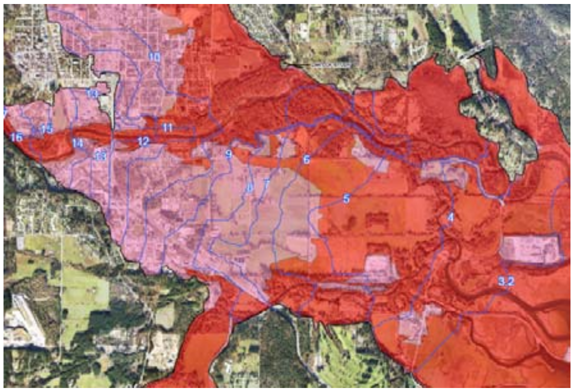
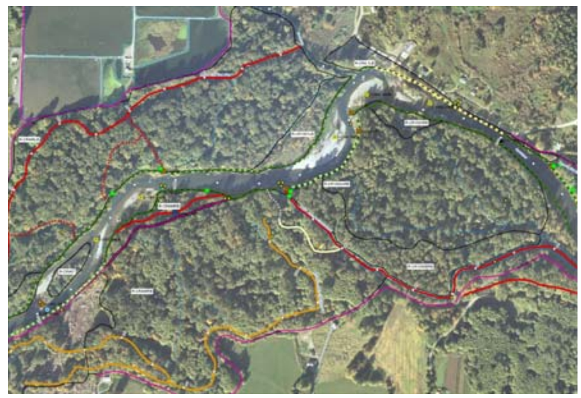
COWICHAN VALLEY REGIONAL DISTRICT





LOWER COWICHAN / KOKSILAH RIVER INTEGRATED FLOOD MANAGEMENT PLAN

FINAL REPORT

SEPTEMBER 2009

nhc northwest hydraulic consultants

Leaders in water resource technology

LOWER COWICHAN / KOKSILAH RIVER INTEGRATED FLOOD MANAGEMENT PLAN FINAL REPORT

Prepared for:

Cowichan Valley Regional District
175 Ingram Street
Duncan, BC V9L 1N8

In partnership with:

Cowichan Tribes
City of Duncan
District of North Duncan

With additional funding provided by:

Union of BC Municipalities Innovations Fund
Cowichan Tribes
BC Provincial Emergency Program

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September 2009

3-4878

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EXECUTIVE SUMMARY

The Cowichan Valley Regional District (CVRD), in partnership with Cowichan Tribes, the City of Duncan and the District of North Cowichan (DNC), retained Northwest Hydraulic Consultants (NHC) to update existing floodplain mapping and to develop an Integrated Flood Management Plan for the Lower Cowichan-Koksilah River floodplain, including major tributaries. Funding for this program was built by a partnership of supporting funds from the following organizations: Union of BC Municipalities Innovations Fund, Cowichan Tribes and the BC Provincial Emergency Program as well as substantial in-kind contributions from local government organizations.

Given the very broad nature of the study, NHC recommended that a phased approach be adopted so that the project goals and objectives could be refined over the course of the project. The main outputs of the project are summarized in four documents:

- Volume 1 – Scoping Report
  - Field investigations and base map development, including substantial field reviews and GIS analysis
  - Literature review of local and international flood management practices
- Volume 2 – Technical Investigations
  - Technical investigations related to hydrology, hydraulics, sedimentation and channel hazards
  - Detailed assessments of the capacity of existing flood control structures using numerical models
  - Environmental investigations including habitat and fisheries values, threats and opportunities
- Volume 3 – Integrated Flood Management Plan (this report)
  - Summary of findings from Volumes 1 and 2
  - Mapping tools for flood hazard, channel erosion and habitat value
  - Analysis of flood management best management practices
  - Project goals, guiding principles and proposed actions (priority and long-term)
- Summary Paper

COWICHAN FLOOD MANAGEMENT PLANNING AREA

The headwaters of the Cowichan River/Koksilah River system are located in the rugged mountains of southern Vancouver Island. The Cowichan River has its headwaters in Cowichan Lake, and then flows in an easterly direction into Cowichan Bay. The smaller Koksilah River joins the south branch of the Cowichan River approximately 1 km upstream of Cowichan Bay. The lower slopes and floodplain of the river system contain significant areas of agricultural land as well as rural, urban and industrial development. Dikes have been built along both banks of the Cowichan River to protect the developed urban core of the City of Duncan and the extensive agricultural and industrial zones downstream. Dikes have also been constructed on lands of the Cowichan Tribes at various times including along the Koksilah River

The Cowichan River is designated as a Heritage River and recognized for its highly valuable and productive fish habitat. The river supports seven species of salmon and trout including important stocks of chinook, coho, chum, steelhead trout, brown trout, rainbow trout and cutthroat trout. The mainstem Cowichan River supports a unique run of summer run chinook that is considered by Fisheries and Oceans Canada (FOC) to be one of the highest value stocks on Vancouver Island based on conservation concerns and rebuilding efforts. The Cowichan River also supports a highly valued wild winter run of Steelhead trout whose status is also a conservation concern with active stock rebuilding efforts undertaken by the BC Ministry of Environment (MOE).

