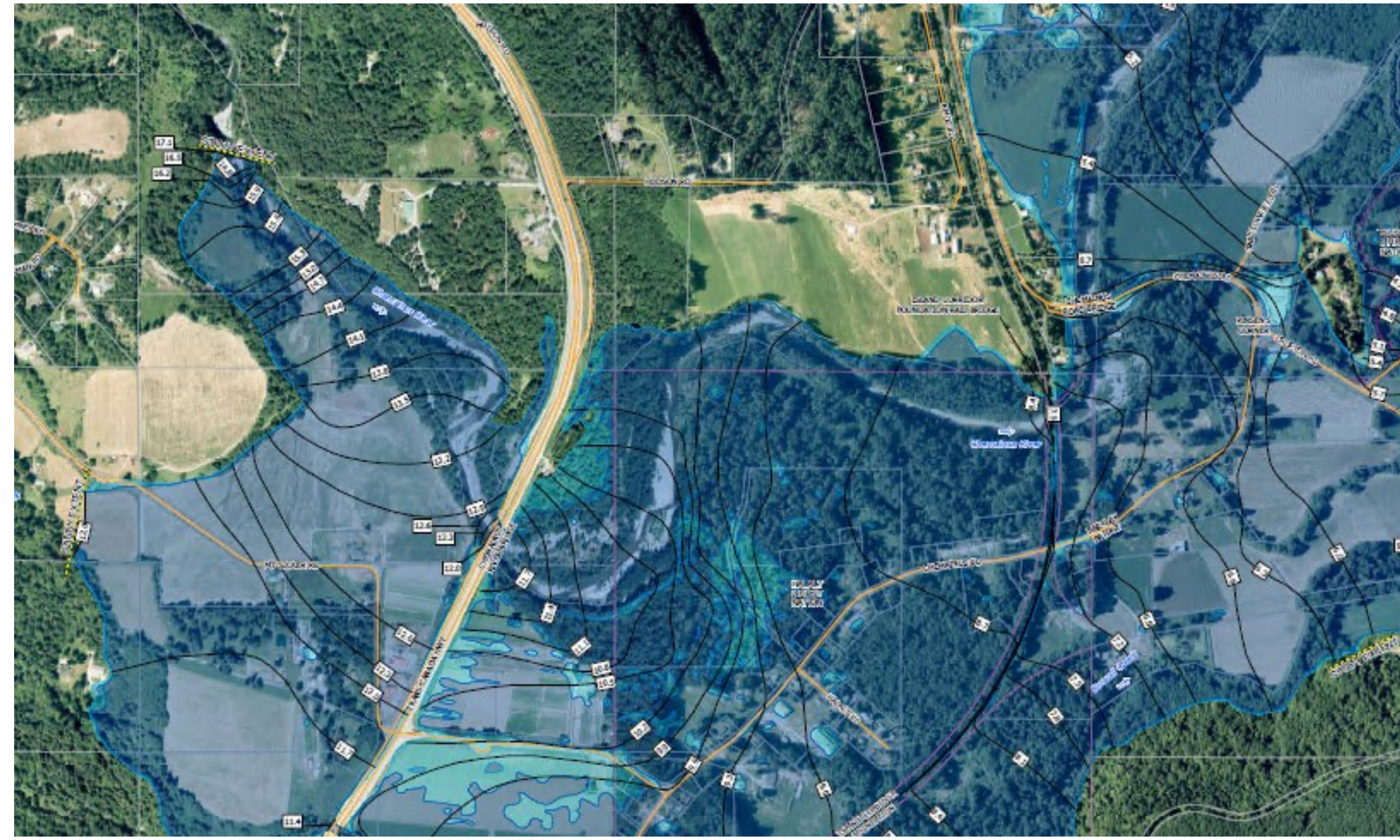


Designated Floodplain Maps

Designated floodplain maps show the estimated flood boundary and associated flood construction levels under the 200-year conditions the with the addition of climate change to the planning time horizon of 2100. Flood construction levels are shown as black lines in the riverine portion of the map. Coastal flood construction zones (teal areas) along the shorelines incorporate wave effects. Flood construction levels include a freeboard of 0.6 meters

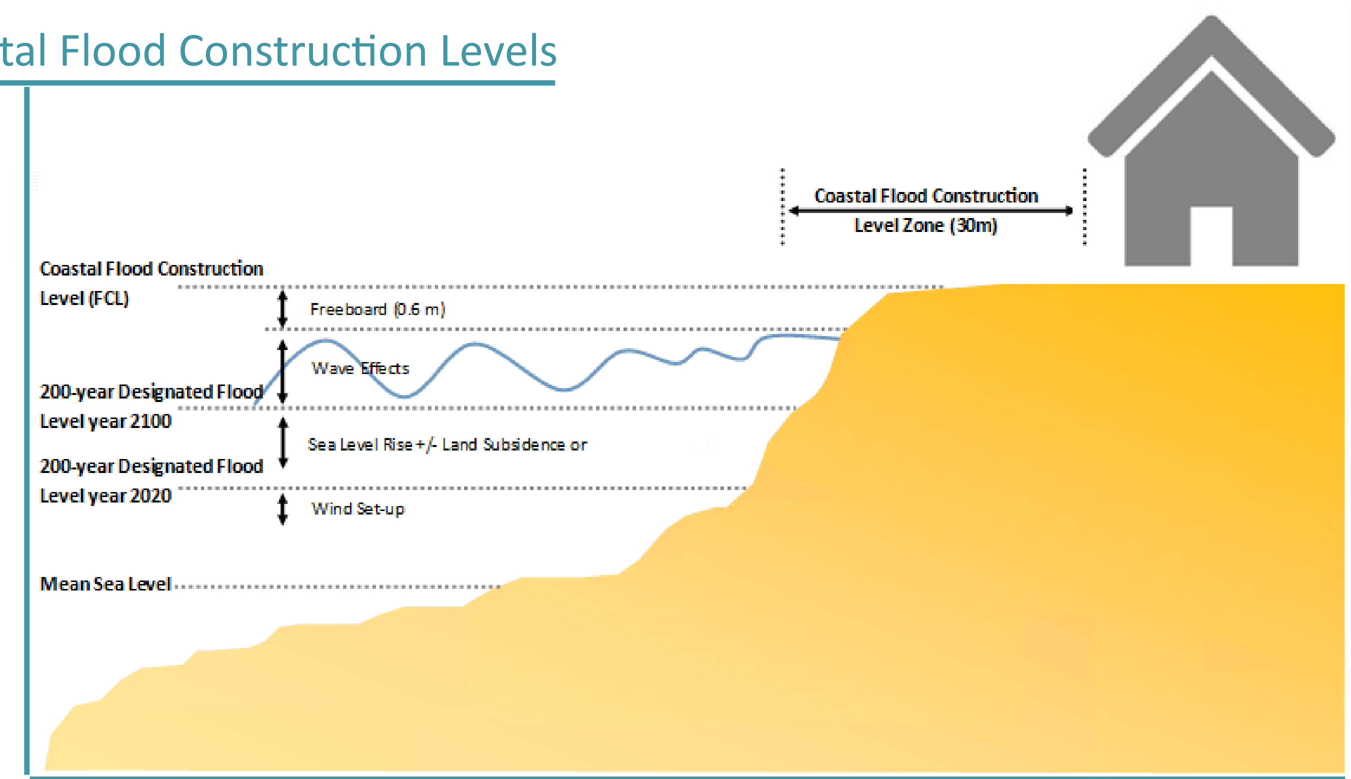
Riverine Flood Construction Levels





> *A **flood construction level (FCL)** is the minimum elevation for habitable buildings in a floodplain.*

Coastal Flood Construction Levels



Geomorphic Hazard Mapping

Modern Valley Bottom: Area where channel migration has likely occurred in the past several thousand years and is susceptible to occurring under the present-day hydroclimate regime.

Historical Migration Zone: Area that the channel occupied in the historical record, based on available imagery and survey data. This area is also susceptible to erosion and avulsion hazards.

Channel Erosion Hazard Zone: Area susceptible to bank erosion by stream flow and to avulsion hazards. Chemainus River floodplain is prone to lateral channel instabilities and shoreline erosion.

Avulsion Hazard Zone: Area that is susceptible to avulsion. This area may also be susceptible to estuary distributary channel hazards in tidally influenced areas.

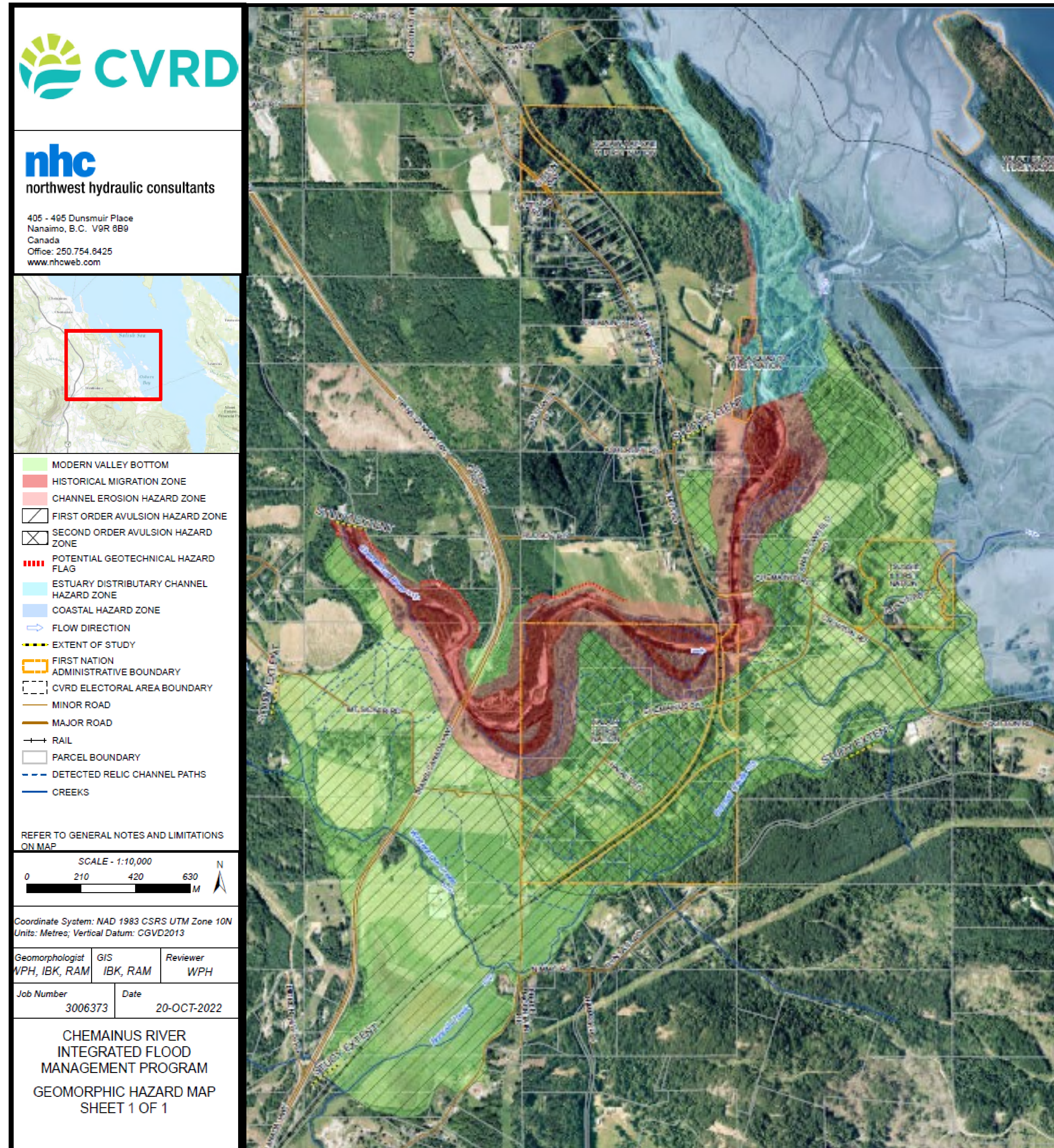
First-order avulsion: sudden and major shift to a new part of the floodplain

Second-order avulsion: sudden reoccupation of an old channel on the floodplain. Second-order avulsion zones may also be subject to first-order avulsions.

Unrated Potential Geotechnical Hazard: Area with steep slopes within the channel erosion hazard zone, which may become geotechnically unstable due to inundation or erosion of the toe of the slope.

Estuary Distributary Channel Hazard Zone: Relatively lower gradient area influenced by tidal processes and susceptible to the formation of distributary channels. This area is also susceptible to channel erosion and avulsion hazards.

Coastal Erosion Hazard Zone: Landward extent of area likely to be at risk of erosion from tidal currents and waves generated during coastal storms, with 1 m sea level rise. This area is also susceptible to channel erosion, avulsion, and estuary distributary channel hazards.



Map for display purposes only, please see full map for description and notes in NHC (2022)

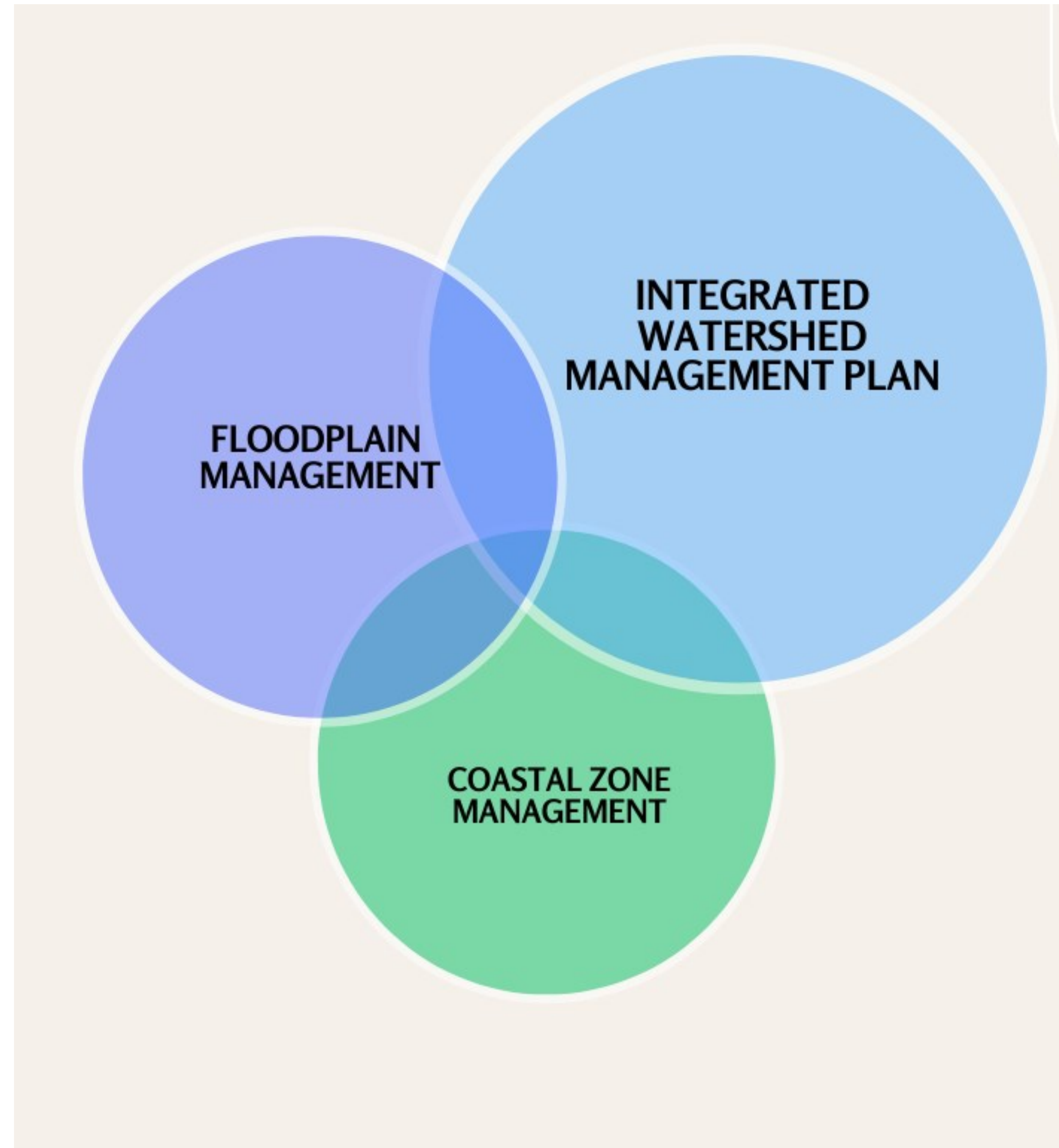
1. Introduction
2. Study Area Overview
3. Part 1 Floodplain Mapping
4. Introduction to Integrated Flood Management
5. Flood Management Strategies
6. Evaluation of Flood Management Strategies
7. Recommendations

4. Introduction to Integrated Flood Management

What is Integrated Flood Management?

This study focuses on strategies that can be taken by local governments and First Nations communities on the floodplain of the lower Chemainus River and portions of Bonsall Creek to reduce flood losses. These strategies are a sub-set of integrated watershed management (IWM), which encompasses the entire basin and considers all phases of the water cycle, not just floods. Watershed management requires the participation of all relevant government agencies whose jurisdiction falls within the watershed, as well as all First Nations, private land-owners , commercial industries, and stakeholders. It is beyond the scope of local governments on their own to implement IWM. Local governments can be instrumental in facilitating the process of IWM development.

Other regional coastal zone management strategies and regulations may need to be incorporated into local floodplain management plans. For example, this plan conforms to Provincial coastal flood hazard and floodplain mapping guidelines



Approaches to flood management:

General approaches to flood management on the floodplain are commonly grouped into four types of actions:

(1) Flood avoidance, by preventing new buildings in flood hazard areas

(2) Flood accommodation , by raising buildings above flood levels or installing floodproofing measures.

(3) Flood protection, by building dikes and flood walls, erosion protection and channel improvements such as excavations

(4) Managed retreat, through land acquisition to re-locate people out of high risk areas.

Approaches 1 and 4 are considered “non-structural” flood management strategies, while Approach 3 is “structural” flood management. Approach 2 can involve a combination of structural and non-structural strategies. It is generally accepted that adopting a mix of structural and non-structural strategies is the most effective approach to mitigating against floods.

Objectives of the Plan

1. **Enhance Public Safety**
   - Adopt strategies that guide future developments to avoid exposure to high risk flood and erosion hazards that threaten public safety.
   - Adopt "no adverse impact" (NAI) flood management strategies in order to avoid constructing projects or new developments that reduce flood risks in one area but increase flood risks to other nearby communities or households.
   - Identify practical solutions to floodproof new and existing developments on the floodplain.
   - Strategies should be robust under future climate changes and sea level rise. This means solutions should be effective over a wide range of climate conditions; measures can be adapted and upgraded in the future as required.
2. **Protect Public Infrastructure**
   - Identify needs for upgrading roads, bridges and other services to withstand present and future hazards.
   - Provide planning tools to avoid placing future critical infrastructure such as schools, health centres, water treatment plants, and emergency response services in high hazard zones.
3. **Protect and Enhance Environment**
   - Use mitigation strategies that preserve the ecological function of natural systems.
   - Wherever possible, develop multi-objective strategies that mitigate against flood damage and also help to restore degraded natural systems.
4. **Enhance community Preparedness and Recovery**
   - Promote improvements and coordination of flood warning, flood preparedness and evacuation plans amongst First Nation, Provincial, and local governments
   - Promote education and training to ensure communities are aware of how future climate change and sea level rise is expected to affect communities on the floodplain.
   - Promote resilience.

Guiding Principles and Limitations

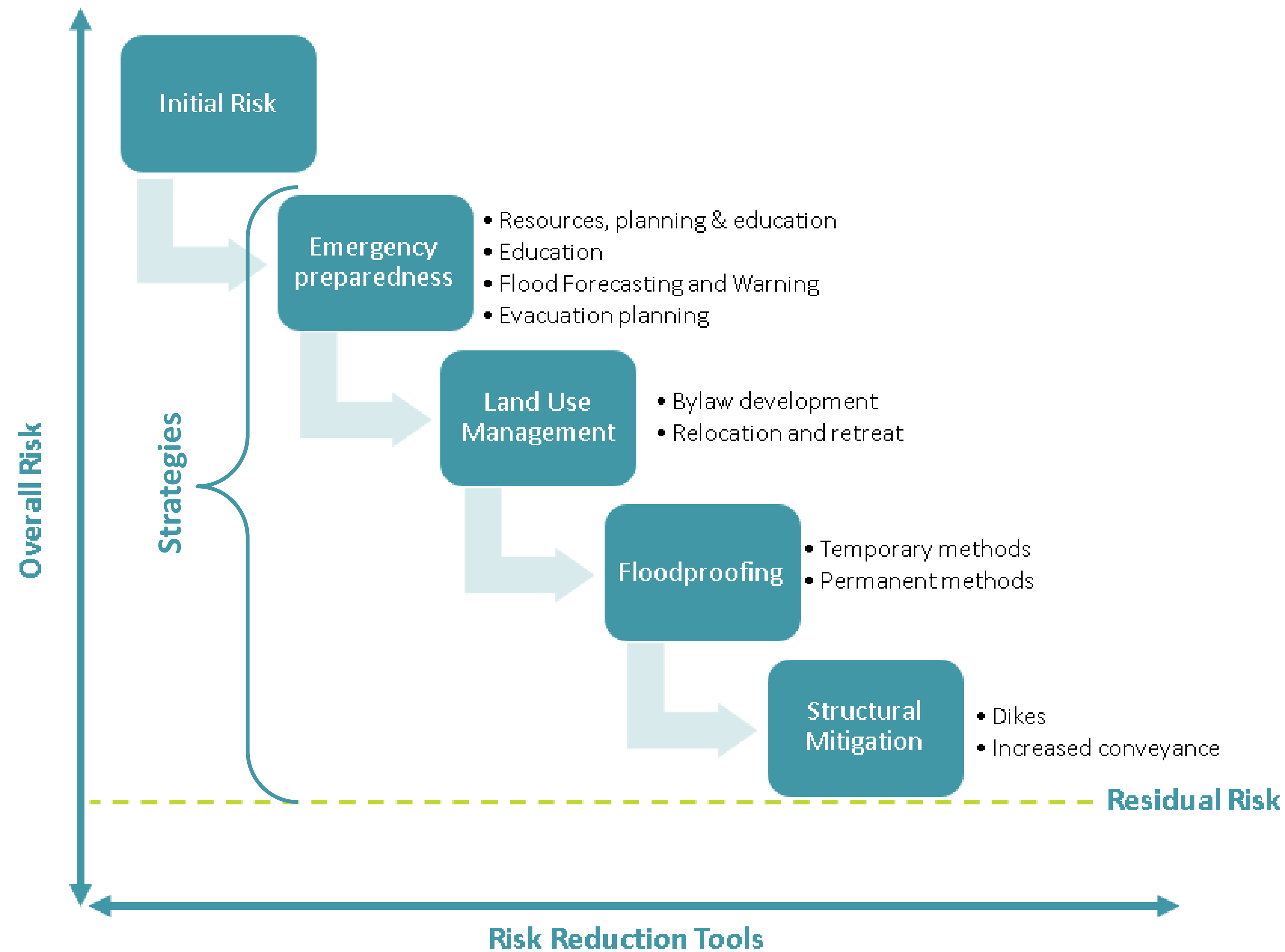
- Adopt a broad mix of non-structural and structural mitigation measures that working in combination, will reduce the flood risk to an acceptable level.
- Where feasible, use strategies that are multi-purpose, such as mitigating flood risk but also will enhance habitat.
- Must be compatible with the social and environmental values of the community.
- Must comply with existing land-use by-laws and floodplain regulations and codes of practice established by Engineers and Geoscientists of BC (EGBC).
- EGBC recommends using the 200-year flood event for design and for reduction of flood risk in the floodplain. This standard has been adopted for assessing the strategies.

Processing for Developing and Assessing Flood Management

Overview process

The method for assessing and evaluating each strategy was as follows:

- The flood and erosion hazard maps and results from Part 1 were presented to the TAG and in public consultation meetings. Input was also received on flood issues and ideas for preventing flooding. Preliminary strategies were identified and defined for further assessment.
- The benefits and potential adverse impacts of each strategy was then assessed using the technical results from the Phase 1 studies and from the flood vulnerability assessment described previously.
- The results were then used to identify the "Strengths" and "Weaknesses" and "Opportunities" and "Threats" (SWOT) associated with each strategy.
- A multi-criteria analysis was then used to rank and compare the strategies. The object of this screening was to identify the most appropriate mix of structural and non-structural measures that reduce the flood risk.
- The results of the assessment were presented in an expanded TAG meeting for comments and further input. The FMP document was then finalized to address these comments.



Summary of Public Input

NHC with the support of LANARC engaged with the residents of the Chemainus floodplain in the Summer of 2022 to hear about the flooding issues and their ideas for improvements. The results of the sessions is summarized in the maps and the key themes are listed below. Residents had an option to come to the sessions or submit their feedback online.

271 unique visits to the project website	**120** downloads of engagement materials	**14** completed and submitted comment forms
~25 participants in the July 18 First Nations Information Session	**23** participants in the July 20 Technical Stakeholder Virtual Working Session	**~60** participants in the July 20 Community Information Session

Key Themes - issues identified:

- Concerns about flooding impacts increasing and intensifying
- Concerns about debris and sediment increasing flood risk
- Concerns abut groundwater impacts
- Impacts of past flood events on communities – physical losses
- Impacts of past flood events on communities – physiological and emotional effect
- Concerns about damage to public infrastructure
- Concerns about impacts to fish habitat
- Concerns about logging impacts
- Concerns about lack of public engagement and communication
- Concerns about implementation and available resources
- Concerns about impacts of other projects

Key themes – ideas for Flood management:

- Dredging and removal of sediments
- Increase storage capacity
- Remove pinch points that restrict water flow
- Build protective dikes and barriers
- Upgrade infrastructure (highways)
- Better manage forestry practices
- Improve emergency response and recovery communication
- Consider key risks in planning
- Integrate coastal flood management planning
- Improve implementation of available funding
- Enhance public engagement and communication

Lower Chemainus Watershed FLOOD MANAGEMENT PLAN

1 ISSUES MAP

Part of flood management planning is building a collective knowledge about an area. Stories share where and how flood events have been experienced.

In the public engagements, participants were asked to share their knowledge including

- An experience they've had with flooding in the area
- Observations about flood impacts
- Locations where there are issues that couldaffect future flooding

This map summarizes information shared by community members.

Lower Chemainus Watershed FLOOD MANAGEMENT PLAN

2 IDEAS MAP

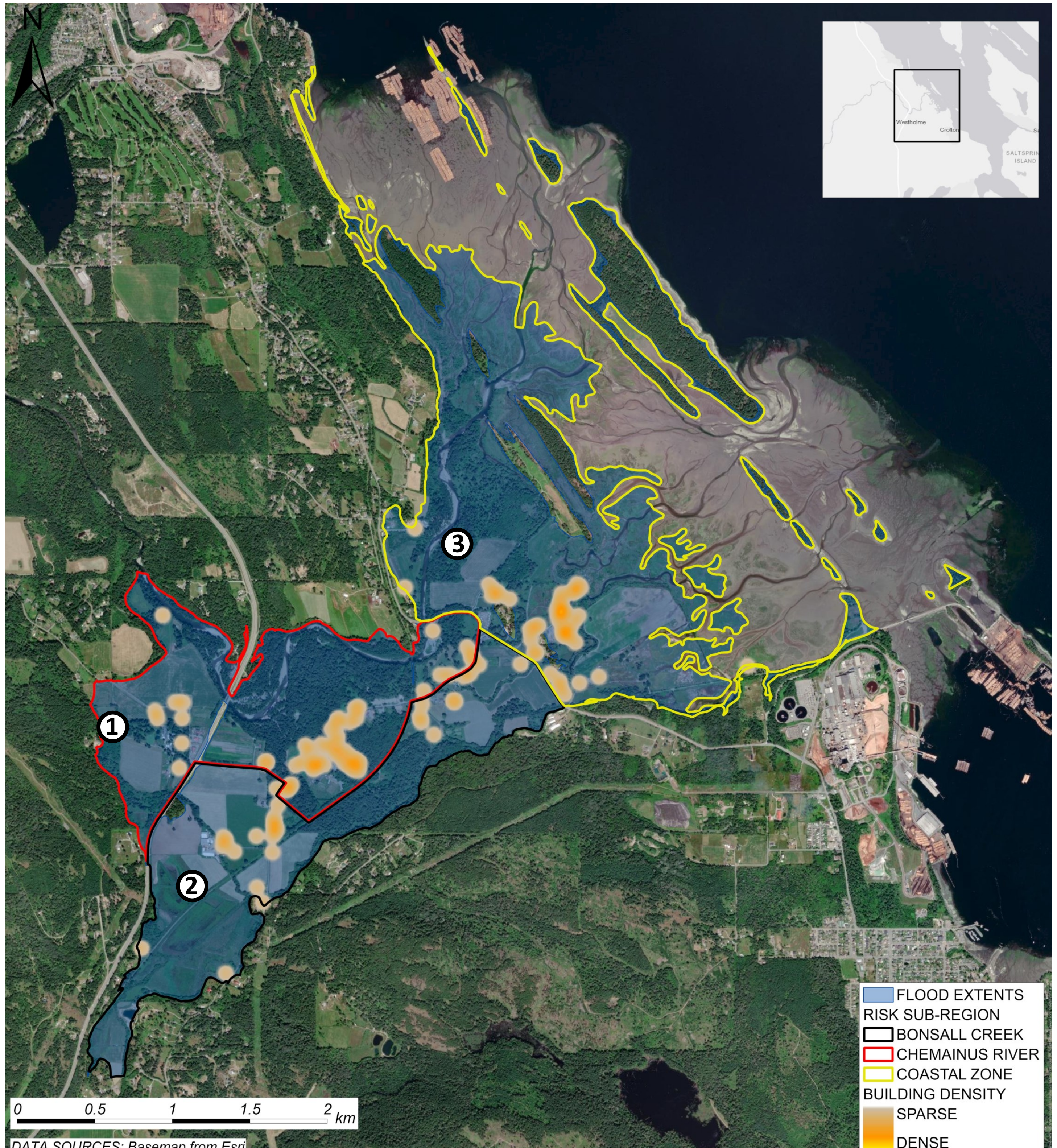
A next step in this process is identifying potentially viable flood management options that could be considered by communities.

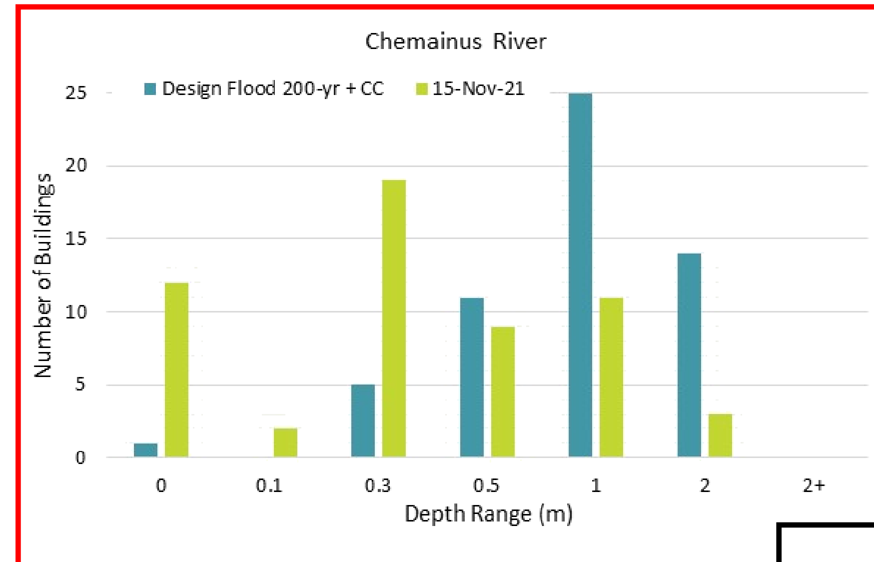
In the engagements, participants were encouraged to identify ideas or suggestions for flood management that couldbe studied.

This map summarizes information shared by community members.

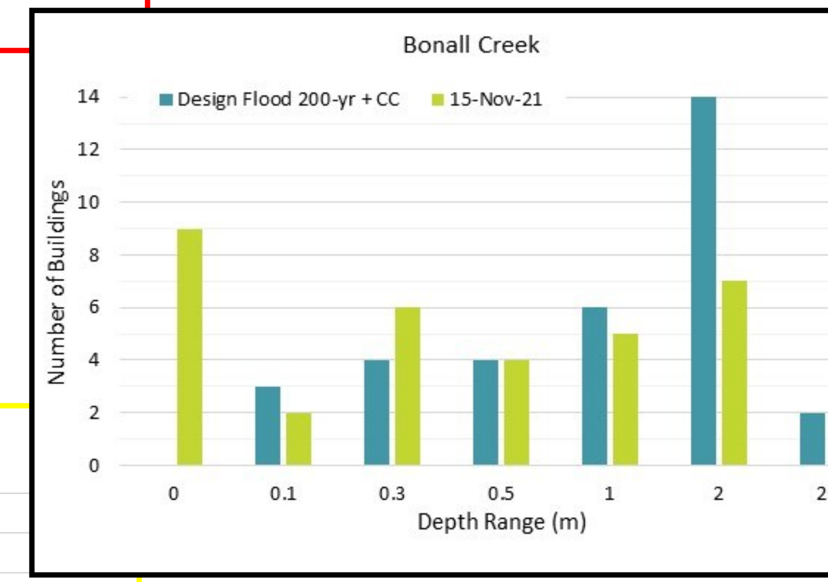
What is a flood Vulnerability Assessment?

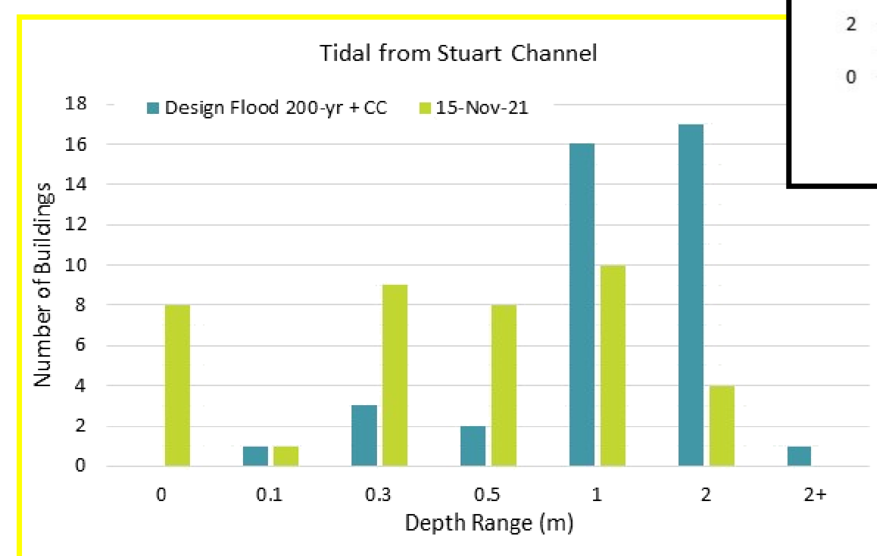
A flood vulnerability assessment is completed to help the community understand who is exposed to flood risk. An assessment of exposure and hazard of a large flood can help inform risk reductions plans and build resilience from such events.





129 buildings (approximately 298 people) had some form of flood water encounter during November 2021 flood





**Population per building calculated by dividing population per census region by number of private dwellings. Resulting value assigned to primary residential building within floodplain.*

Flood Region	Number of Buildings in Floodplain where Velocities > 1 m/s		Number of People At Risk*	
	November 15, 2021	200-yr + CC	November 15, 2021	200-yr + CC
Region 1: Chemainus River	1	5	63	86
Region 2: Bonsall Creek	1	6	136	164
Region 3: Tidal from Stuart Channel	4	9	99	118

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5. Flood Management Strategies

Floodplain Management Strategies Overview

Based on input from the public consultation meetings, input from the TAG, EGBC guidelines and experience on other rivers, the following strategies were assessed.

Land Use Management
- By-law Development
- Relocation and Retreat

Emergency Preparedness and Response
- Resources, planning & education
- Communication
- Warning and Monitoring
- Evacuation

Flood Proofing
- Temporary methods
- Permanent methods

Structural Mitigation
- Dikes
- Removal of blockages from floodplain
- Increased conveyance of Chemainus River

Floodplain management uses multiple strategies to address flood risk. **No one strategy can solve all flood problems, particularly in the Chemainus Floodplain**. A combination of strategies is required.

The purpose of this section is to identify flood management strategies that, in combination, can reduce flood risk. **Although they are presented, not all options are suitable for the floodplain**. **Please see the evaluation of the strategies and the recommendations for the most suitable strategies for the Chemainus Floodplain.**

All options were assessed using the 200-year flood for the Chemainus Floodplain as per flood management practises. Some of the strategies (or different strategies) may be more effective at lower return periods than during the design event. There may also be alternative solutions to address smaller return period floods than listed here.

None of the structural flood management strategies presented are suitable for design. The scenarios created are conceptual mitigation options that were suggested by the public and investigated by simulating each scenario to maximize the potential effect of each measure. This was done in order to demonstrate whether they were effective or not. Different layouts or structures would create different results. Conceptual mitigation measures would need to be modified substantially to produce final mitigation solutions.

Strategy 1: Land Use Management

Land use management is a proven and cost-effective way to reduce the effects of flooding on lives and property. The main features of this strategy follows the guidelines and best management practices specified by the Province and EGBC.

Overview of Land Use Management

Land use is regulated by local governments, provincial approving officers and provincial land officers responsible for Crown land. Local governments have the authority to:

- Develop flood hazard area bylaws
- Grant flood hazard area land development exemptions.
- Establish requirements for subdivision in flood prone areas, which includes engineering reports assessing flood hazards and restrictive covenants.

Managing the floodplain to minimize future losses on the floodplain can be integrated with other broader land use regulations such as the Provincial governments Agricultural Land Use regulations.

Floodplain mapping is an important first step in developing a flood hazard management plan. Designated floodplain maps were issued by the Province in 1990 and have been incorporated into existing land use by-laws by the Municipality of North Cowichan. The new floodplain maps prepared under Phase 1 are the first update since 1990 and should supersede the earlier maps. The updated flood maps incorporate additional hydrological information, used more advanced hydraulic modelling methods and account for future climate change and sea level rise. In addition, erosion hazard maps have been developed to identify risks from bank erosion and channel avulsions.