The valley has experienced many flood events resulting from high flows in the Cowichan River and its tributaries, and from ponding in low-lying areas during heavy rain events. Large flow events in the Cowichan River were documented in 1979, 1986 and 2007. The most recent flood event of 2007 resulted in the closure of the Island Highway as well as the evacuation of 17 families living on the floodplain.

The flood management area extends along the Cowichan River from below the Catalyst water intake down to the ocean and along the Koksilah River from just below Bright Angel Park down to the ocean. Also included in the project area are Somenos Creek and Somenos Lake. In order to assess the hydrology, sedimentation processes and factors affecting channel erosion and debris hazards, the investigations have extended beyond the limits of the Flood Management Planning Area. These related studies have been conducted at a watershed scale and extend over the Cowichan River basin downstream of Cowichan Lake and portions of the Koksilah basin.

The City of Duncan, with a population of approximately 5,000, lies at the centre of the floodplain. The Cowichan Tribes has about 3,800 members, many of whom live on the floodplain. In addition to residential areas, there is urban and agricultural development in the floodplain as well as significant critical infrastructure. To date, landuse planning has not controlled the development of houses and other critical infrastructure on the floodplain.

PROJECT TOOLS AND RESULTS

This present study has provided technical information and a range of new management tools (GIS-based flood, erosion and habitat maps) that can be used as a road map for implementing Integrated Flood Management in the Cowichan-Koksilah basin. However, it will take various stakeholders, local organizations and participating agencies to build and implement a long-term sustainable program.

Over the course of the project, two major technical tools were developed to help in the planning process. A two-dimensional hydraulic model was developed to assess the magnitude and extent of flood hazards in the study area. The development of this model is detailed in Volume 2 – Technical Investigations (NHC 2009). In addition, a comprehensive GIS database that includes habitat sensitivity and flood hazard mapping was developed. Map 1 shows flood hazard areas established from the hydraulic models and erosion hazard assessments. Two hazard zones have been defined, where areas in the “floodway” are expected to experience deeper and faster flows, and therefore more hazardous conditions, during a flood event. By comparison the “flood fringe” represents the portion of the floodplain that may be subject to inundation and ponding but only contributes marginally to conveying the flood.

Extensive background studies were made using the models and mapping to assess the magnitude and extent of the flood hazards in the study area. Key conclusions from the hydraulic analyses are as follows:

- None of the existing dikes have adequate freeboard for a 200-year flood over their entire length. Portions of the City of Duncan are vulnerable to flooding due to overtopping or breaching of the JUB lagoon dike, as well as from backwater flooding from Somenos Creek in the Lakes Road area. Critical infrastructure such as the JUB sewage lagoons and outfall are vulnerable to damage from flooding and bank erosion.
- Under 200-year flood conditions, large spills occur along both banks of the Koksilah River, resulting in overtopping of the Trans-Canada Highway. Deep and fast flow conditions occur on the floodplain, which could pose high erosion hazards to buildings or other structures on the floodplain.
- Flooding and bank erosion can be aggravated by log jams and sediment deposition, so that the most severe potential flood damages may not necessarily arise from the most severe hydro-meteorological events. The log debris and sediment originate in the headwaters of the watersheds, upstream of the Flood Management Planning Area.
- Flood levels and flood spills over the entire floodplain area are vulnerable to alterations in dike crest levels. Furthermore, raising roads on the floodplain can have a similar effect as raising dikes. Raising or extending a dike or road at one location may raise flood levels farther upstream. It appears many local dikes were constructed without assessing their effect on adjacent areas. Further raising or extension of dikes should not be permitted unless it can be demonstrated there will be no net water level rise at other locations.
- The Cowichan River has been artificially straightened, re-located and confined by riprap dikes, producing a canal-like appearance over much of its length. This produces high velocities and scour through narrow sections, together with localized gravel deposition and channel instability in wider sections. This type of channelized river generally requires regular maintenance and repair. Also, it adversely impacts fisheries habitat by reducing complexity.
- Currently simulated 200-year flood levels on portions of the Cowichan River, portions of Koksilah River upstream of the Trans-Canada Highway, and all of Somenos Creek and Somenos Lake are generally higher than those predicted in earlier studies. Most of the bridges in the study area appear to have inadequate

clearance under open water conditions, and are therefore susceptible to trapping logs and floating debris and potential structural failure.

- Existing legislation has not stemmed development on the floodplain to date. New approaches to flood management are required in order to mitigate flood vulnerability in the Cowichan Valley.
- Continued reliance on structural flood control measures alone would be costly and may not be practical if only limited funding for upgrading and ongoing maintenance is available.

The habitat sensitivity pilot project completed as part of this study is intended to be an iterative product that will be reviewed and updated with collection of new data or integration with other mapping products. The intent of the pilot mapping tool is to provide a starting point as a tool for land and resource management that illustrates known fisheries and wildlife habitat values and conceptual habitat restoration opportunities.