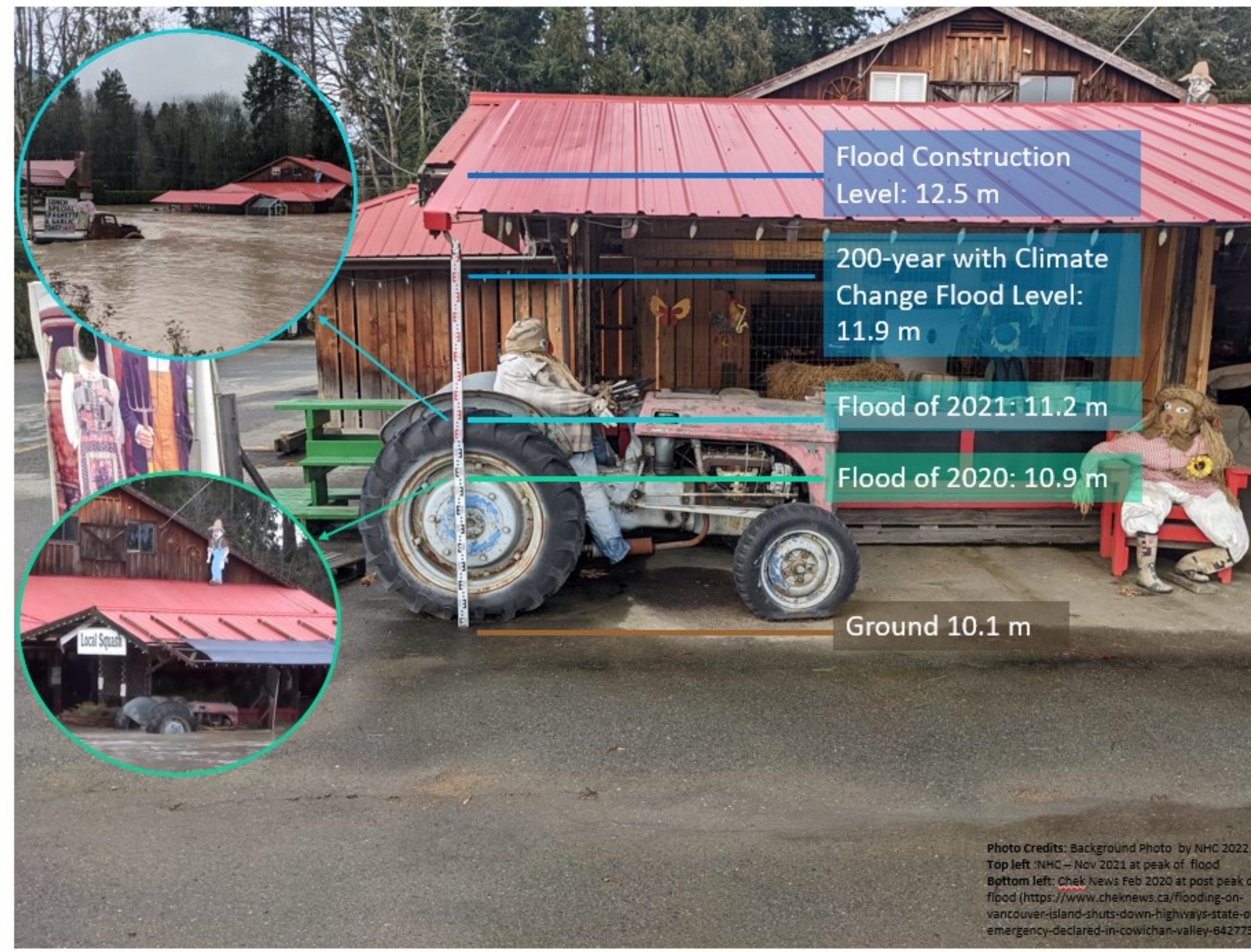
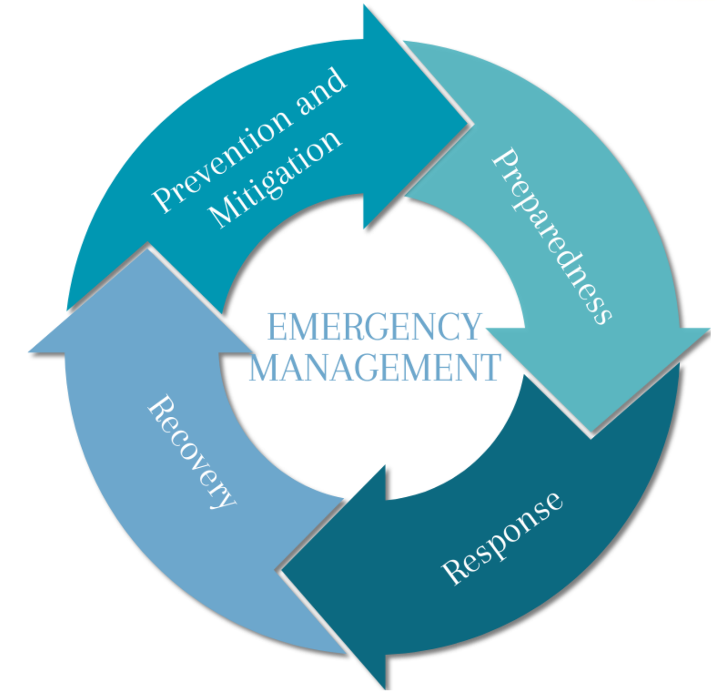


Photo Credits: Background Photo by NHC 2022
Top left :NHC – Nov 2021 at peak of flood
Bottom left: Chek News Feb 2020 at post peak of flood (https://www.cheknews.ca/flooding-on-vancouver-island-shuts-down-highways-state-of-emergency-declared-in-cowichan-valley-642773/)

Strategy 2: Emergency Preparedness & Response

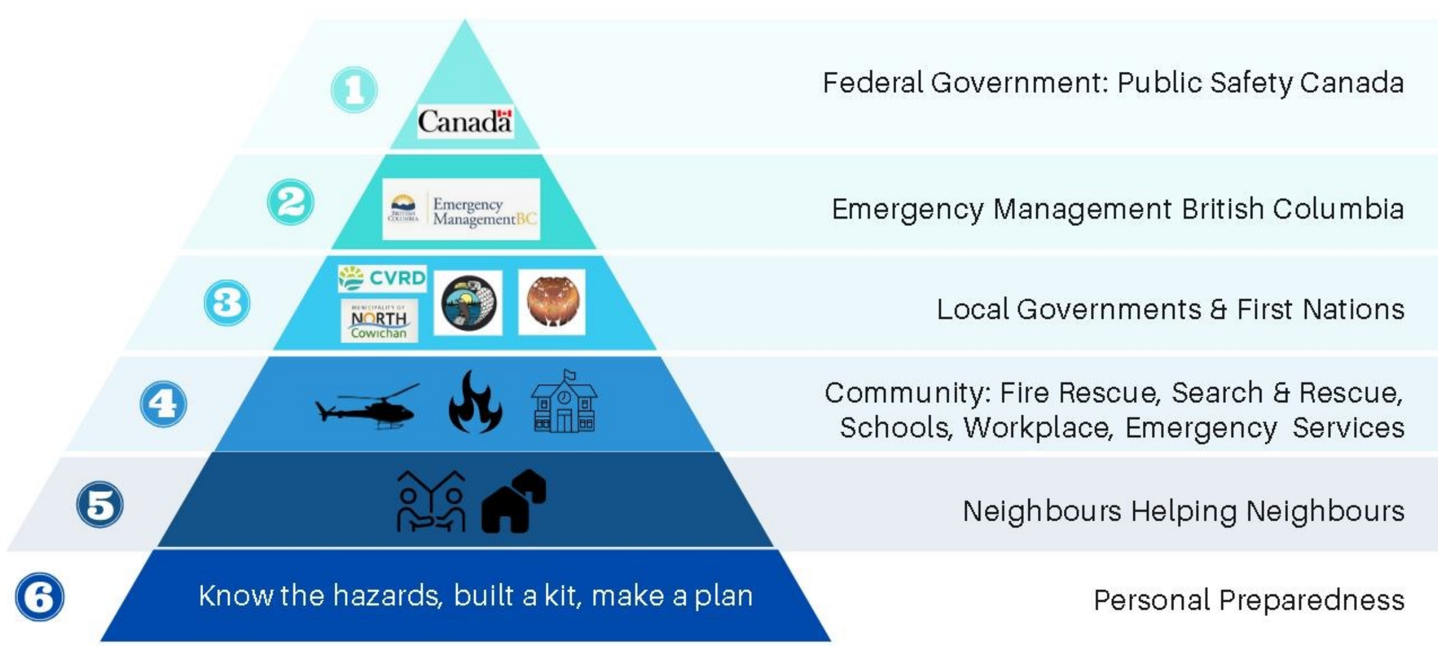
Emergency Management protects communities by coordinating and integrating all activities necessary to build, sustain, and improve the capability to mitigate against, prepare for, respond to, and recover from threatened or actual natural disasters. Emergency Management can be defined by 4 phases:

1. Prevention and mitigation
2. Preparedness
3. Response
4. Recovery



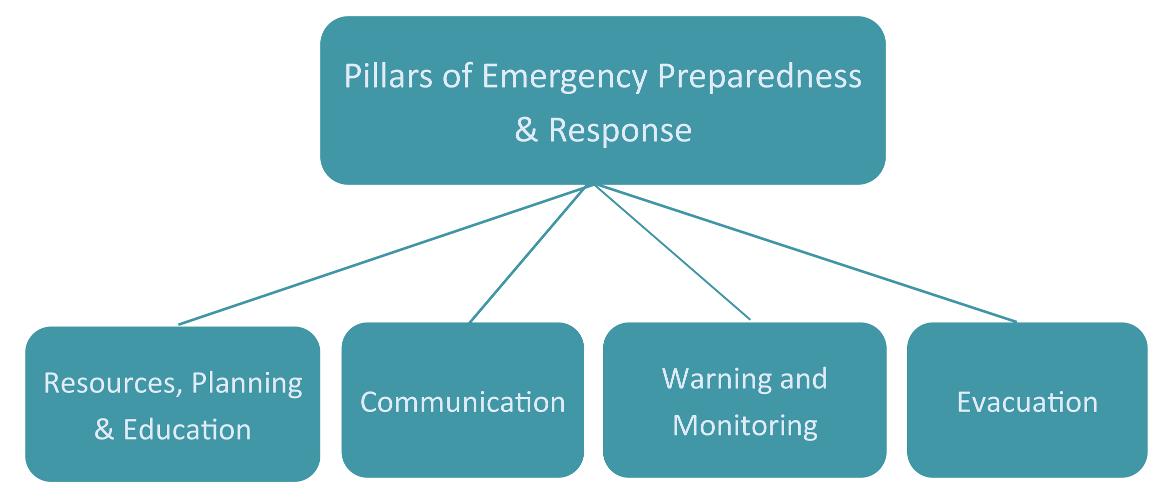
In the Chemainus River floodplain, emergency management is the responsibility of everyone:

Emergency Planning and Response



Several resources are available to support emergency preparedness and response for the communities in the Chemainus floodplain. The key areas of emergency preparedness and response are:

- Planning & Education
- Communication
- Flood warning and Monitoring
- Evacuation



Strategy 2: Emergency Preparedness & Response

Pillars of Emergency Preparedness & Response
- Resources, Planning & Education
- Communication
- Warning and Monitoring
- Evacuation

Resources for government, schools and various organizations

Resources

Funding opportunities for local governments and Indigenous communities

- Emergency Management BC outlines available funding for disaster mitigation, disaster response and recovery. BC Emergency management financial support

Education

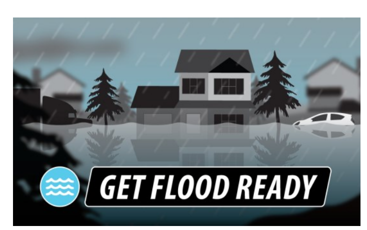
Emergency Management BC Master of Disaster grades 4-8 classroom program

- Emergency Management BC has developed the 'Master of Disaster', a free education classroom program designed to help young people learn about emergency preparedness. The program teaches youth in grades 4 to 8 about hazards in B.C and how they can get themselves and their homes prepared. Master of Disaster Program

Emergency Management Training provided by Emergency Management BC and the Justice Institute of British Columbia

- Courses are provided at no cost to participants, and intended for staff and volunteers from Indigenous communities and local governments who fill various roles during emergency and disaster response. Courses are available for emergency management, operations, communications, evacuations, and psychosocial resilience. Emergency Management Training

Communication



Emergency Management BC Social Media Toolkit

- Emergency Management BC has developed free social media toolkits for flooding. The flood ready content can be posted directly into Facebook or twitter channels. Emergency Management BC Social Media Toolkit

BC River Forecast Centre

- The River Forecast Centre predicts river flows and assesses flood risk to inform emergency managers and the public about upcoming streamflow conditions. River Forecast Centre

Resources for communities in the Chemainus Floodplain

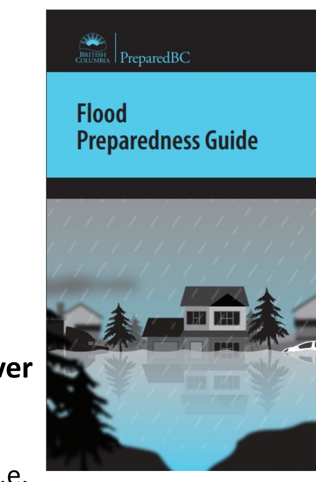
Planning

Municipality of North Cowichan Emergency Services website

- Considerations that community members can take before, during and after a flood: North Cowichan emergency services website

Emergency Management BC flood guide

- The flood guide outlines specific steps individuals can take to protect their home, property and family from flooding. A fill-in-the-blanks emergency flood guide is available at the following link: EMBC flood guide



Up to date flood mapping for the Chemainus River and Bonsall Creek floodplains

- The Cowichan Valley Regional District provides up to date flood mapping for the Chemainus River: Chemainus Flood Maps

Municipality of North Cowichan Interactive 200-year flood depth mapping tool for Chemainus River Floodplain

- This tool provides guidance to users on how high to construct temporary flood protection measures (i.e. sandbags) on protect their property. Interactive 200-year flood depth tool

Local Emergency Response Neighbourhoods Program

- Through participation in this program the Cowichan Valley Regional District provides neighborhood communities with information, training, and skills to be self-sufficient for a minimum of 7 days following a disaster: Local Emergency Response Neighbourhoods Program

Cowichan Alert

Communication

Cowichan Emergency Alert App

- Community members can subscribe to the Cowichan Valley emergency notification services App. This system informs subscribers of major emergencies or disasters in the Cowichan Region. Cowichan Emergency Alert App

Emergency Map BC

- This online mapping interface is overseen by Emergency Info BC and provides locations of current emergencies. It serves as a general reference for current public safety conditions during emergencies (floods, fires, landslides tsunami). Emergency Map BC

Strategy 2: Emergency Preparedness & response

Pillars of Emergency Preparedness Response

- Resources, Planning & Education
- Communication
- Warning and Monitoring
- Evacuation

Flood Warning and Flood Monitoring

Current Status

The River Forecast Centre uses the Chemainus Water Survey of Canada (WSC) gauge (08HA001) to inform flood forecasting and flood warnings for the area. During high flow events (February 1, 2020 and November 15, 2021), water spills from the right bank of the Chemainus River immediately upstream from the Highway 1 bridge. The overbank spill flows southward across the floodplain, through the Russel Farm Market and eventually passes under the Highway 1 crossing into Whitehouse Creek. Hydraulic analysis from the current study indicates bank overflow occurs when discharge at the WSC gauge exceeds 350-400 m^3/s. Flow losses up to 30 percent occur over the right bank prior to passing the WSC gauge.

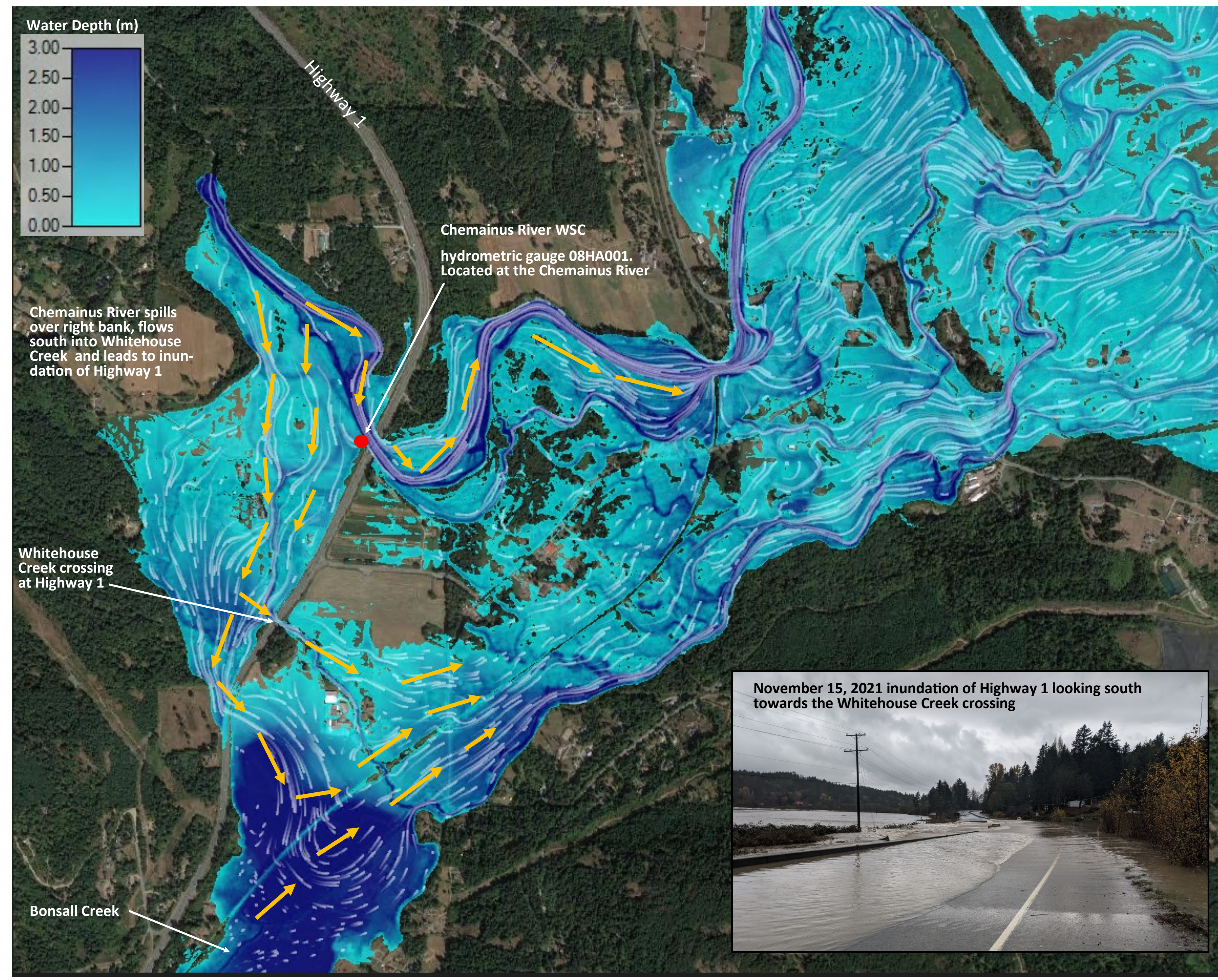
Under current conditions, the WSC gauge does not account for the fact that water spills out of the right bank before flood stage occurs. This results in a disconnect between when flooding actually happens and when the River Forecast Centre issues alerts. During the November 15, 2021 flood event, overbank spill lead to inundation and closing of Highway 1 between 8am-10am. The Chemainus River peak discharge occurred between 10am-12pm. The River Forecast Centre upgraded the alert for the Chemainus River from a flood watch to a flood warning at 2pm that afternoon.

Recommendations

Install real-time hydrometric stations on the Chemainus River and Bonsall Creek floodplains at the following locations to support flood warning and flood monitoring:

- **Upstream of the WSC gauge**: this gauge would need to be located upstream of where the bank spill occurs and be able to capture total river flow. This location would provide information about total river discharge that could support the River Forecast Centre in providing flood warning data for the Chemainus River.
- **Chemainus Road bridge or railway bridge**: this location would provide an indication of flood stage for the lower river reach near highly impacted residential areas.
- **Bonsall Creek at Westholme road:** this location would provide an indication of flood stage for the Bonsall Creek floodplain near impacted residential areas.

Inundation extents for the Chemainus River, Bonsall Creek and Whitehouse Creek during November 15, 2021 flood event



Strategy 2: Emergency Preparedness & Response

Pillars of Emergency Preparedness & Response

Resources, Planning & Education | Communication | Warning and Monitoring | Evacuation

Flood Timing and Evacuation

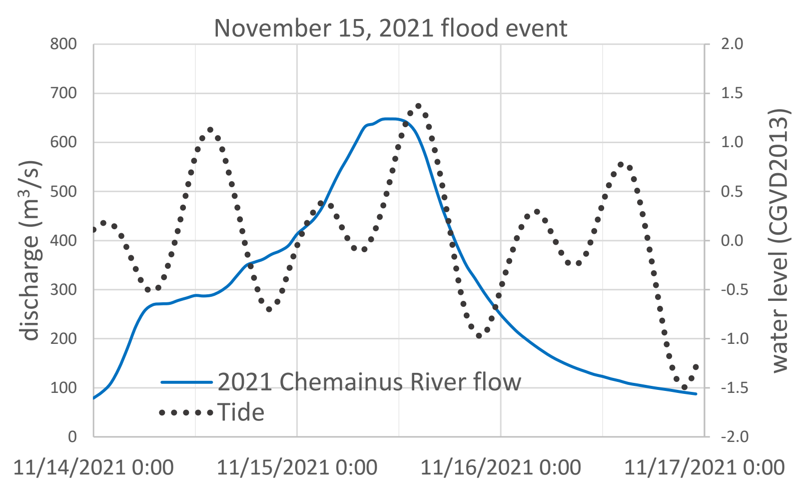
Which areas of Chemainus and Bonsall floodplains flood first?