Several different types of flood mapping products were produced in this study.

Updated Floodplain Maps: showing 200-year flood construction levels, flood extent, and a higher hazard "floodway" zone. The floodway classification is intended to differentiate the higher hazard (deeper and faster flood water) areas on the floodplain from the lower hazard (shallow or low velocity) "flood fringe" zone. An estimate of an appropriate planning setback distance for the Cowichan and Koksilah Rivers was made for a 25 year planning period. The corresponding set-backs were 50 m for the Cowichan River and 40 m for the Koksilah River.

Flood Scenario Maps: are intended to assist in emergency response planning since they show a number of hypothetical flood spills and inundation zones during future events. The information is available in three formats - printed copies, digital GIS output and as digital output that can be displayed via the internet using Google Earth.

Habitat Sensitivity Maps: A habitat ranking system has been developed and applied to the Habitat Pilot Study Area using a GIS-based mapping system to support strategic planning and operational investigations related to habitat and restoration.

INTEGRATED FLOOD MANAGEMENT PLAN GOALS AND STRATEGIES

Integrated Flood Management (IFM) is a relatively new concept, emerging out of broader water management policies that promote the development and management of water, land and related resources without compromising the sustainability of vital ecosystems. WMO (2004) stated:

> *The defining characteristic of IFM is integration, expressed simultaneously in different forms: an appropriate mix of strategies, location of interventions, types of interventions (structural or non-structural), and a participatory and transparent approach to decision making, particularly in terms of institutional integration.*

Improving integrated flood management in the region will be a challenge. Fortunately, there is a strong base of community stakeholder involvement through the Cowichan Round Table and a Water Management Plan has already been prepared. The overall strategy and goals of the plan are consistent with the aims and general direction in the new BC Living Water Smart initiative.

The overall goals of this study, as stated in the Call for Proposals, are as follows:

Goal 1

The plan should aim to reduce flood risk to all communities on the floodplain, while protecting aquatic and riparian habitat and addressing the cultural values of the rivers.

Goal 2

The plan should promote innovative methods of flood hazard management to minimize short and long-term economic, environmental and social costs and where possible, provide an increase in the environmental and social capital of the region.

In addition to these two explicit goals, the scope has also been broadened to incorporate new information and lessons-learned from other integrated flood management planning organizations.

Goal 3

The plan should be achievable and should be supported by project stakeholders and the community at large. And, tools and recommended actions should be sustainable in the long-term.

The following ten strategies have been followed in preparing preliminary concepts and initiatives in support of the plan and the goals outlined above.

- **Strategy 1: Return the rivers to a more naturalized state.** The Cowichan River has been artificially straightened and confined by riprap and dikes. This type of channelized river generally requires a high degree of maintenance and repair. It also adversely impacts fisheries habitat by reducing habitat complexity. Therefore, restoring the river to a more “naturalized” channel configuration that has room to convey water within a broad floodway should be a part of a long-term strategy
- **Strategy 2: Sustain the natural state of existing floodplain**. Remaining undeveloped floodplain areas should be sustained in a natural state. And, initiatives should be compatible or be integrated with programs that protect and enhance aquatic and riparian habitat
- **Strategy 3: Site future development in areas with low flood hazard and low habitat sensitivity**. Future development should be sited in areas with low flood risk and low habitat sensitivity
- **Strategy 4: Ensure new or upgraded flood protection structures do not adversely increase the overall flood hazard.** Based on past experience along the river, a “no-net adverse impact” flood level policy for future developments on the floodplain, including

future diking and flood protection works, is needed. Constructing new dikes or extending existing ones should not increase the risk of flood damage in other vulnerable areas

- **Strategy 5:** Decrease vulnerability of existing development areas: Where key infrastructure and residential areas currently lie on the floodway and cannot easily be moved, decrease the vulnerability of these people and structures. This can be achieved through floodproofing of existing structures, and through improvements to public education, flood warning and flood response systems.
- **Strategy 6: Mitigate impacts of high flows on mainstem.** Impacts of high flows on mainstem should be mitigated by facilitating flow through suitable off-channel habitat
- **Strategy 7: Maintain channel conveyance**. Consider and maintain sites of debris jams and debris/gravel accumulation. An "adaptive" maintenance approach that incorporates habitat enhancement as part of channel maintenance is needed
- **Strategy 8: Create accessible and sustainable tools for flood management**. New tools developed for the project need to be designed so they can be used interactively and dynamically for emergency management, improved landuse planning, public awareness and education
- **Strategy 9: Promote basin-wide planning initiatives.** Basin-wide planning is important, particularly since most of the flood water, sediment and debris originates upstream of jurisdictional boundaries in the basin headwaters.
- **Strategy 10: Monitor and maintain flood management program.** Monitoring and maintenance are essential components of a flood management program. This should not just apply to dikes or bank protection works, but the channel as a whole.