It depends on the dominant flood mechanism, but in general a riverine flood with a high tide will flood the following areas in order of occurrence. Timestamps represent approximate timing of November 15, 2021 flooding.

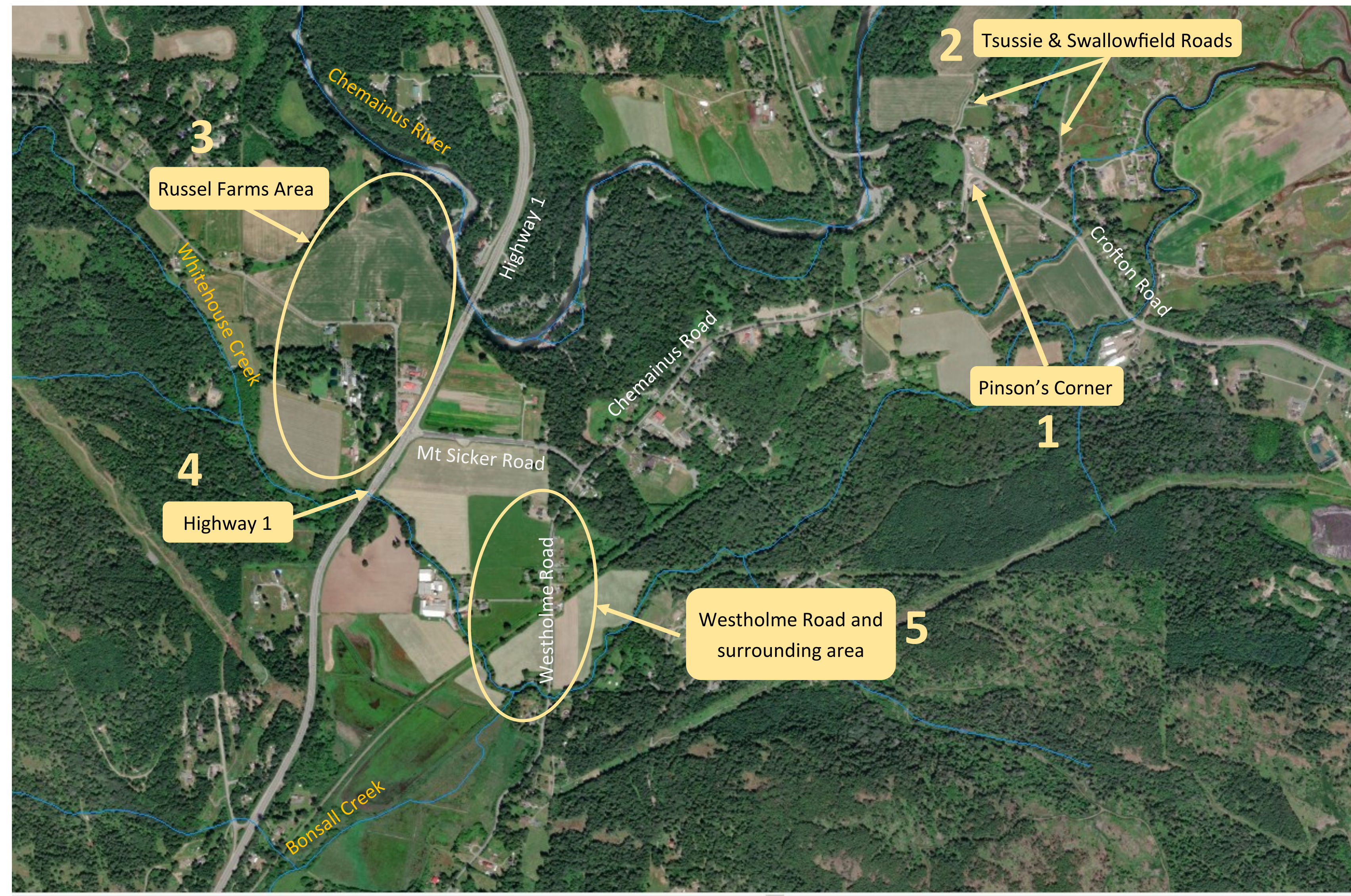
1. Pinson's Corner (intersection of Crofton Road and Chemainus Road, 01:45). Flooding in this area is caused by Chemainus River water overflowing its banks on river right into distributary side channels between the Railway Bridge and Chemainus Rd Bridge.
2. Tsussie & Swallowfield Roads. (02:15) Flooding in this area is from a combination of high tides and Chemainus River water flowing through distributary side channels.
3. Russel Farms Area (03:15): Chemainus River water spills from the right bank upstream of the Highway 1 bridge and flows south into Whitehouse Creek.
4. Highway 1 (04:30): Chemainus River water spills from the right bank and flows south into Whitehouse Creek. The Whitehouse Creek channel becomes overwhelmed and floodwaters inundate Highway 1 at the Whitehouse Creek crossing.
5. Westholme Road and area (04:45): Flooding in this area is from a combination of Chemainus River water from the Whitehouse Creek crossing and Bonsall Creek spilling its banks.

How long does flooding last?

Flood events on the Chemainus River typically rise and fall within 24 hours. The time in which it takes flood waters to drain depends on the tidal signal. February 1, 2020 and November 15, 2021 went from baseflow to peak and back to baseflow in 24 hrs.



Flood timing for the Chemainus River, Bonsall Creek and Whitehouse Creek



Evacuation Routes out of the floodplain

The main roads used for evacuation out of the floodplain are:

Crofton Road and Highway 1A | Chemainus Road | Highway 1 | Westholme Road | Mt Sicker Road

During a significant flood event, all evacuation routes out of the Chemainus River and Bonsall Creek floodplains can become blocked within 3 hours. Due to the very short response time, emergency preparedness plans and floodproofing measures need to be in-place before the start of the flood.

Floodproofing Overview

Strategy 3: Floodproofing

Floodproofing is a viable option for the residents of the Chemainus floodplain. It involves modifications directly to a structure to remove the risk of the flood reaching the inside of the structure but does not reduce the probability of flooding. Floodproofing of residential buildings is implemented to prevent damage, not to create usable space below the flood protection level. There are two categories for floodproofing a structure: **wet floodproofing** and **dry floodproofing**. Wet floodproofing allows flood waters to enter and drain out of the structure, and dry floodproofing prevents flood water from entering the structure (see images below).

Dry floodproofing can be temporary or permanent. Temporary measures are more suited to locations with long warning times (Fraser Basin Council, n.d.). Examples of Temporary and permanent floodproofing measures are listed below. Details on each of the methods are listed on the following pages.

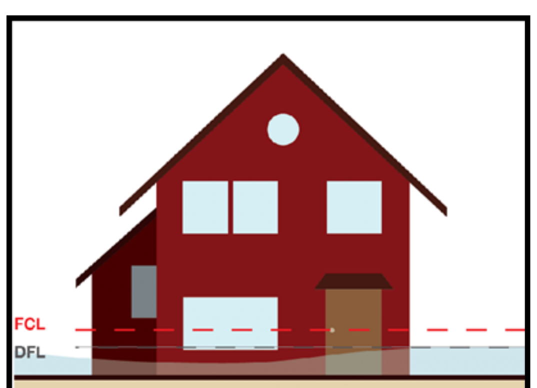
Permanent Methods of Floodproofing

- House Raising
- Constructing a ring dike

Temporary Methods of Floodproofing

- Sand bags to create barriers
- Removable gates and walls such as Floodstop Barriers, AquaFence, Flood Barricades, Water-Gate, and Tiger Dam

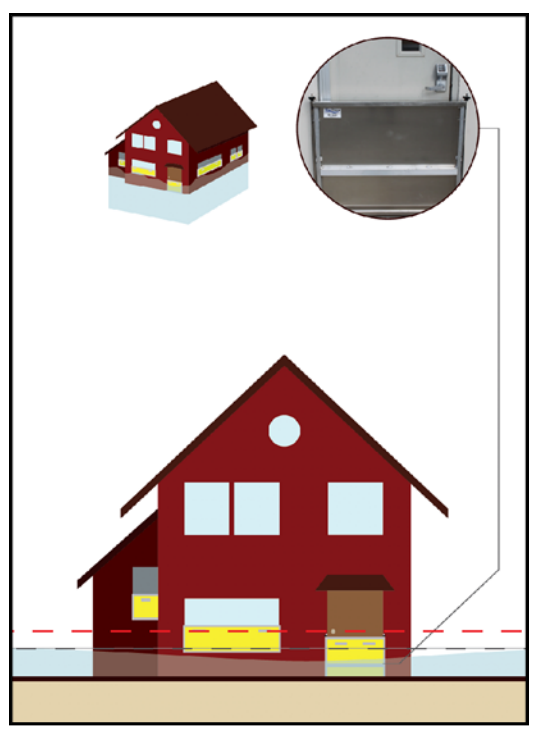
Existing Conditions



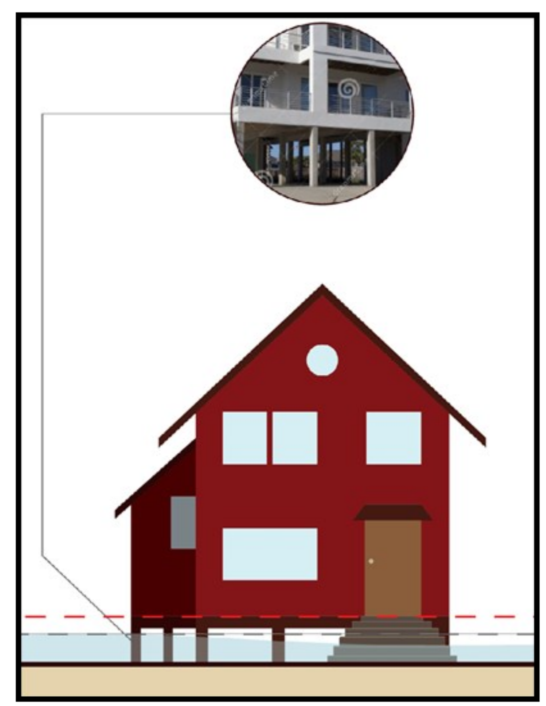
Source: Modified from Fraser Basin Council (n.d.)

FCL—Flood Construction Level (includes freeboard)
DFL—Design Flood Level

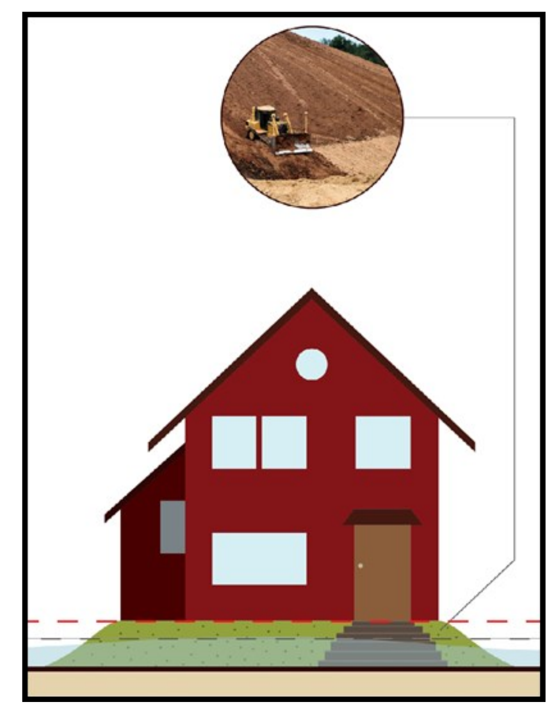
Dry Floodproofing
Door and window Barriers



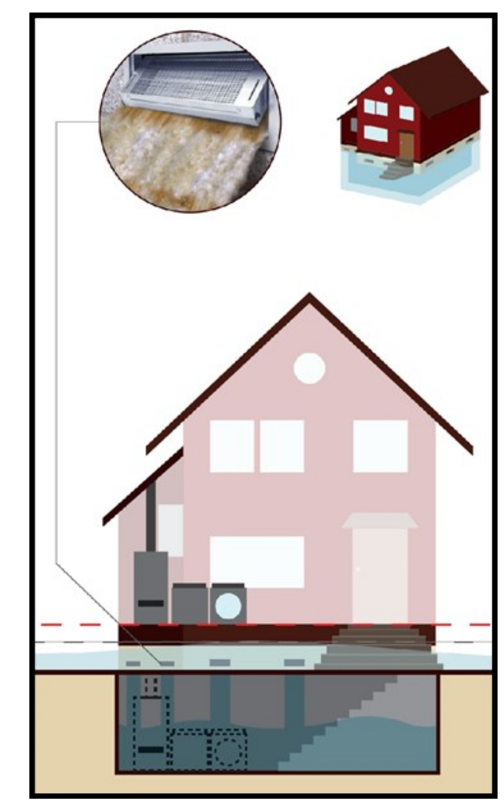
Dry Floodproofing
Raising Structure on Stilts / Supports



Dry Floodproofing
Raising Structure with Fill



Wet Floodproofing
Flooding permitted in Storage / non-living space



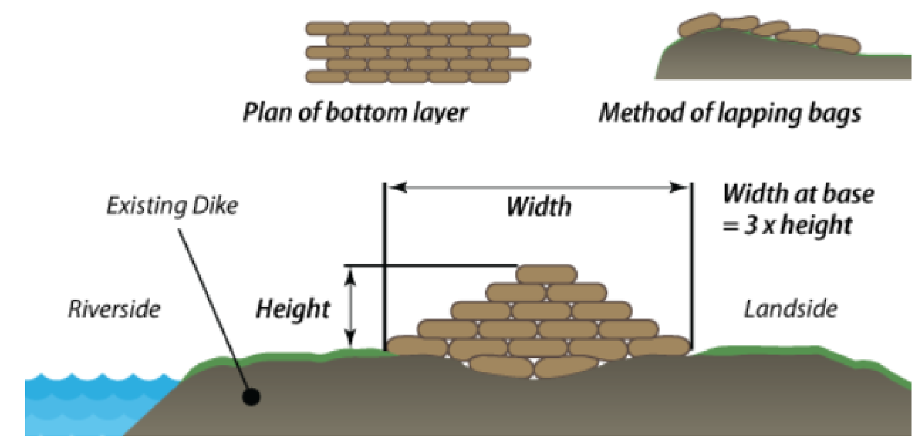
Temporary Floodproofing: Sandbagging

Sandbagging involves filling multiple sand bags with sand, silt or clay and layering them together to form a wall. It takes two people about one hour to fill and place 100 sand bags (roughly 1 foot high, 200 feet long wall).

Sand bags need to be placed on high ground as close as possible to your house. A bonding trench is dug, and then sand bags are layered in reversing direction (lengthwise then crosswise). They don't need to be tied off, just pressed firmly in place.

Bags required per 100 linear feet of dike:

Height above dike	Bags required
1/3 metre	600
2/3 metre	2,000
1 metre	3,400



Source: Province of BC, n.d.

Pros

+ **Low cost**. Local governments may cover the cost of sand bags for flood protection. Costs are low compared to other options for floodproofing.
+ **Tested and proven floodproofing method**. Alternative measures are more recent developments with less (sometimes minimal) real world testing.
+ **Accessible to most everyone**. Most people able to use a shovel can fill a bag and eventually have enough for floodproofing. Anyone outside this category is able to be aided by someone else.

Cons

– **Not environmentally friendly.** Countless tonnes of sandbag sand is sent to landfill, or improperly used; people are advised not repurpose sand from sandbags, since there could be waterborne maladies, which the bags were sitting in. Sand bags can only be used for a single flood season.

– **Time consuming to create**. To protect against 0.3m of flood depth for a length of 30 m, approximately 600 bags are required according to the Province of BC (n.d.). Peak discharge on the Chemainus River can occur within hours of a large storm event, leaving little time to construct protection.

– **Heavy/labour intensive**. Each sandbag weighs approximately 18 kg (40 lbs), and creating a barrier will require hundreds to thousands of bags. This quickly becomes infeasible for a single person preparing for an imminent flood.

– **Suitable to flood depths less than 1 m**. When flood depths approach or exceed 1 m, this method becomes infeasible.


Source: Massier, 2009

Assessment of Strategy

Sandbagging is an effective emergency measure of flood proofing. It can be deployed relatively quickly with materials that are typically readily available or can be obtained quickly. Enough warning is still required to be able to employ this method effectively but when given, this is a reliable flood proofing option for the Chemainus floodplain. However, its not suitable for deep areas of which there are many on the Chemainus floodplain or where there is expected to be high velocities.

Temporary Floodproofing: Walls

Temporary Floodproofing: Walls

FloodStop Barriers

A private company that provides flood protection in the form of plastic barriers that lock together.

- Reusable and Recyclable
- Able to be assembled by a single person
- Self balancing (no bolting required)
- Available heights range from 0.6 m—0.9 m
- Possibly cheaper than sandbags. Request quotes for specific needs
- Quicker deployment than using sandbags

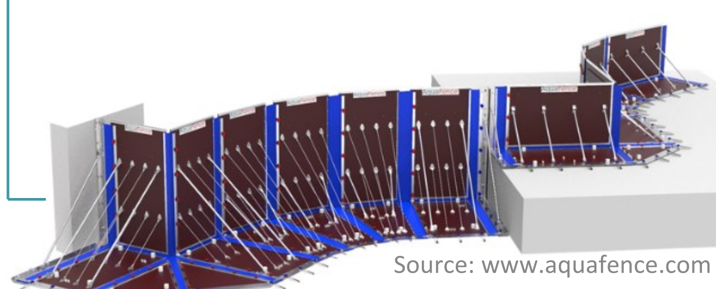
Source: floodstopbarrier.com

AquaFence

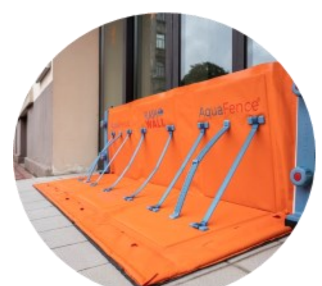
Is another company that supplies flood protection in the form of walls. Their products include the FloodWall, FlashWall and FloodBarricade

1. FloodWall

- Reusable - certified for 60+ deployments
- Moderately quick to install, depending on desired length to protect. Faster than using sandbags
- Multple Heights ranging from 0.75 m—2.7 m
- Anchoring to hardscape is recommended
- Debris shield attachment available
- Best for perimeter protection



Source: www.aquafence.com

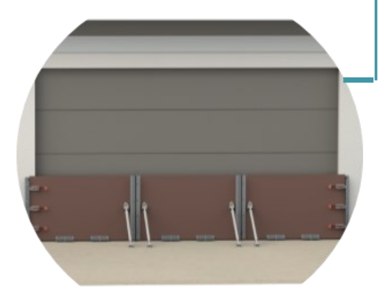


2. FlashWall

- Able to lay flat for minimal disruption once installed; extend to full height when flooding is imminent
- Aimed towards shorter length for protection
- Able to be assembled by a single person
- Light weight and compact storage
- Quick and easy to install
- Available height: 0.5 m
- Reusable

3. FloodBarricade

- Reusable and eco friendly - made from surplus FloodWall materials
- No standard height/length (tailored to fit opening)
- Quick and easy to install (approx. 3 minutes per panel
- Able to be assembled by a single person



How applicable is are these for the Chemainus Floodplain?