Recommended Actions

A portfolio of planning and structural (engineering) measures was developed as part of the flood plan. Key structural projects are shown in Figures 8.1 and 8.2. Twenty specific projects that promote the guiding principles (above) and include habitat enhancement as a project component are also outlined in this report and include:

- Dike upgrades or new dike construction (two priority projects are described below)
- Channel maintenance and improvement programs
- Gravel removal and maintenance programs
- Log jam removal and modification programs
- Selective vegetation removal
- Set-back dike construction
- Upstream sediment and debris control
- Road modifications
- Bridge replacements
- Recommended compensation projects

The existing flood protection around critical infrastructure and higher density populated areas in Duncan should be upgraded as soon as possible. In particular, the existing dikes around the JUB sewage lagoon should be raised and provided with erosion protection and tied in to the Cowichan (City of Duncan) Dike. A design review of the lagoons should be carried out as part of this work.

The Koksilah Village Dike is vulnerable to overtopping and erosion and local residences are exposed to a higher flood risk than most other locations on the floodplain. Given the deep and fast flow conditions after a dike breach, flood-proofing the residences is not a practical option. Discussions should be held with residents on options for dike strengthening and raising versus re-settlement.

Landuse planning instruments including the use of flood-proofing and a two-zone flood map are described in this report. These are in addition to further policy instruments including public education, flood warning mechanisms and emergency response planning.

Finally, consideration was given on ways to promote integrated flood management in the region and assisting in its implementation. Forming a Basin Council (modelled on the Fraser Basin Council) would be one option for promoting integrated, basin-wide sustainable water management. The Council would still require existing authorities for implementing major projects. Forming a Basin Water Board (modelled after the Okanagan Board) would provide powers for raising funds and implementing programs directly. The two organizations are not incompatible.

CONCLUSIONS

The results of this study are intended to assist the communities with developing strategies and plans to address flood hazards over the next decade. The measures include both structural flood control and non-structural flood mitigation initiatives in addition to providing resources for future planning. The aim is to help provide a “road map” leading to more flood-resistant communities and a more natural, ecologically productive and sustainable river system. This approach requires that floodwaters and floodways be seen as a resource and opportunity rather than simply a management issue, and that habitat enhancement is carried out as part of the flood protection work, rather than simply trying to mitigate environmental impacts from new flood infrastructure. Ultimately, the stakeholders, local governments and Cowichan Tribes will need to frame their own goals and objectives in order to implement the final plan.

CREDITS AND ACKNOWLEDGEMENTS

We wish to acknowledge the assistance of all stakeholders and study participants who have provided time, knowledge and information to assist in the study. We also wish to acknowledge the logistical support provided by members of the Cowichan Tribes during our field surveys and field observations along the rivers. Ms. Kate Miller, Cowichan Valley Regional District is project coordinator for the study. Support and background information has also been provided by the District of North Cowichan, City of Duncan and Cowichan Tribes.

The following personnel participated on the project from NHC.

David McLean:	Project manager and river engineering
Tamsin Lyle:	Flood management and hydraulic modelling
Vanessa O'Connor:	Hydraulic modelling
Robert Odell	Hydraulic modelling review
Darren Ham:	Fluvial geomorphology
Joe Drechsler:	GIS and spatial mapping
Sarah North:	GIS support and spatial mapping
Will Skitmore:	River surveys

Environmental sub-consulting services were provided by:

Violet Komori:	Environmental planning
Rupert Wong:	Habitat enhancement

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1 INTRODUCTION

1.1 PURPOSE

The Cowichan Valley Regional District (CVRD), in partnership with Cowichan Tribes, the City of Duncan and the District of North Cowichan (DNC) retained Northwest Hydraulic Consultants (NHC) to update existing floodplain mapping and to develop an Integrated Flood Management Plan for the Lower Cowichan-Koksilah River floodplain, including major tributaries (Somenos Creek). The overall goals of the study, as stated in the Call for Proposals, are as follows:

- Reducing flood risk to all communities on the floodplain, while protecting aquatic and riparian habitat and addressing the cultural values of the rivers.
- Promoting innovative methods of flood hazard management to minimize short and long-term economic, environmental and social costs and where possible, provide an increase in the environmental and social capital of the region.

It was indicated the plan should incorporate the goals and objectives from key stakeholders as well as the wider community and should integrate with existing planning and strategic documents such as the Cowichan Basin Water Management Plan and municipal Official Community Plans. Finally, the project will provide information and tools that can be easily updated in response to future developments and plans in the region.

The results of this study are intended to assist the communities to develop strategies and plans to address flood hazards over the next decade. The measures include both structural flood control and non-structural flood mitigation initiatives. The aim is to help provide a "road map" leading to more flood-resistant communities and a more natural, ecologically productive and sustainable river system. This approach requires that floodwaters and floodways be seen as a resource and opportunity rather than simply a management issue, and that habitat enhancement is carried out as part of the flood protection work, rather than simply trying to mitigate environmental impacts from new flood infrastructure. The approach is consistent with the general principles that have been presented by the provincial government's "Living Water Smart" initiative (BC 2008).