Flood Depth Classes	Are FloodStop Barriers Suitable?	Notes
0 to 0.1 m	Yes	Method may be excessive
0.1 to 0.3 m	Yes	Good use
0.3 to 0.5 m	Yes	Good use
0.5 to 1.0 m	Possibly	Alternative options may be better suited
1.0 to 2.0 m	No	Flood depths exceed structure height.
> 2.0 m	No	

Flood Depth Classes	Is AquaFence Suitable?	Notes
0 to 0.1 m	Yes	Method may be excessive
0.1 to 0.3 m	Yes	FlashWall or FloodBarricade
0.3 to 0.5 m	Yes	Any AquaFence option
0.5 to 1.0 m	Yes	Flood Wall or FloodBarricade
1.0 to 2.0 m	Yes	Flood Wall is best option
> 2.0 m	Yes	

Assessment of Strategy

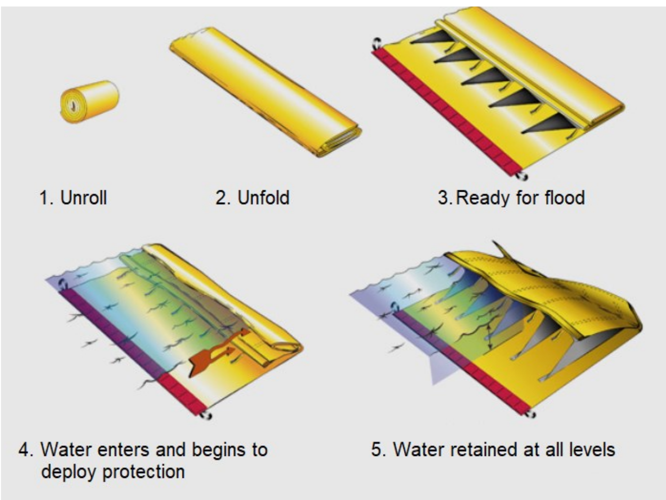
Both temporary floodproofing methods can work for the residents located in the Chemainus Floodplain. The FloodStop barriers work well for anything under 0.5 m of water but over that, they are not suitable. Similarly, the AquaFence can be used for most depths but it would require considerable time and preparation for deeper water.

Temporary Floodproofing: Large Structures

Temporary Floodproofing: Large Structures

Water-Gate

- Reusable - stated to be greater than 20 years
- Assembly by two people
- Self stabilizing (no bolting required)
- Flood protection up to 2 m
- Quicker deployment than using sandbags. A straight length of 100 m can be deployed in 5 minutes with 2 people.
- Light weight
- Structure self deploys - as flood water encounters the Water-Gate, it seeps into its cells and rises with the water levels
- Low maintenance and easy repair
- Resistant to debris impacts



Source: megasecur.com

Tiger Dam

- Significant water requirement— water filled bladder technology
- Dams fill quickly and without need for heavy equipment
- Each 0.46 m Tiger Dam weighs 23 kg dry, and approx. 2800 kg when filled. The Tiger Dam must be in the desired location prior to filling
- Flood protection stackable up to 9.7 m. Individual heights range from 0.46 m — 1.1 m.
- Resistant to debris impacts and roll up for easy storage
- Reusable; technology used in Abbotsford flood, 2021

Source: usfloodcontrol.com

How Applicable is Water-Gate for the Chemainus Floodplain?

Flood Depth Classes	Is a Water-Gate Suitable?	Notes
0 to 0.1 m	No	Likely not enough water for protection to deploy
0.1 to 0.3 m	Yes	Method may be excessive
0.3 to 0.5 m	Yes	Good use
0.5 to 1.0 m	Yes	Good use
1.0 to 2.0 m	Possibly	Flood depths exceed safety threshold. Flood depths at or above structure height (2 m).
> 2.0 m	No	

Assessment of Strategy

Both temporary floodproofing methods can work for the specific residents located in the Chemainus Floodplain. They are not suitable for many of the residents where there is deep or fast moving water. The Water-Gate barrier works well for anything under 1.0 m of water, can be put together by just two people and has a simple setup. The Tiger Dam can be used reliably for most depths as it is stackable and can extend long distances. However, it would require water to inflate and considerable time and preparation for deeper water.

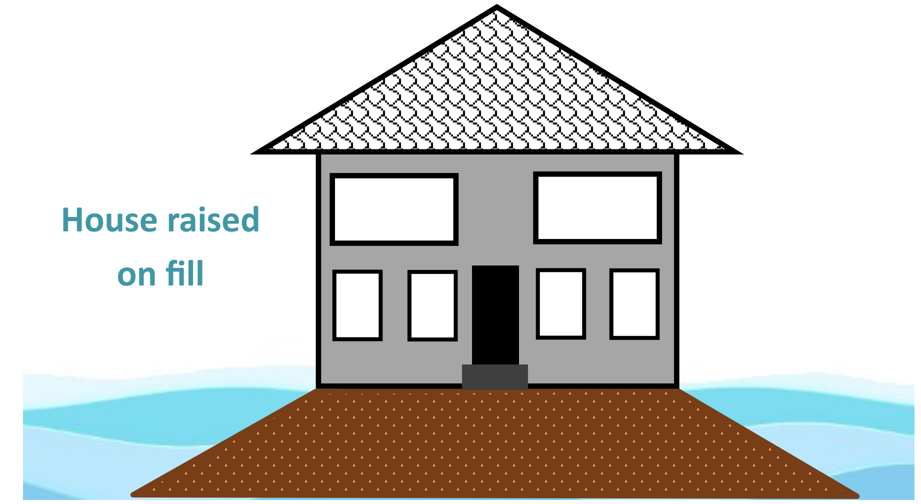
How Applicable is a Tiger Dam for the Chemainus Floodplain?

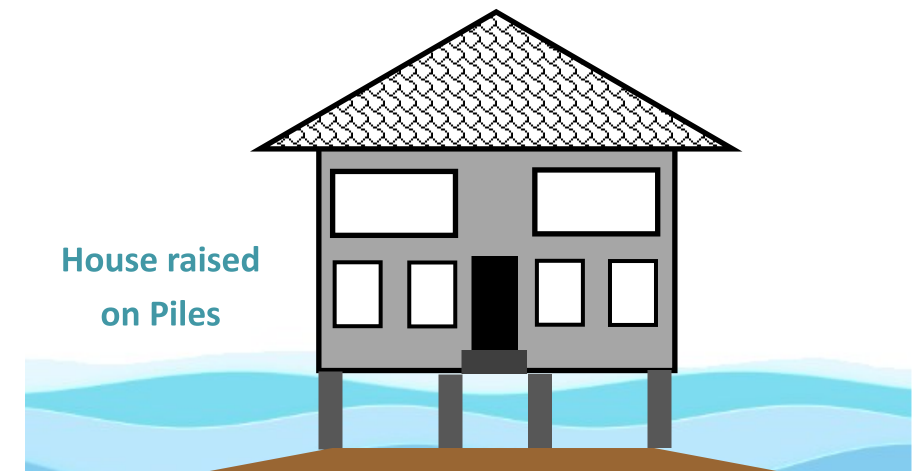
Flood Depth Classes	Is a Tiger Dam Suitable?	Notes
0 to 0.1 m	No	Method may be excessive
0.1 to 0.3 m	Yes	Good use
0.3 to 0.5 m	Yes	Good use
0.5 to 1.0 m	Yes	Good use
1.0 to 2.0 m	Yes	Flood depths exceed safety threshold.
> 2.0 m	Yes	

Permanent Floodproofing: House Raising

House raising involves removing the building from the foundation and elevating it, typically either using fill or piles. This method is aimed at detached homes and is less common for industrial buildings (e.g., rec centers, community halls, churches, schools, malls, etc.). Prior to raising the structure, the allowable zoned building height should be determined (LIDA Homes, n.d.). If the structure is to be raised above the zoned tolerance, this option may not be feasible. If the local authority will allow an exception, special permitting would likely be required to continue.

To avoid flood damage to the house, the living space should be elevated above the flood construction level set by the local government. The space below this elevation could be used for closed storage, such as a basement or garage, could be left open to allow free flowing water and reduce hydraulic forces on the structure, or the building could be elevated on fill with no space below the living space.





Pros

+ **Tested, proven and robust floodproofing method**. This technique is used world wide to avoid issues caused by flooding.
+ **Less need for relocation**. People in areas where flood depths are above 1 m should consider relocating for safety, rather than raising the house. House raising is beneficial where flood depths are anticipated to be below 1 m.

Cons

– **Potential for stranding during floods**. While this form of flood protection allows residents to remain in their houses during a flood, there is the potential of becoming trapped inside until the flood water recedes.

– **Costly**. Cost is dependent on house condition, footprint area, and how high it is to be raised. House raising starts around $80,000. Individual quotes are recommended for practical estimates . Additional costs could be required for updating house foundation to todays standards, any internal repairs due to shifting during the process, and possible requirement for structural reinforcing afterwards.

– **Inconvenient during the process.** This option for floodproofing will require multiple trades and building permits, and will require an alternative place to stay during the raising process.

– **Floodproofing for house, not property**. Any structures not raised would be impacted by flooding

Flood Depth Classes	Is House Raising Suitable?	Notes
0 to 0.1 m	No	Excessive. Unnecessary expense
0.1 to 0.3 m	No	Excessive. Unnecessary expense
0.3 to 0.5 m	Yes	Good use. Raising on fill is an option
0.5 to 1.0 m	Yes	Good use. Raising on fill is an option
1.0 to 2.0 m	Yes	Flood depths exceed safety threshold. Raising on fill is not a practical option.
> 2.0 m	Yes	

Assessment of Strategy

House raising is a viable and reliable strategy for the Chemainus floodplain. It removes the risk of flood damage and allows for people to maintain properties in the floodplain. It allows people to shelter in place during a flood and not risk evacuation if it is not safe to do so. It is one of the best options for floodproofing for the Chemainus floodplain given the relative short duration of flooding. However, it is costly to implement and depends on the house condition.

Permanent Floodproofing: Ring Dikes

Permanent Floodproofing: Ring Dikes

A ring dike is a dike that is built around the perimeter of an area intended for flood protection. These can be temporary and quickly built/removed using materials such as sand bags, or they can be permanent, with engineered designs to withstand up to a certain return period flood event. These can be constructed around primary residence, around an entire property, or around a larger area to provide protection to multiple properties.

To avoid flood damage, the crest of the dike should be constructed above anticipated flood levels. Additional constructed height (freeboard) of 0.3 m above flood levels is recommended. Ring dike structures can easily be combined with other flood protection works such as house raising, or constructing new builds on raised surfaces.

Ring Dike — Cons

- **Potential for stranding during floods**. While this form of flood protection allows residents to remain in their houses during a flood, there is the potential of becoming trapped inside until the flood water recedes.
- **Costly**. Cost is dependent on length and height of constructed dike. Professional designs will be necessary.

Ring Dike — Pros

- **Tested, proven and robust floodproofing method**. This technique is used world wide to avoid issues caused by flooding.
- **Less need for relocation**. People in areas where flood depths are above 1 m should consider relocating for safety, rather than constructing a dike. Ring dikes are beneficial where flood depths are anticipated to be below 1 m.
- **Dike can be constructed to protect whole property**. Rather than just the primary residence, out buildings can also be protected

Flood Depth Classes	Is a Ring Dike Suitable?	Notes
0 to 0.1 m	Yes	Good use. minimal engineering required
0.1 to 0.3 m	Yes	Good use. minimal engineering required
0.3 to 0.5 m	Yes	Good use. Engineering required
0.5 to 1.0 m	Yes	Good use. Engineering required
1.0 to 2.0 m	Possibly	Flood depths exceed safety threshold.
> 2.0 m	No	

Assessment of Strategy

Ring dikes only have a limited use for the Chemainus floodplain. It does reduce the risk of flood damage and allows for people to maintain properties in the floodplain, however they can locally transfer flood risk to neighbors and are subject to all the risks associated with a dike, including breaching. Additionally, if they overtop, they can trap flood water behind the dike unless pumps are used to remove the water or drains are installed. They are relatively costly to implement and require significant space around your house to build.

Source: Lambert (2019)

Strategy 4: Structural Mitigation

Structural Strategies

1. Dike upstream of Hwy 1

Dike from high ground to the highway and prevent spill of the Chemainus River into Whitehouse and Bonsall Creek

2. Dike Upstream and downstream of Hwy 1 continuing to Chemainus Rd

Continue the dike downstream of the highway setback from the river through Halalt FN, tie into the E&N Rail Embankment and wrap around Pinsons Corner to tie into Hwy 1a or Chemainus Rd Bridge.

3. Remove Blockages from floodplain

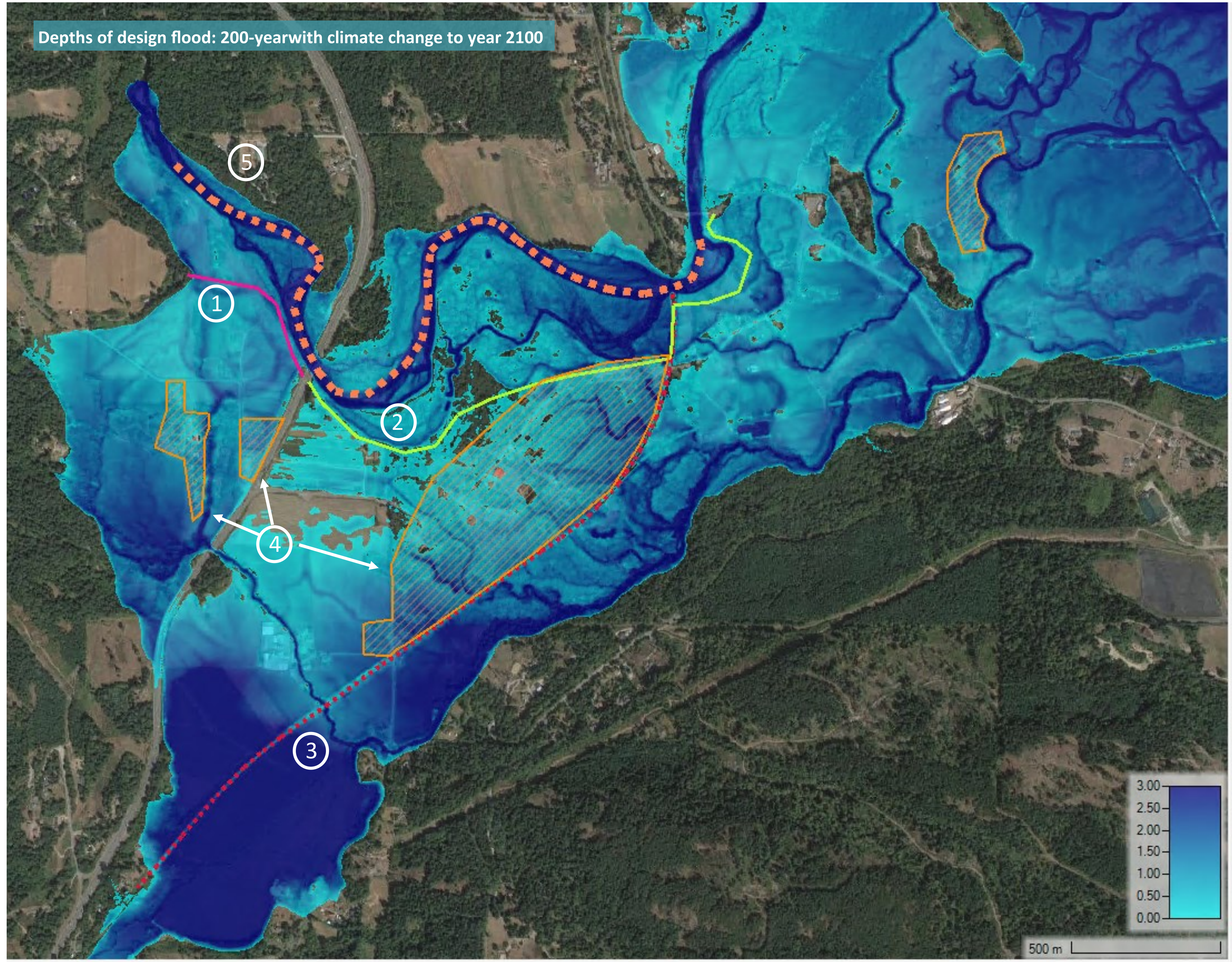
Remove the E&N railway embankment from the floodplain

4. Ring Dikes

Build ring dikes around small gatherings of houses or communities such as those off Mt Sicker Rd, Halalt First Nation, area near Westholme, Tsussie First Nation.

5. Increase Conveyance of Chemainus River

Dredge 100,000 m3 of sediment over 4km of the Chemainus River from just downstream of the canyon to Chemainus Rd.



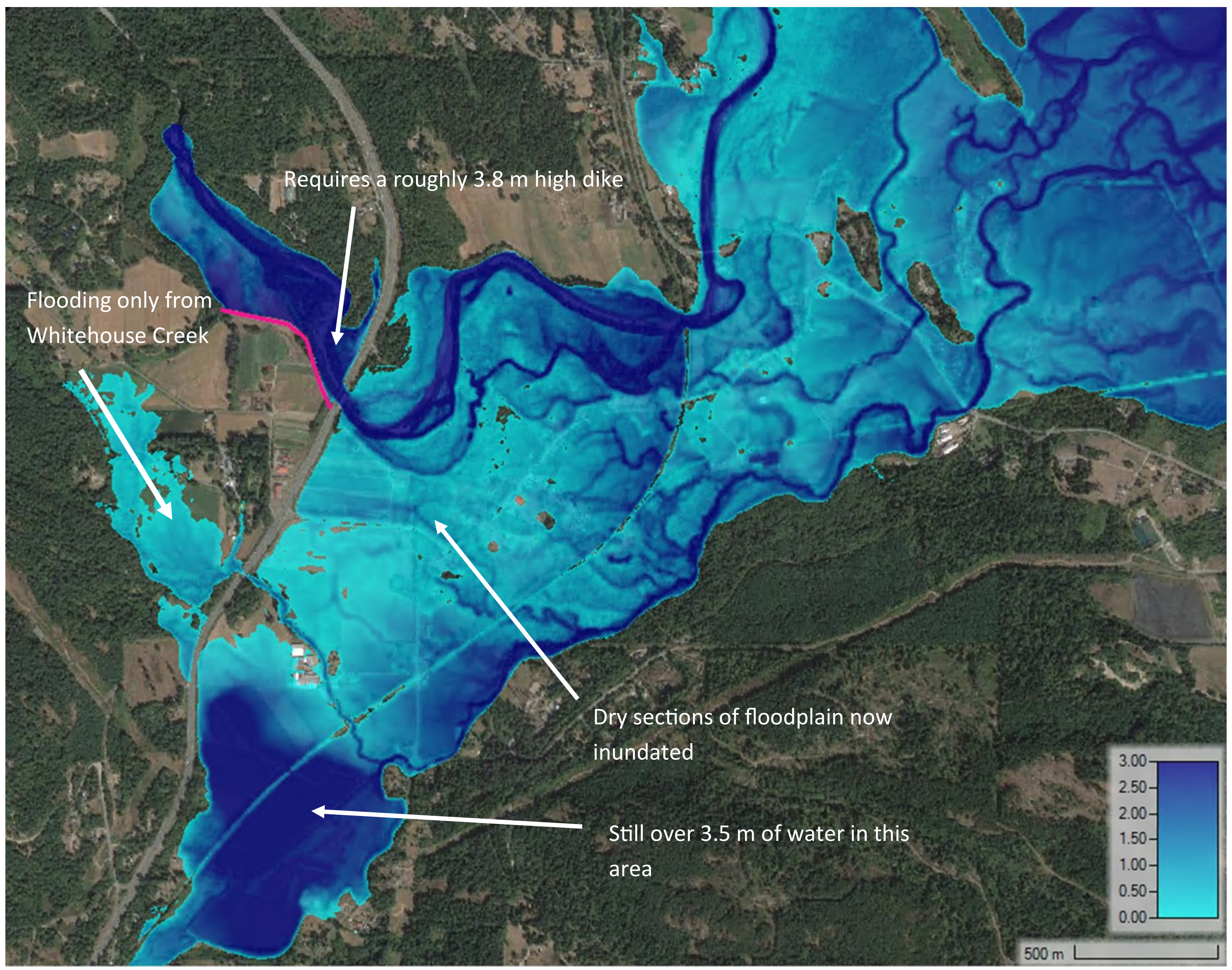
These are not designs, these are conceptual mitigation options that were suggested by the public and investigated by simulating each scenario to maximize the potential effect of each measure. This was done in order to demonstrate whether they were effective or not. Conceptual mitigation measures would need to be modified substantially to produce final mitigation solutions.

Structural Mitigation 1: Diking upstream of Hwy 1

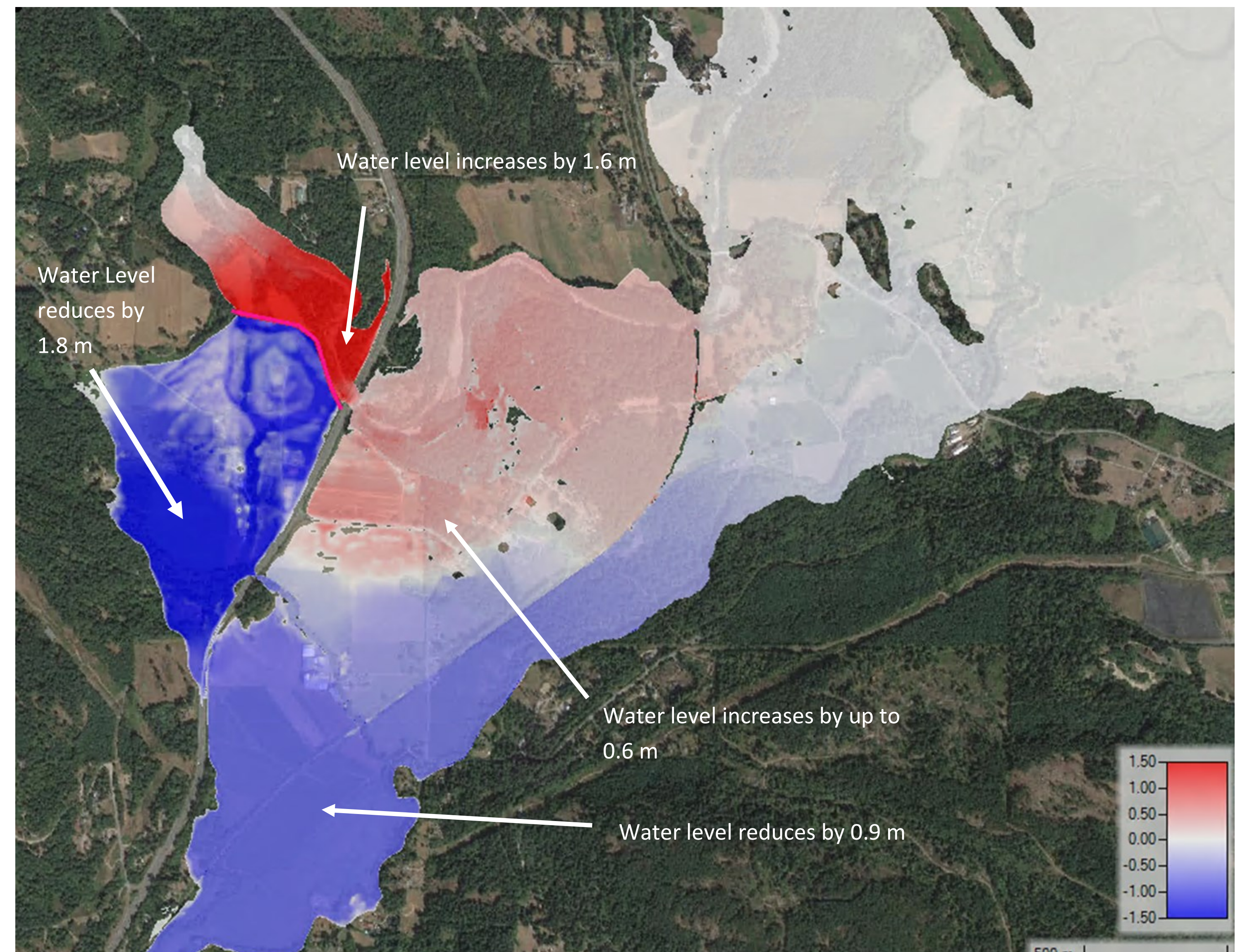
Description

Dike from high ground to the highway and prevent spill of the Chemainus River into Whitehouse and Bonsall Creek

Diking upstream of Hwy 1 prevents water from spilling into the Whitehouse Creek floodplain and from spilling over the highway. It reduces the overall water level on the Bonsall floodplain as well by 0.9 m. However it raises the water level behind the dike by approximately 1.6 m and it puts more water on the floodplain just downstream of the bridge. The transfer of the flood risk to the downstream side of Hwy 1 bridge violates the principles of flood management. This mitigation would require a roughly 3.8 m high dike on average (with sections reaching 4.4 m high). The cost of this dike is expect to be on the order of $6 million to construct. Additionally, over time the dike will increase the degree of channel incision into the floodplain, disconnecting the mainstem channel from floodplain channel habitat and affecting hyporheic aquifer. Reduced overbank flows will also starve the floodplain from natural floodplain building processes.



Depths of design flood with mitigation: diking upstream of Hwy 1 applied in metres.



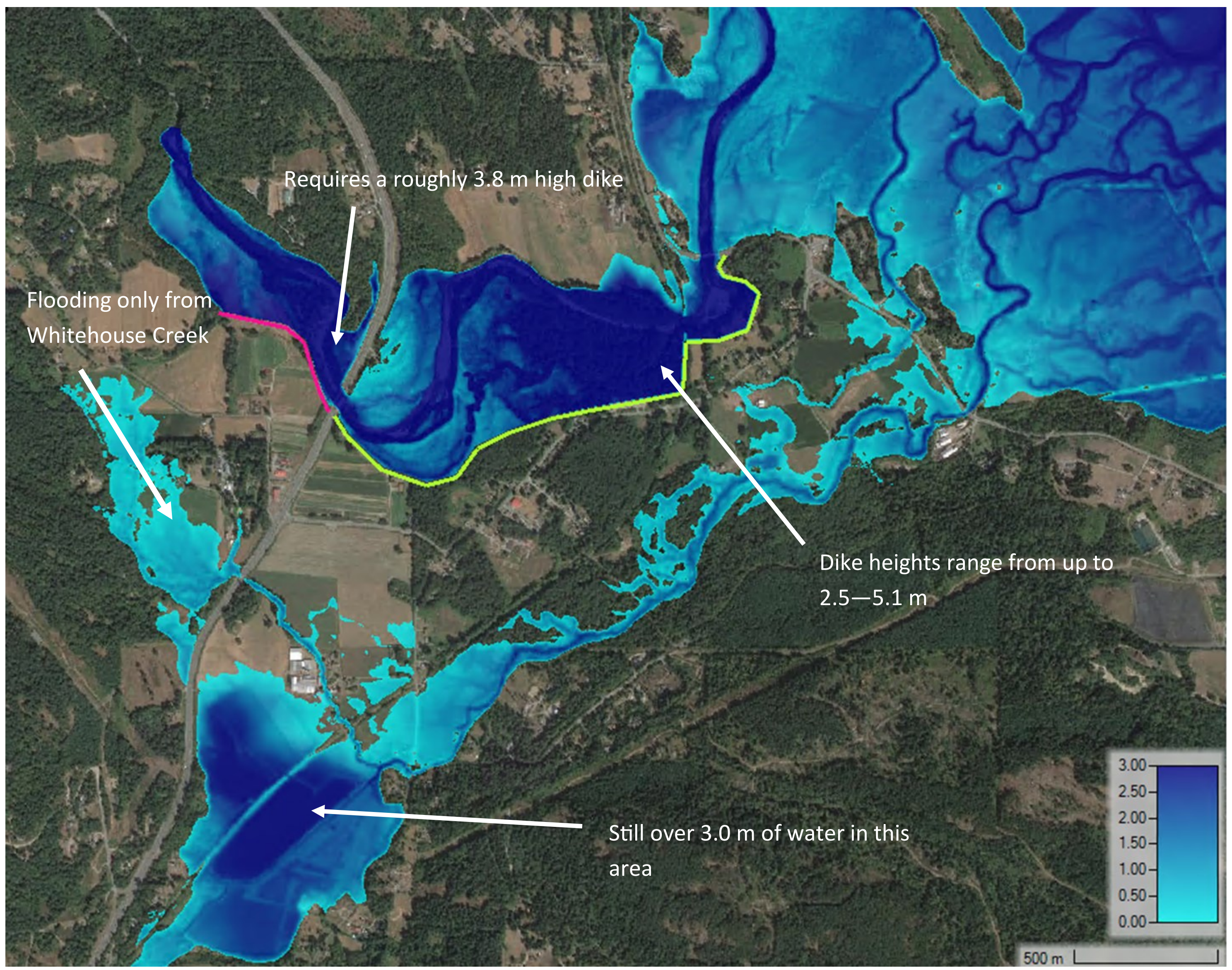
Difference between design flood and mitigation: Diking upstream of Hwy 1 in metres.

Structural Mitigation 2: Diking Downstream of Hwy 1 to Crofton Rd

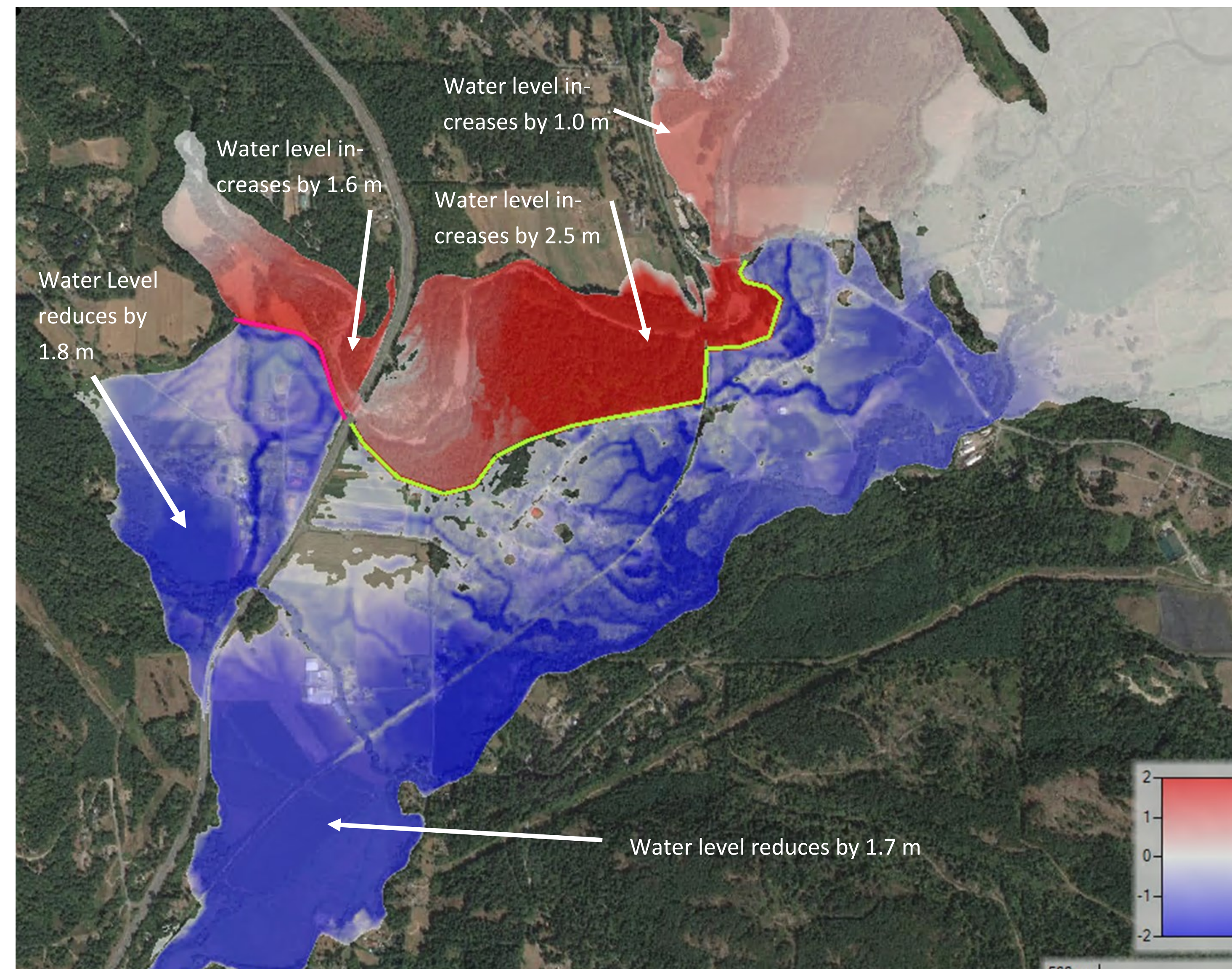
Description

Continue the dike downstream of the highway setback from the river through Halalt FN, tie into the E&N Rail Embankment and wrap around Pinsons Corner to tie into Hwy 1a or Chemainus Rd Bridge

Diking downstream of Hwy 1 in combination with the upstream dike prevents water from spilling into the Whitehouse Creek floodplain and from spilling over the highway. It reduces the overall water level on the Bonsall floodplain, removes water from the Chemainus floodplain down to Chemainus Rd and Pinson's corner. However it raises the water level behind the dike by approximately 1.6 m at Hwy 1, 2.5 m at the rail bridge and it puts more water on the floodplain just downstream of the Hwy 1a bridge. The transfer of the flood risk to the downstream side of Hwy 1a bridge violates the principals of flood management. It would require a roughly 3.5 m high dike on average (with sections reaching 5.1 m high). The cost of this dike is expect to be in the order of $24 million to construct. Additionally, over time the dike will increase the degree of channel incision into the floodplain, disconnecting the mainstem channel from floodplain channel habitat and affecting surface to ground water interaction. Reduced overbank flows will also starve the floodplain from natural floodplain building processes.



Depths of design flood with mitigation: diking downstream of Hwy 1 to Crofton Rd applied in metres.



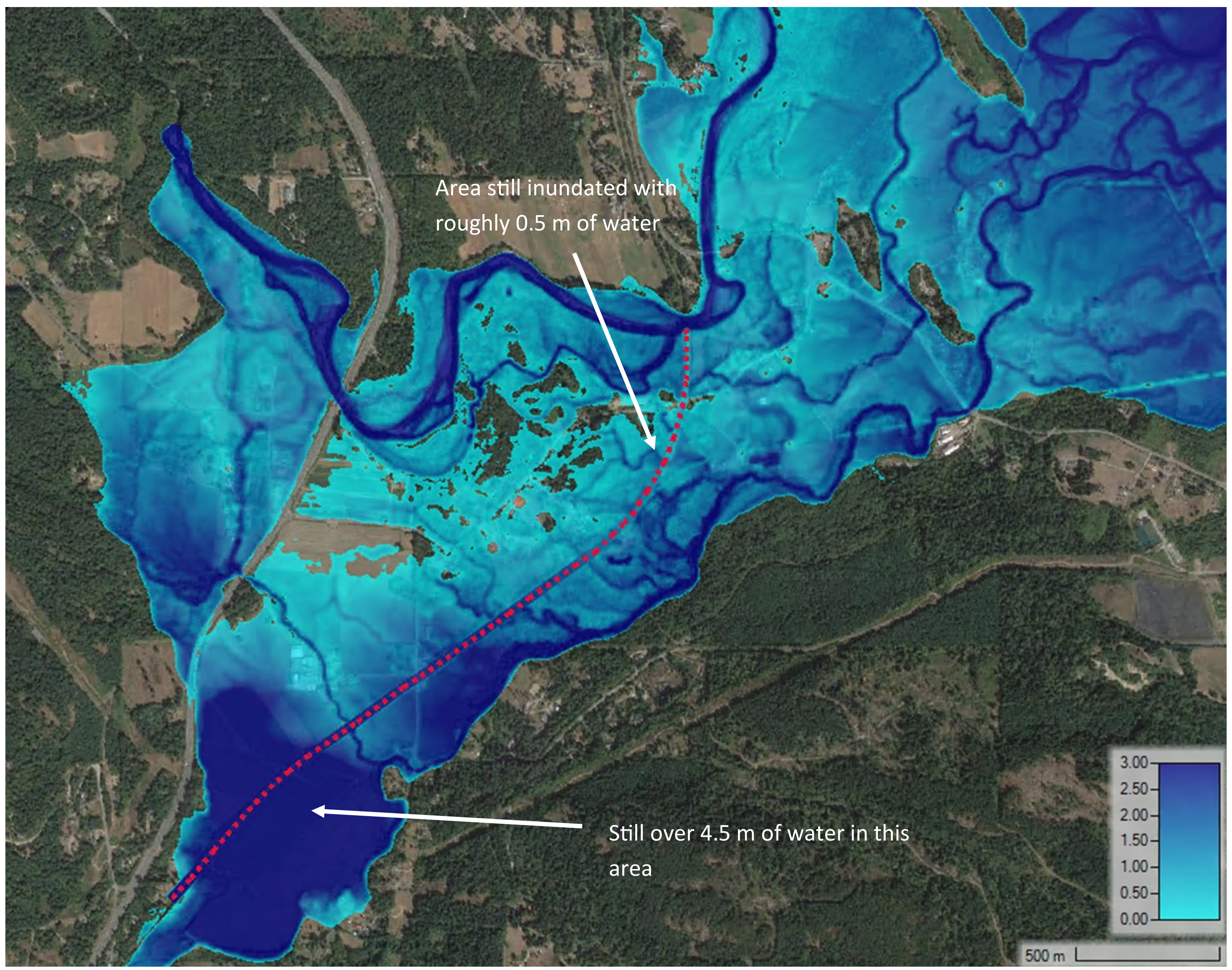
Difference between design flood and mitigation: diking downstream of Hwy 1 to Crofton Rd in metres.

Structural Mitigation 3: Removal of E&N Rail Embankment

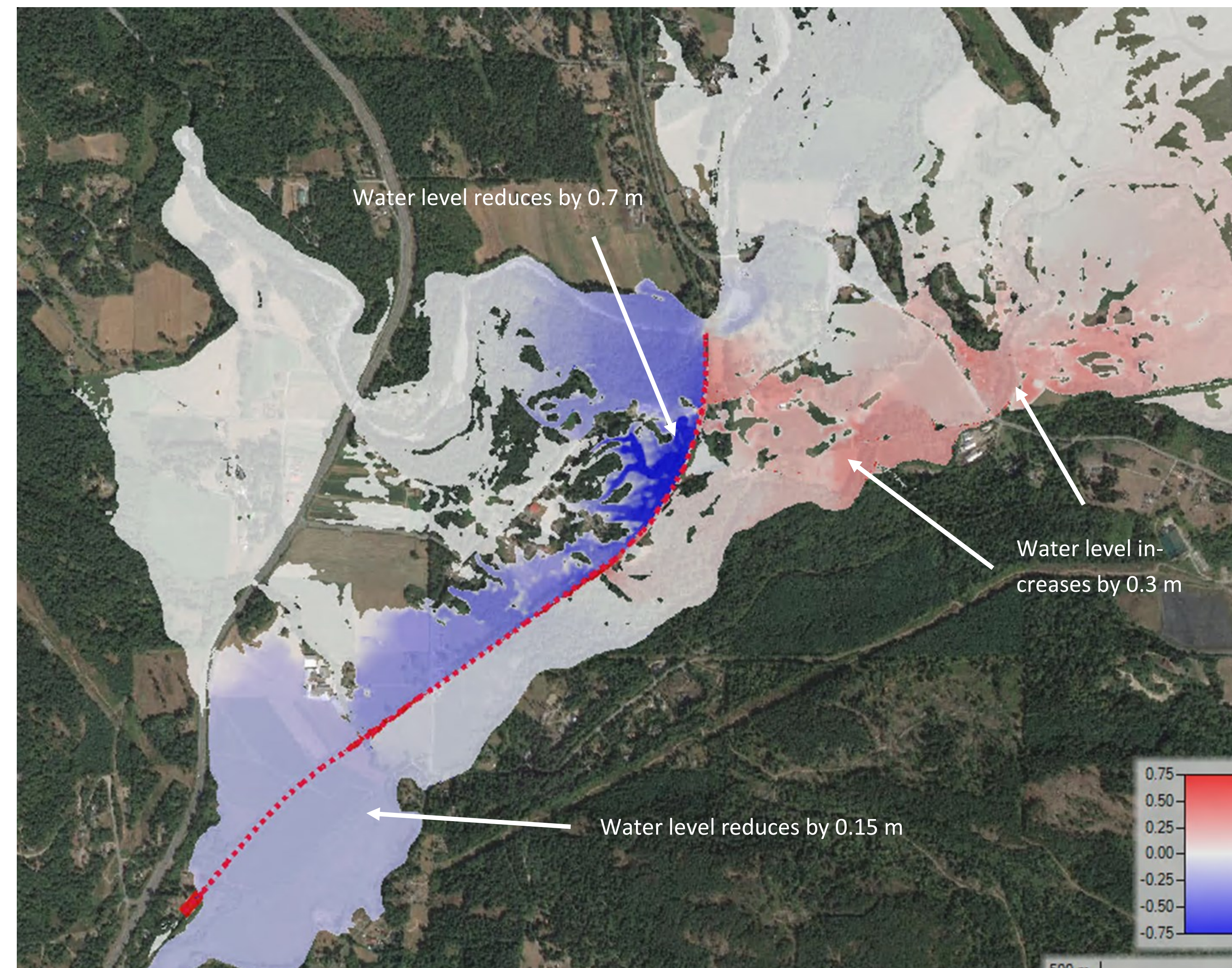
Description

Remove the E&N railway embankment from the floodplain

Removing the E & N Railway embankment would increase food conveyance through the floodplain and move toward re-naturalization of the floodplain. It would restore some of the floodplain channel connectivity that was cut off. It would decrease the flood levels upstream of the embankment but increase some of the flood levels downstream toward Tsussie. Additionally, the embankment currently serves as an emergency egress route for those within the floodplain who can access it during a flood. Therefore, flood mitigation benefits are very limited. Furthermore, it would remove an evacuation route that could be accessed by those trapped in the floodplain.