1.2 INTEGRATED FLOOD MANAGEMENT

Integrated Flood Management (IFM) is a relatively new concept, emerging out of broader water management policies that promote the development and management of water, land and related resources without compromising the sustainability of vital ecosystems (WMO 2004). IFM recognizes that planning needs to be on the river basin scale, and the starting point is a vision of what the river basin should be. WMO (2004) stated:

"The defining characteristic of IFM is integration, expressed simultaneously in different forms: an appropriate mix of strategies, points of intervention, types of interventions (structural or non-structural), short or long-term and a participatory and transparent approach to decision making-particularly in terms of institutional integration".

Five key elements are identified as part of an integrated flood management plan:

- Manage the water cycle as a whole;
- Integrate land and water management;
- Adopt a best mix of strategies;
- Ensure a participatory approach;
- Adopt integrated "all-hazards" emergency management approach.

Basin flood management planning is a sub-set of an integrated water resource management plan.

Implementing an integrated flood management plan requires the involvement and commitment of a wide range of government organizations and stakeholders. WMO (2004) identified four key institutional requirements for successful implementation:

- Clear and objective policies supported with legislation and regulations;
- Appropriate linkages between various institutional structures (in this case federal, provincial and local governments, First Nations and other stakeholders);
- Community-based institutions;
- Information management and exchange.

Implementing an integrated flood management plan for the Cowichan-Koksilah River system will require the combined efforts of a broad range of stakeholders, as well as the support and commitment from a number of government agencies. It will not be a simple process. However, important steps have already been achieved, including:

- Completion of the Cowichan Basin Water Management Plan (CBWMP) and Cowichan Estuary Environmental Management Plan;
- Progress towards the formation of a Cowichan Basin Water Management Advisory Council.

Furthermore, there is a long established history of collaborative planning in the basin through the efforts of the Cowichan Stewardship Round Table as well as successful projects led by the Living Rivers-Georgia Basin/Vancouver Island initiatives. The overall vision expressed in the Cowichan Basin Water Management Plan has been used as a basis for guiding the flood management plan. However, it will take more than any single study or investigation to establish integrated flood management on the Cowichan-Koksilah River basin. The results of this study should be an important step in the process.

1.3 PROJECT DIRECTION

Flood management has evolved over the last decade. A holistic integrated approach is now common practice around the world, while a more engineered structural approach was customary in the past. Given that an integrated approach is now considered best practice, and that the goals for this project and the goals for the recently completed Cowichan Basin Water Management Plan align with the integrated approach, we have developed guiding principles and projects on this basis. In particular, we have developed long-term strategies that focus on naturalizing the river as opposed to recommending structural (diking) solutions. This is a departure from the past approach to flood management in the Cowichan Valley, and as such will require strong stewardship to implement this plan.

1.4 STUDY EXTENT

The extent of the Flood Management Planning Area for this study is shown in

Figure 1.1 The upstream limits of the study are as follows:

- Catalyst Water Intake on Cowichan River;
- Near Mays Road on Somenos Creek;
- 1 km downstream of Bright Angel Park on Koksilah River.

The study limits were set in the terms of reference, primarily by the availability of high resolution topographic mapping data. The downstream limit of the study is in Cowichan Bay at mean sea level.

The floodplain, as defined by earlier studies, covers an area of 21.5 km^2 and includes portions of the City of Duncan, North Cowichan Regional District, Cowichan Tribes lands and Cowichan Valley Regional District. Jurisdiction boundaries are shown in

Figure 1.2 The channel system includes several inter-connected branches and tributaries. The primary channel reaches described in this report are as follows:

Cowichan River – extends downstream past Allenby Bridge, E&N Railway Bridge and Trans-Canada Highway Bridge to the bifurcation with the North and South Branches;

Cowichan River South Branch – extends from bifurcation down to the junction with Koksilah River, and then flows under Clem Clem Bridge into Cowichan Bay near Westcan Terminal;

Cowichan River North Branch – extends from the bifurcation with the Cowichan River and flows downstream under Pimbury Bridge on Tzouhalem Road to Cowichan Bay;

Koksilah River – extends from just downstream of Bright Angel Park down past the Trans-Canada Highway Bridge and joins the Cowichan River just upstream of the Clem Clem Bridge.

Somenos Creek – includes Somenos Lake and the 2 km mainstem down to the junction with the Cowichan River just upstream of its bifurcation.

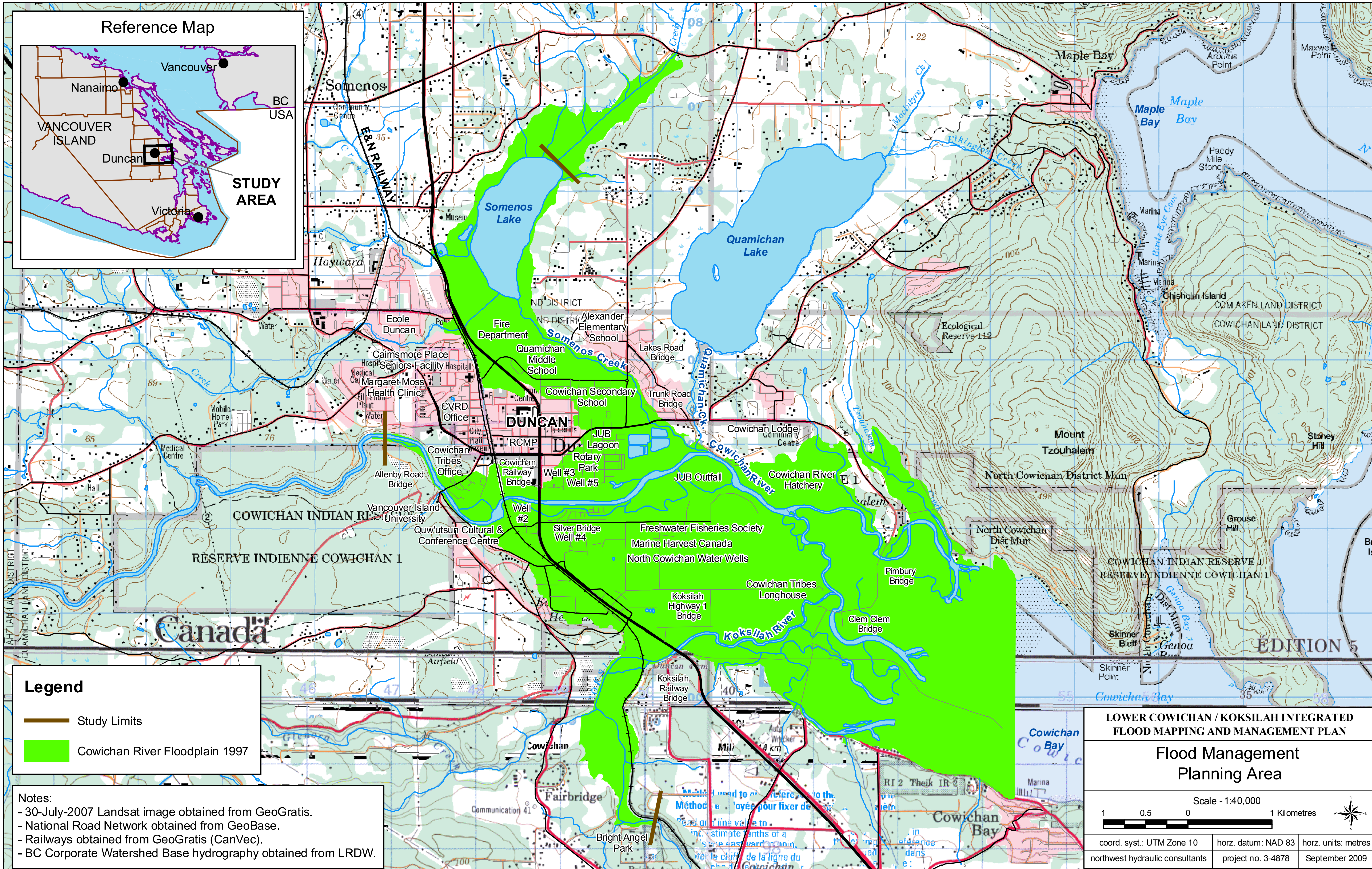
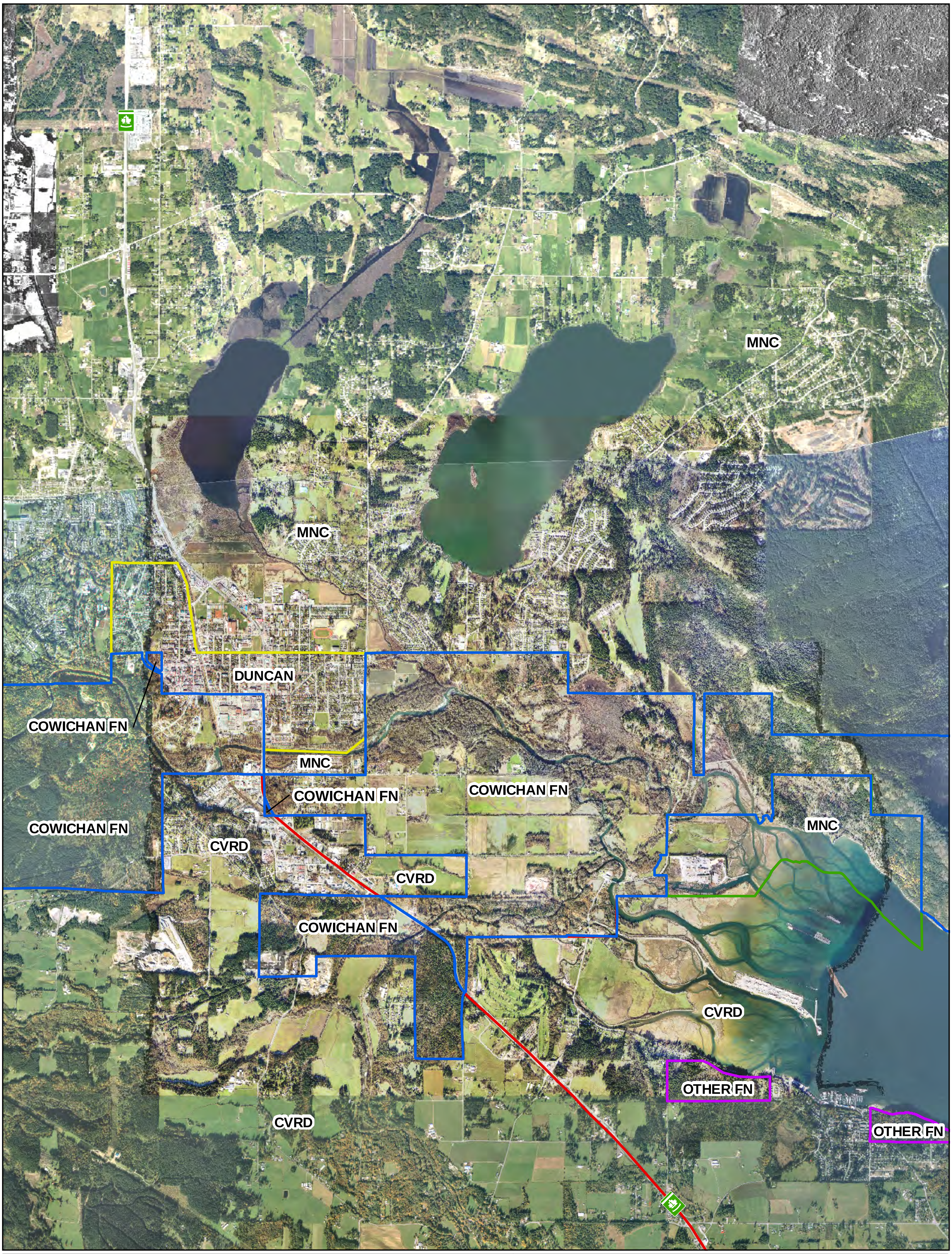