Depths of design flood with mitigation: removal of blockages applied in metres.



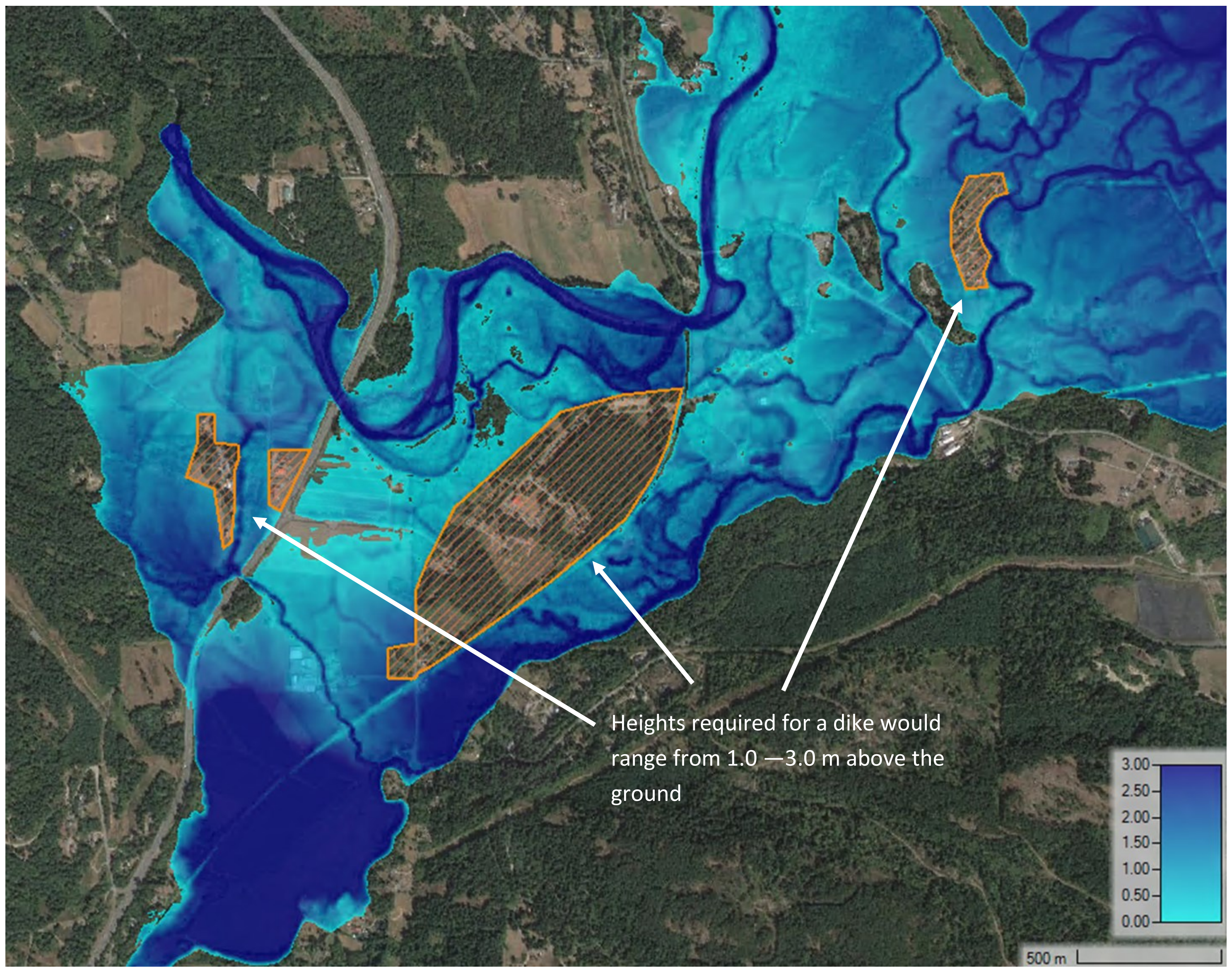
Difference between design flood and mitigation: removal of blockages applied in metres.

Structural Mitigation 4: Ring Dikes

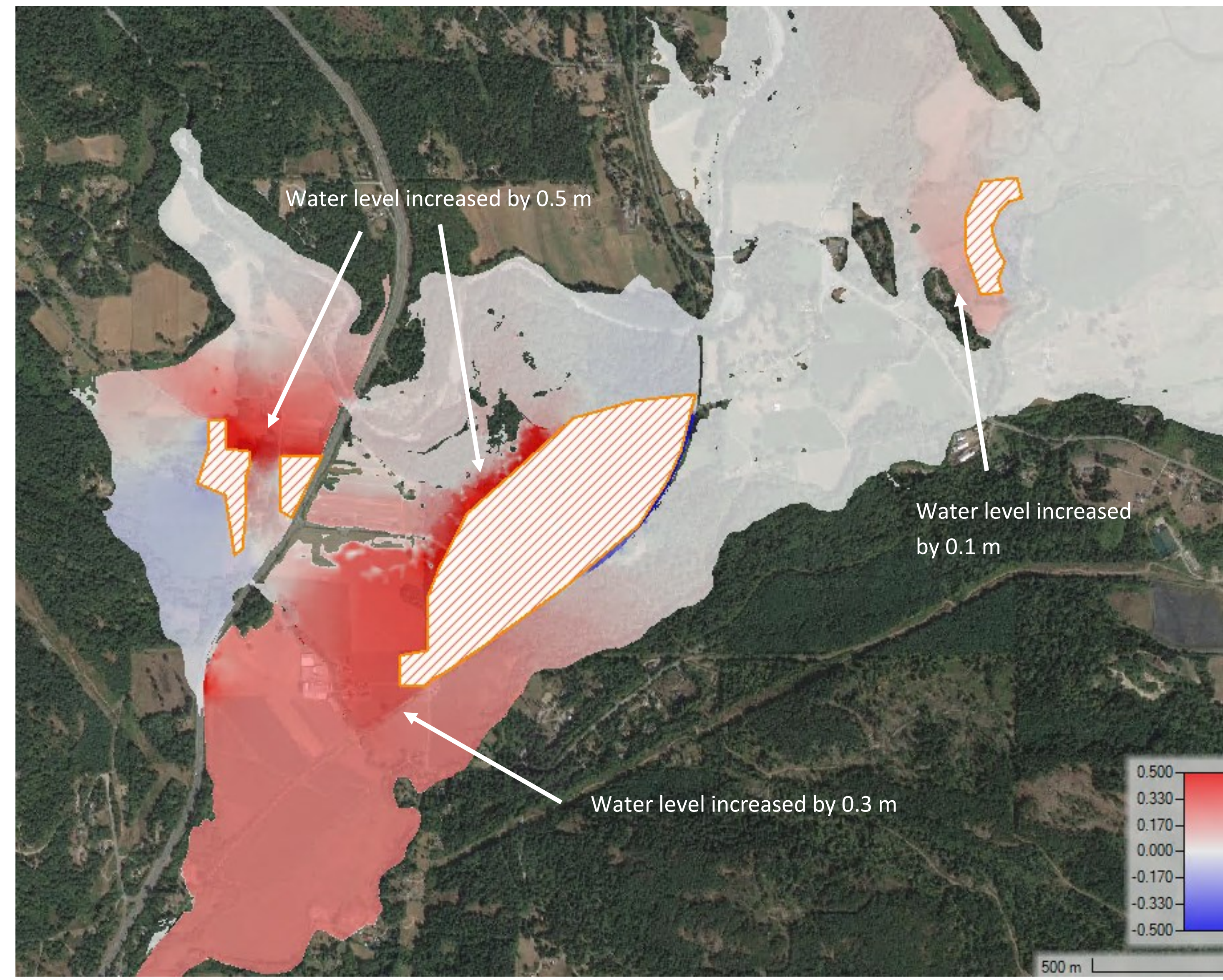
Description

Build ring dikes around small gatherings of houses or communities such as those off Mt Sicker Rd, Halalt First Nation, area near Westholme, Tsussie First Nation.

Ring dikes installed around communities or groupings of houses on the floodplain would protect some of the populated areas of the floodplain. However, as with the dikes along the river, local dikes still reduce conveyance and increase the flooding around them transferring the flood risk. It raises the water level immediately next to the structures by roughly 0.5 m. The ring dikes do not reduce the flood construction level and are dangerous if overtopped. The water becomes trapped behind the dike within the community or houses and cannot drain away without pumps or additional infrastructure. They can expensive to build and require space around the properties.



Depths of design flood with mitigation: ring dikes around communities in metres



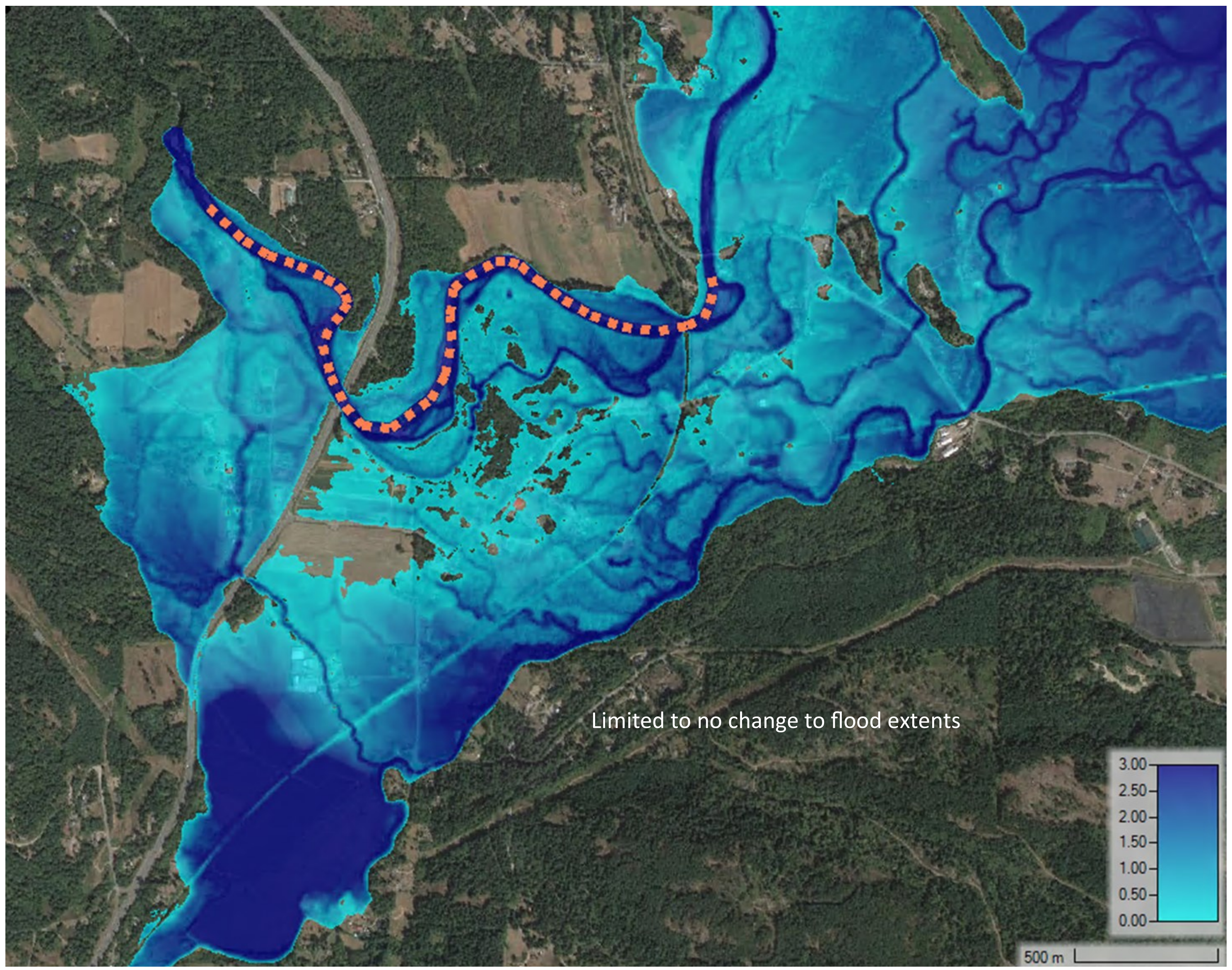
Difference between design flood and mitigation: ring dikes around communities in metres

Structural Mitigation 5: Gravel excavation to Increase Conveyance

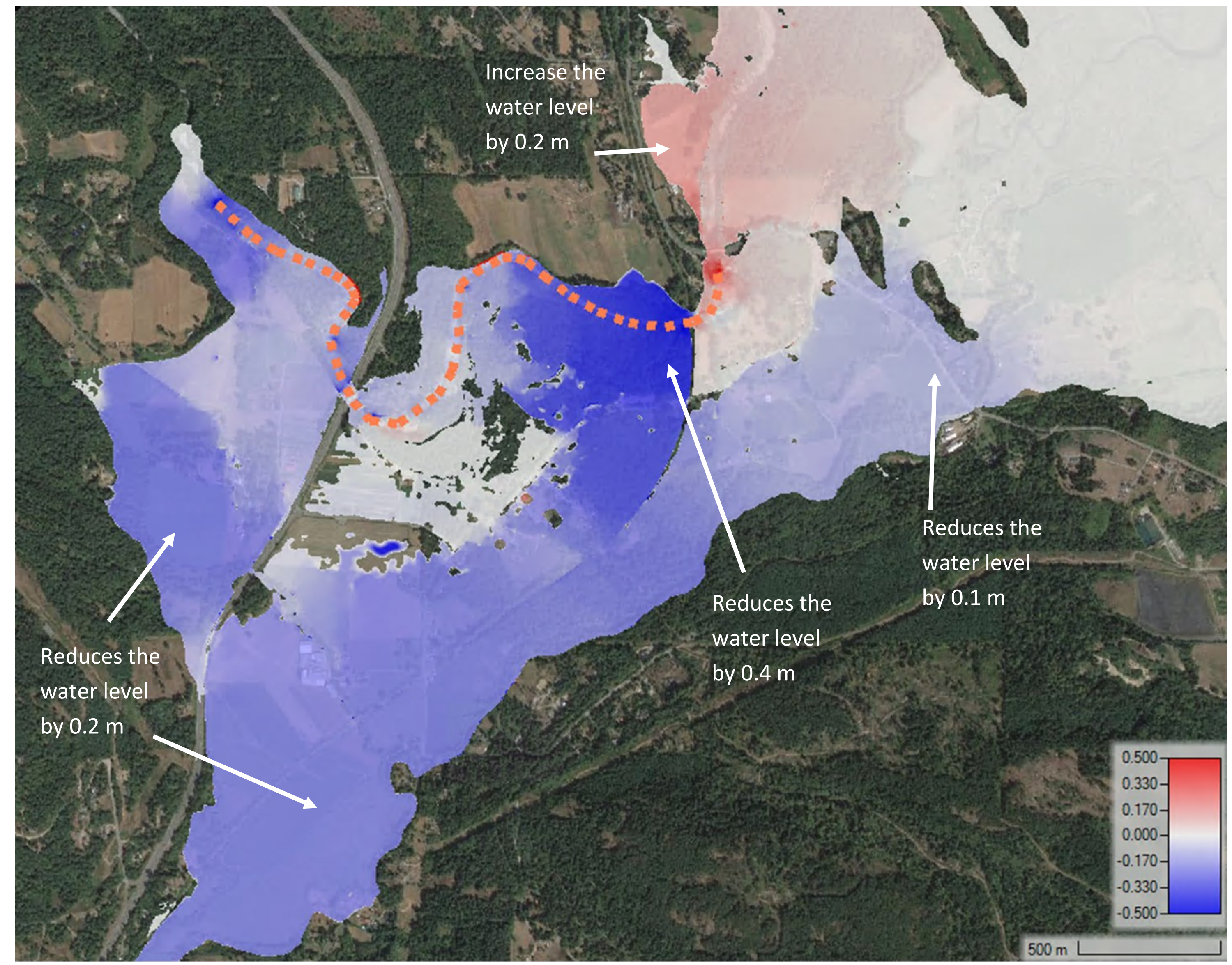
Description

Dredge 100,000 m3 of sediment over 4km of the Chemainus River from just downstream of the canyon to Chemainus Rd

Previous experience, shows that channel excavation, when carefully planned and monitored, can be an important component to flood management and can also be integrated with other habitat enhancement projects. To-date, gravel removals have been relatively small (in the range of 3,000 cubic metres) and have been sporadic in nature. Preliminary hydraulic modelling was carried out over a 4 km reach of the Chemainus to assess potential hydraulic effects. The effect of lowering the main channel 1 m over a 4 km reach was tested with the hydraulic model. The simulation show the overall reduction in flood levels from sediment removal is small during an extreme flood, as illustrated in figures below. Hydraulic effects would be greater during minor floods. Targeted gravel removals could also potentially reduce the risk of bank erosion or avulsions. Other related channel improvements could include removing log jams and debris that obstructs bridges or is threatening channel erosion. Additional geomorphic studies are required to assess rates of sedimentation and to define a long-term program. Further information on historic and potential future sediment deposition/instability are discussed in Appendix C, Phase 1 report. An environmental impact assessment is required to identify mitigation and compensation requirements.