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN
Flood Management Planning Area
Scale - 1:40,000
1 0.5 0 1 Kilometres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
Reference Map
Vancouver
Nanaimo
BC
USA
VANCOUVER ISLAND
Duncan
STUDY AREA
Victoria
Legend
Study Limits
Cowichan River Floodplain 1997
Notes:
- 30-July-2007 Landsat image obtained from GeoGratis.
- National Road Network obtained from GeoBase.
- Railways obtained from GeoGratis (CanVec).
- BC Corporate Watershed Base hydrography obtained from LRDW.
Somenos
Somenos Lake
Quamichan Lake
Maple Bay
E&N RAILWAY
Hayward
Ecole Duncan
Fire Department
Alexander Elementary School
Cairnsmore Place Seniors Facility
Quamichan Middle School
Somenos Creek
Lakes Road Bridge
Margaret Moss Health Clinic
Cowichan Secondary School
Trunk Road Bridge
Quamichan Ck.
CVRD Office
DUNCAN
JUB Lagoon
Cowichan Lodge
RCMP
Rotary Park
Cowichan Tribes Office
Cowichan Railway Bridge
Well #3
Well #5
Allenby Road Bridge
JUB Outfall
Cowichan River
Cowichan River Hatchery
Mount Tzouhalem
North Cowichan District Mun
Vancouver Island University
Well #2
Quw'utsun Cultural & Conference Centre
Silver Bridge
Well #4
Freshwater Fisheries Society
Marine Harvest Canada
North Cowichan Water Wells
COWICHAN INDIAN RESERVE
RESERVE INDIENNE COWICHAN 1
Pimbury Bridge
Cowichan Tribes Longhouse
Koksilah Highway 1 Bridge
Clem Clem Bridge
Koksilah River
Canada
Koksilah Railway Bridge
Fairbridge
Bright Angel Park
Cowichan Bay
EDITION 5
Stoney Hill
Grouse Hill
Chisholm Island
Skinner Bluff
Genoa Bay
Ecological Reserve 112
COWICHAN LAND DISTRICT

Figure 1.1



LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Jurisdiction Boundaries

Scale - 1:37,000

0.5 0.25 0 0.5 1 1.5 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

Legend

- DUNCAN - City of Duncan
- COWICHAN FN - Cowichan First Nations
- CVRD - Cowichan Valley Regional District
- MNC - Municipality of North Cowichan
- OTHER FN - Other First Nations

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan

VFOC, X:\34878 Cowichan FPM\GIS_PhaseTwo_34878_Cowichan_VFOC_Jurisdictions_11X17_R1.mxd

Figure 1.2

1.5 OUTLINE OF PROJECT

Given the very broad nature of the study NHC recommended that a phased approach be adopted, so that the project goals and objectives could be refined over the course of the project. The main outputs of the project are summarized in three documents:

- Volume 1 – Scoping Report
- Volume 2 – Technical Investigations
- Volume 3 – Integrated Flood Management Plan (this report)

The draft Scoping Report (Volume 1) was issued on September 16, 2008 (NHC 2008). That report included a detailed review of all available information and previous studies, and assessed available methods for hydraulic modelling, floodplain hazard mapping, and habitat inventory and sensitivity mapping. Based on this assessment, recommendations were made on the method of approach, hydraulic modelling and other key outputs for the study.