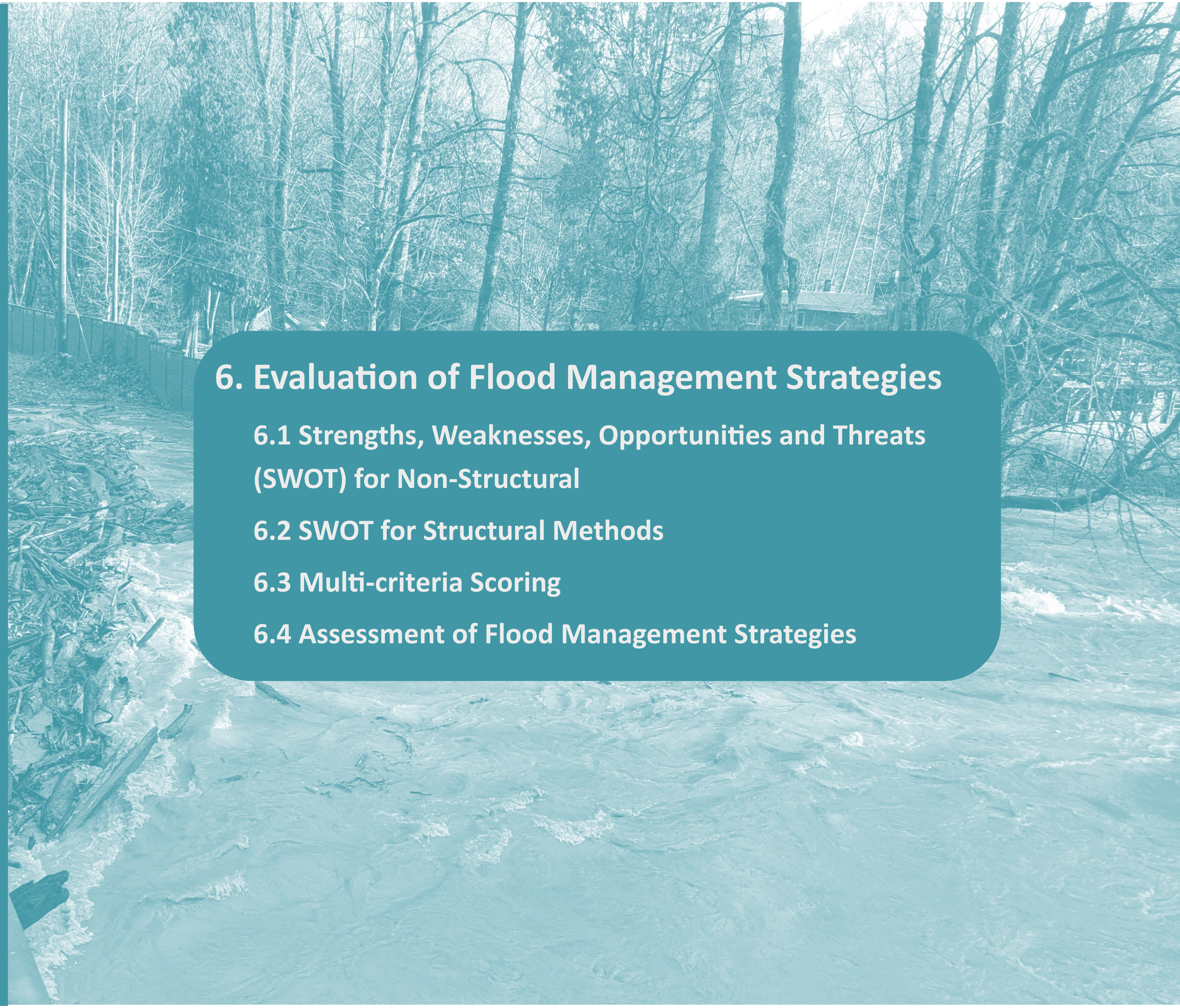


Depths of design flood with mitigation: increase conveyance in metres



Difference between design flood and mitigation: increase conveyance in metres

1. Introduction
2. Study Area Overview
3. Part 1 Floodplain Mapping
4. Introduction to Integrated Flood Management
5. Flood Management Strategies
6. Evaluation of Flood Management Strategies
7. Recommendations



6. Evaluation of Flood Management Strategies

Evaluations of Strategies: Non-Structural Methods

Flood Management Strategies	Description	Present		Future	
		Strengths (present)	Weaknesses (present)	Opportunities (future)	Threats (future)
Emergency Response	Flood warning Resources and planning Communication Evacuation Flood Recovery	Reduces risk to residents of the floodplain. People forewarned and forearmed are able to have plans to know what to do in an evacuation, have go bags ready to go, have valuables moved to a safe place and understand the impacts of flood.	The watershed response time is so short for the Chemainus, that the flood warning has limitations. Difficult to order evacuation without putting people at increased risk on roads that get inundated. Maye be safer to shelter in place. People with extensive knowledge of a flood may become over confident in their preparedness and choose not to evacuate and become endangered later and require rescue.	It helps with education and preparedness. It strengthens community ties and creates opportunities for a coordinated response (i.e. activate communication channels between indigenous emergency planning and District of North Cowichan)	The flood warning system creates a false sense of security that you will have time to plan and react to an emergency. The intensity of hazard will increase in the future and it will be more difficult to provide adequate warning into the future. The warning system only looks at clearwater conditions, doesn't capture the geomorphic hazards that may also occur. Population expansion could result in more difficulty responding to floods. Instabilities in headwaters could make it more difficult to forecast and provide warning for floods.
Land Use Management	Regulation by Bylaws Community Development Plan Relocation and Retreat	Adopting Phase 1 floodplain mapping products builds on and updates existing provincial and local government regulations. Compatible with existing land-use plans such as the ALR. Allows governing bodies to prevent or phase out high risk facilities and people in dangerous areas of the floodplain. Allows for development specifically built to withstand hazards. Removes risk to people and infrastructure if relocation is applied. Promotes environmental uses for the floodplain. Promotes longer time community resilience.	Geared to new development and doesn't address flooding hazards existing structures and communities. Doesn't address the flood risk or exposure to anyone caught on the floodplain without protection. Can cause hardship and loss to people required to relocate or retreat from hazard area. May be a challenge for First Nations living on reserves where regulatory frameworks may not accommodate.	Can change land use management strategies with climate change to reduce risk to communities located in the floodplain and eventually phase people out of the danger areas. Re-naturalization of large riparian areas and habitats will create more resilience for flooding with increasing size of floods as a result of climate change	Can change under future conditions and future pressure for development (i.e. conflicting development interests). Future Infrastructure and development plans can make flood management plans outdated. Frequent update of plans may be necessary, particularly under climate change. Population expansion could result in more difficulty responding to floods (i.e., egress routes and communication challenges).
Temporary Flood-proofing	Flood Barrier Sand bags	Reduces risk of flood damage to structures and assets in the floodplain.	Requires warning to set up. Chemainus has very limited flood warning time. Mainly suitable for shallow flood depth or slow moving water. Can be expensive, time consuming or labour intensive to set up.	Technological advances may make flood proofing more accessible or practical in the future.	Flood proofing will be increasingly difficult to implement under climate change and increasing hazards. Can create a false sense of security in protection and that there will be time to implement temporary flood proofing.
Permanent Flood-proofing and House Raising	House Raising Ring Dikes	Reduces risk of flood damage to structures and assets in the floodplain without causing significant transfer of flood risk to others. Requires little or no warning to be effective. May allow residents to shelter in place during a flood if unable to evacuate. Compatible with other land-use management practises in place.	Add costs to new structures, may be prohibitively expensive to existing structures.	Opportunity for governments to provide support for flood proofing measures.	Threats of climate change could make house raising impractical or unrealistic. Unpredictable erosion hazards that's flood proofing does not address.

Flood Management Strategies	Strengths	Weaknesses	Opportunities	Threats
Diking Upstream of Hwy 1	Protects area behind dike immediately upstream of Hwy 1 Transfer less water into Bonsall Creek Prevents water flowing over Highway 1	**Increases water levels and flood extents for the area immediately downstream of Hwy 1 on** the Chemainus River causing increase in scour and erosion in the river. Does not reduce FCL for floodplain Susceptible to breaches and erosion hazards from geomorphic processes. Reduces channel—floodplain interaction, will disconnect floodplain channel habitat and start to affect hyporheic aquifer. Will starve floodplain of natural floodplain building processes. May put Hwy 1 bridge infrastructure at risk. Expensive to construct and maintain.	Short term economic benefits for those located in the protected area.	Under Climate change, the Dike has a higher probability of breaching and the risk will increase and be amplified by the existence of the dike. Attracts people to move into protected area, but increases long term damages due to increased exposure. Reduced channel—floodplain interaction, will disconnect floodplain channel habitat and affect hyporheic aquifer. Will starve floodplain of natural floodplain building processes.
Diking upstream of Hwy 1 and downstream to Chemainus Rd	Protects area behind dike from Above Hwy 1 to Chemainus Bridge (Hwy 1a) Transfer less water into Bonsall Creek Prevents water flowing over Highway 1	**Increases water levels and flood extents for the area immediately downstream of Chemainus Rd Bridge (Hwy 1a)** on the Chemainus River Does not reduce FCL for floodplain Susceptible to breaches and erosion hazards from geomorphic processes. May put bridge infrastructure at risk. Expensive to construct and maintain. Reduces channel—floodplain interaction, will disconnect floodplain channel habitat and start to affect hyporheic aquifer. Will starve floodplain of natural floodplain building processes.	Short term economic benefits for those located in the protected area	Under Climate change, the Dike has a higher probability of breaching and the risk will increase and amplified by the existence of the dike. Attracts people to move into protected area, but increases long term damages due to increased exposure. Reduced channel—floodplain interaction, will disconnect floodplain channel habitat and affect hyporheic aquifer. Will starve floodplain of natural floodplain building processes.
Remove E&N Rail Embankment from Floodplain	Allows more conveyance through the floodplain Reduces water level immediately upstream of embankment Would decrease FCLs upstream of structure	Increases water level for area it currently protects on the downstream side of structure Would raise FCLs immediately downstream of structure Does not eliminate flooding. Overall flood reduction benefits are minor. Serves as an egress route in the flood for those that can access it.	Increased resilience for those upstream of the embankment, larger floods under climate change will pass through more quickly. Supports re-naturalization of the floodplain.	Evacuations routes may be more important in the future due to climate change. Eliminates the potential opportunities to use it as flood evacuation.
Localized Ring Dikes	Localized flood protection around specific infrastructure, homes or business.	Difficult to build on individual scale Spaced out communities are not likely to benefit. Transfer of risk still exists. Does not reduce FCL for floodplain Susceptible to breaches and erosion hazards from geomorphic processes. Expensive to construct and maintain.	Short term economic benefits for those located in the protected area.	Under Climate change, the Dike has a higher probability of breaching and the risk will increase and amplified by the existence of the dike. Attracts people to move into protected area, but increases long term damages due to increased exposure
Increased Conveyance on the Chemainus River	Can be used to reduce risk of erosion and avulsion. May be compatible with other environmental objectives and habitat improvements. Reduces the potential of longer term aggradation and increases in flood levels.	Sediment would likely infill quickly. Sedimentation rates on not very well understood on this river. Would further disconnect the mainstem river from the floodplain which could cause scour and erosion in mainstem. Environmental impacts are associated with sediment removal. Expensive to complete, would need regular maintenance Does not reduce FCL and only minor reduction in flood levels.	Can tie into future habitat enhancement. Leads to increased understanding of the rivers hazards and processes. Potential economic benefits if materials can be repurposed, potentially for flood proofing.	Long term sediment management on the river would require ongoing funds and maintenance and could be expected to get worse with increasing size of flood events.

*** Bolded text represents points that directly conflict with the guiding principles of flood management.**

Using the SWOT analysis results, a multi-criteria scoring matrix was developed for the strategies and is presented below. For this study, only technical criteria was evaluated. The project partners undertook additional feedback related to socio-economic an environmental issues. The results of that feedback is on file with the CVRD.

Multi-Criteria Scoring matrix:

All the options are ranked from 1-3 based on how they are classified. The results are normalized, the weighting is applied and then the results are summed. The highest scores (darkest green) indicate the most suitable choices based on the criteria.

Rankings	Class	Price ($)
1	Low	>1M
2	Medium	>500,000
3	High	<500,000

	Strategy	Reduces flood damages?	Transfer of Flood Risk?	Feasibility / practicality	Capital Costs	Maintenance costs	Robustness to Climate Change	Integration to other options	Overall Score
	Weight	14%	14%	14%	14%	14%	14%	14%	100%
Non-Structural Methods	**Emergency Response**	low	low	high	$	$$	high	high	0.86
	Land Use Management	high	low	high	$	$	high	high	**1.00**
	Temporary Floodproofing	low	medium	low	$	$	high	high	0.76
	Permanent Floodproofing	high	low	medium	$$	$	medium	high	0.86
Structural Methods	**Diking Upstream of Hwy 1**	high	high	low	$$$	$$$	medium	low	0.48
	Diking to Crofton Rd	high	high	low	$$$	$$$	medium	low	0.48
	Remove E&N Embankment from Floodplain	medium	medium	low	$$$	-	high	high	0.71
	Localized Ring Dikes	high	high	low	$$	$$	medium	low	0.57
	Channel Management	medium	low	medium	$$	$$$	high	high	0.76

Assessment of SWOT Analysis

NHC assessed four different strategies with multiple applications and configurations. Although many ides were shared during the engagement, not all strategies and suggested measures were found to be technically feasible. Using the SWOT analysis associated with each strategy, the strategies were evaluated in terms of their effectiveness under a 200 year flood condition, accounting for future climate change and sea level. This approach is intended to ensure that the adopted strategies will provide long-term protection against flooding. The top ranking results are a mix consisting primarily of non-structural mitigation methods and are presented below.

1. Strategy 1: Land Use Management

Develop or enact land use management strategies such as developing floodway and flood fringe boundaries, prohibiting development in specific areas or only allowing development with appropriate flood protection as well as relocation and retreat options.

2. Strategy 2: Emergency Response

Enhance emergency Preparedness and response for the Chemainus floodplain by focusing on the 4 components: Resources, Planning & Education, Communication, Warning and Monitoring, and Evacuation. Installation of flood warning and active flood monitoring can help effectively evacuate people as necessary. Given the very short response time of the Chemainus River, emergency preparedness plans and floodproofing measures need to be in place before the start of a flood.

3. Strategy 3-2: Permanent Floodproofing

Implement permanent flood proofing for existing buildings and ensure new develops adhere to floodproofing requirements (such as Flood Construction Levels or FCLs).

4. Strategy 3-1: Temporary Flood Proofing

Implement effective flood proofing measures for the floodplain during low return period floods. Ensure floodproofing measure are effective and in place before a large flood arrives, either at the start of the storm season (October) or in preparation for a large storm.

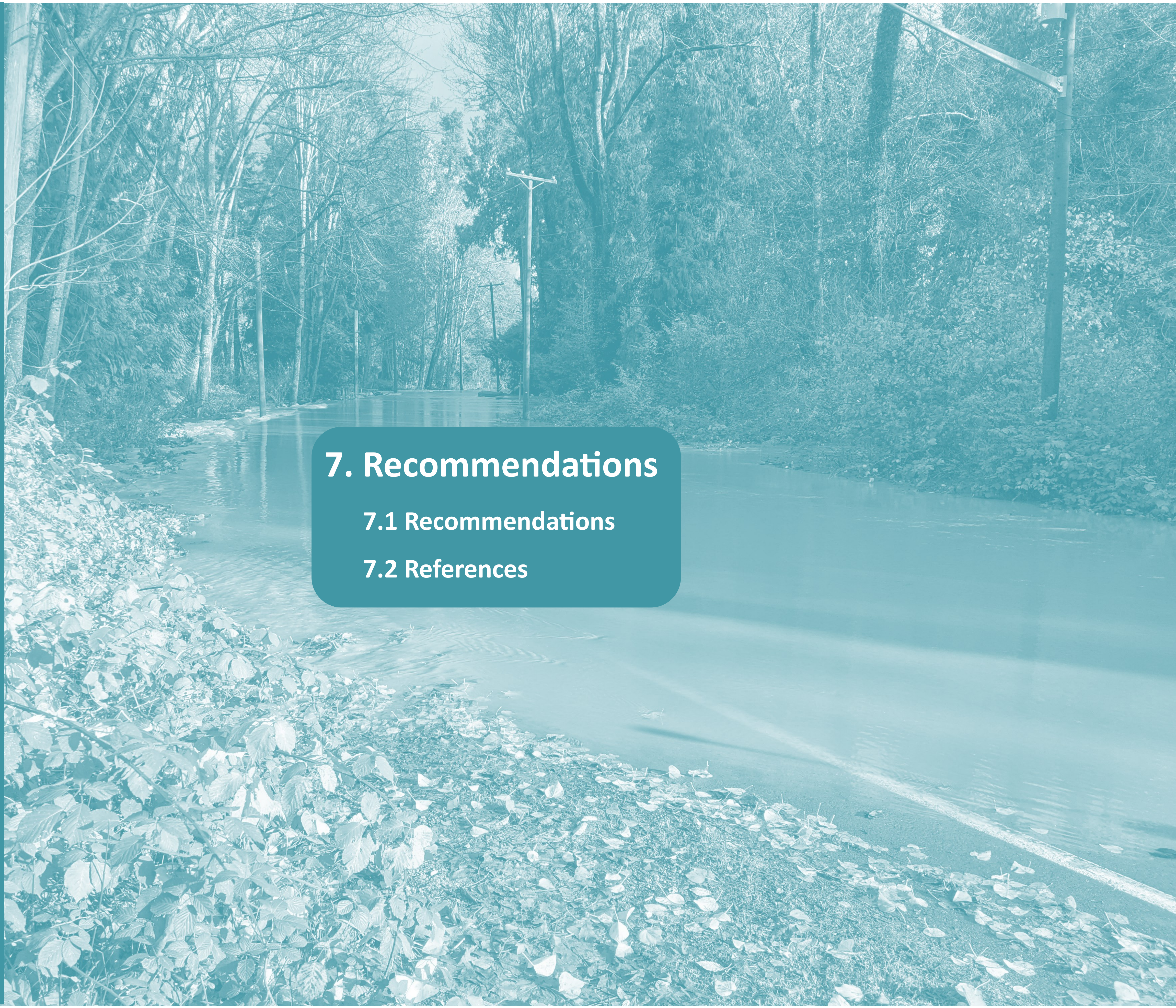
5. Strategy 4-5: Channel Management

In response to the suggestions provided during the public engagements and based on the results of the SWOT analysis, consider conducting gravel removal and debris control, as it appears to be a potentially useful measure for maintaining a more stable channel. The effect of gravel removal on flood levels is expected to be minor (less than 0.3m) for extreme floods. Additional technical and environmental studies should be carried out to prepare a long-term channel gravel removal and channel management program. An essential component of this work is to develop a sediment budget to assess the long-term rates of aggradation on the river.

These measures can address both short-term and long-term flood hazards, without the need for large scale structural interventions such as flood dikes.

Due to the expected adverse impacts, NHC does not recommend building continuous dikes (Strategy 4-1 and 4-2). Building continuous dikes along the Chemainus River will protect some areas, but the confinement effect will raise flood levels significantly, which will increase flooding at other unprotected communities. The confinement effect of dikes will also raise flood construction levels over large areas of the floodplain, increasing the need to further elevate new homes and future infrastructure.

1. Introduction
2. Study Area Overview
3. Part 1 Floodplain Mapping
4. Introduction to Integrated Flood Management
5. Flood Management Strategies
6. Evaluation of Flood Management Strategies
7. Recommendations



7. Recommendations

Recommendations

Recommendations:

- Adopt a mix of primarily non-structural flood mitigation methods, including land use management (Strategy 1), emergency preparedness and response (Strategy 2), floodproofing (Strategy 3) and gravel removal and debris control (Strategy 4-5) as the core strategies for reducing future flood damages.
- Upgrade and expand emergency response plans (including support for temporary floodproofing measures) and flood recovery plans. Due to the extremely flashy nature of the Chemainus River, emergency response plans and resources should be in-place at the start of the flood season.
- Adopt the floodplain maps and erosion hazard maps developed in Part 1 for approving and regulating new developments on the floodplain. Site specific investigations by a qualified professional should be carried out to assess the need for erosion mitigation counter measures.
- Implement permanent flood proofing and house raising (Strategy 3) on existing buildings as well as for new developments. These measures can address both short-term and long-term flood hazards, without the need for large scale structural interventions such as flood dikes. Site specific investigations by a qualified professional should be carried out to assess the need for erosion mitigation counter measures.
- Due to the expected adverse impacts, building continuous dikes (Strategy 4-1 and 4-2) cannot be recommended. Building continuous dikes along the Chemainus River will protect some areas, but the confinement effect will raise flood levels significantly, which will increase flooding at other unprotected communities. The confinement effect of dikes will also raise flood construction levels over large areas of the floodplain, increasing the need to further elevate new homes and future infrastructure.
- Removing the E&N Rail embankment (Strategy 4-3) was identified in the public consultation meetings as a possible measure to reduce flooding. Hydraulic modelling showed the removing the embankment lowered water levels locally upstream of the embankment and increased levels downstream. Since there is little overall hydraulic benefit, this strategy would require further investigation and consultation with he community. Also, there may be other benefits of maintaining the embankment in-place, since it provides a potential evacuation route.
- Gravel removal and debris control (Strategy 4-4), was suggested during public consultation meetings and appears to be a potentially useful measure for maintaining a more stable channel. The effect of gravel removal on flood levels is expected to be minor (less than 0.3m) for extreme floods. Also, any increases to channel conveyance are temporary unless the work is carried out regularly over a long period of time (decades). This means long-term funding is essential for it to be useful. It is recommended that additional work be carried out to define the program further (as described below).
- Initiate technical and environmental studies to prepare a long-term channel gravel removal and channel management program. An essential component of this work is to develop a sediment budget to assess the long-term rates of aggradation on the river. This study would also identify the most critical sites for removing gravel and would assess potential impact on habitat and mitigation/compensation measures that would be needed. A task of this study would be to assess sediment sources and sediment supply in the watershed upstream of Highway 1 in order to assess future trends in sediment yield and to identify whether erosion control measures could be carried out to reduce sediment supply to the lower river.

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