The draft Technical Investigations Report (Volume 2) was issued on April 15, 2009 (NHC 2009). The report describes the development and testing of a comprehensive MIKE FLOOD hydrodynamic model of the river network and floodplain in the study area. The model was used to simulate a wide range of flood events and scenarios (such as dike breaches, dike raising and climate change). The report summarizes key findings related to hydrology, river hydraulics, sedimentation and channel hazards (erosion and debris jamming) and assesses the capacity of the existing flood control infrastructure.

This report, Integrated Flood Management Plan (Volume 3), builds on the results of the previous findings and integrates this information with concurrent habitat sensitivity mapping and environmental studies. Updated floodplain hazard maps have been produced to provide more realistic depictions of flood hazards by making use of recent advances in LiDAR and GIS technology. The report also recommends long-term strategies and programs for reducing flood damages.

There are three primary limitations to the study scope:

- The study is focused only on the lower floodplain, not the entire basin;
- The study is primarily focused on identifying flood hazards and technical/institutional issues. There is insufficient data for quantifying flood damages or estimating cost-benefits of various flood mitigation alternatives;
- The study relied on the Water Management Plan and periodic input from local government authorities and stakeholders, but did not undertake independent consultations with the community at large.

1.6 OUTLINE OF REPORT

This report consists of nine chapters and three appendices. The main themes of each chapter topics are highlighted below:

Chapter 2: Biophysical Setting provides an overview of the physical and biological characteristics of the study area, particularly its physiography, flooding characteristics, history of floodplain development, aquatic resources and habitat features. It also summarizes information on flood control and fisheries enhancement infrastructure.

Chapter 3: Assessment of Flood Hazards describes the estimated extent of flooding for a range of different flood magnitudes and scenarios. This includes assessing the effect of different dike breaches, assessing the effect of raising the dikes, setting-back selected dikes and assessing the potential climate change impacts (discharge and sea-level rise) on the flooding extent. This information has been condensed from the previous technical report (Volume 2).

Chapter 4: Mapping Tools describes the preparation of new floodplain hazard maps to show the extent of potential flooding and flood construction levels, and presents information on higher hazard “floodway” areas on the floodplain. This chapter also describes the production of various GIS database systems for displaying the flood hazards.

Chapter 5: British Columbia’s Flood Management Climate summarizes the roles of local, provincial, federal agencies, First Nations and other stakeholders in floodplain management and habitat management in the study area. An assessment of the organizations' present capability to undertake integrated flood management is provided.

Chapter 6: Integrated Flood Management-Best Management Practices reviews the evolution of flood control and flood hazard management in various jurisdictions in Canada, the USA and Europe and summarizes the best management practices that have been developed in recent years. The different approaches and issues related to integrated flood management are described.

Chapter 7: Integrated Flood Management for the Cowichan River-Guiding Principles outlines the goals, strategies and key challenges for implementing a comprehensive flood management plan in the region. The chapter also identifies some of the alternative approaches for implementing the plan.

Chapter 8: Integrated Flood Management for the Cowichan River-Proposed Actions provides a portfolio of structural and non-structural initiatives for implementing the adopted strategy. A number of priority projects for upgrading existing flood protection works are described. The next steps and key challenges for implementing the plan are also outlined.

Chapter 9: Conclusions and Recommendations provides key recommendations for upgrading flood protection in the study area and for implementing an integrated flood management program.

2 BIOPHYSICAL SETTING

2.1 STUDY AREA

The Cowichan Valley is located halfway between Victoria and Nanaimo on Vancouver Island. The valley is the traditional home of the Coast Salish First Nations - the Cowichan, or Quw'utsun', whose name has been translated as "back warmed by the sun" or "the warm land". The area has a mean annual temperature of 11°C, the highest in Canada. The valley has a population of about 78,000 and is serviced by the City of Duncan at the centre of the floodplain, with a population of approximately 5,000. The Cowichan Tribes has about 3,800 members.

The first European settlers arrived in the area in 1848. In 1866, when the Esquimalt & Nanaimo (E&N) Railroad was completed, a train stop was installed on farmland belonging to William Duncan. This location later became incorporated as the City of Duncan in 1912.

Forest related industries, agriculture and tourism are the main economic forces of the area. Figure 2.1 shows the primary landuse. The central and eastern portion of the floodplain is primarily agricultural, and agricultural lands also extend along Somenos Creek and Somenos Lake.

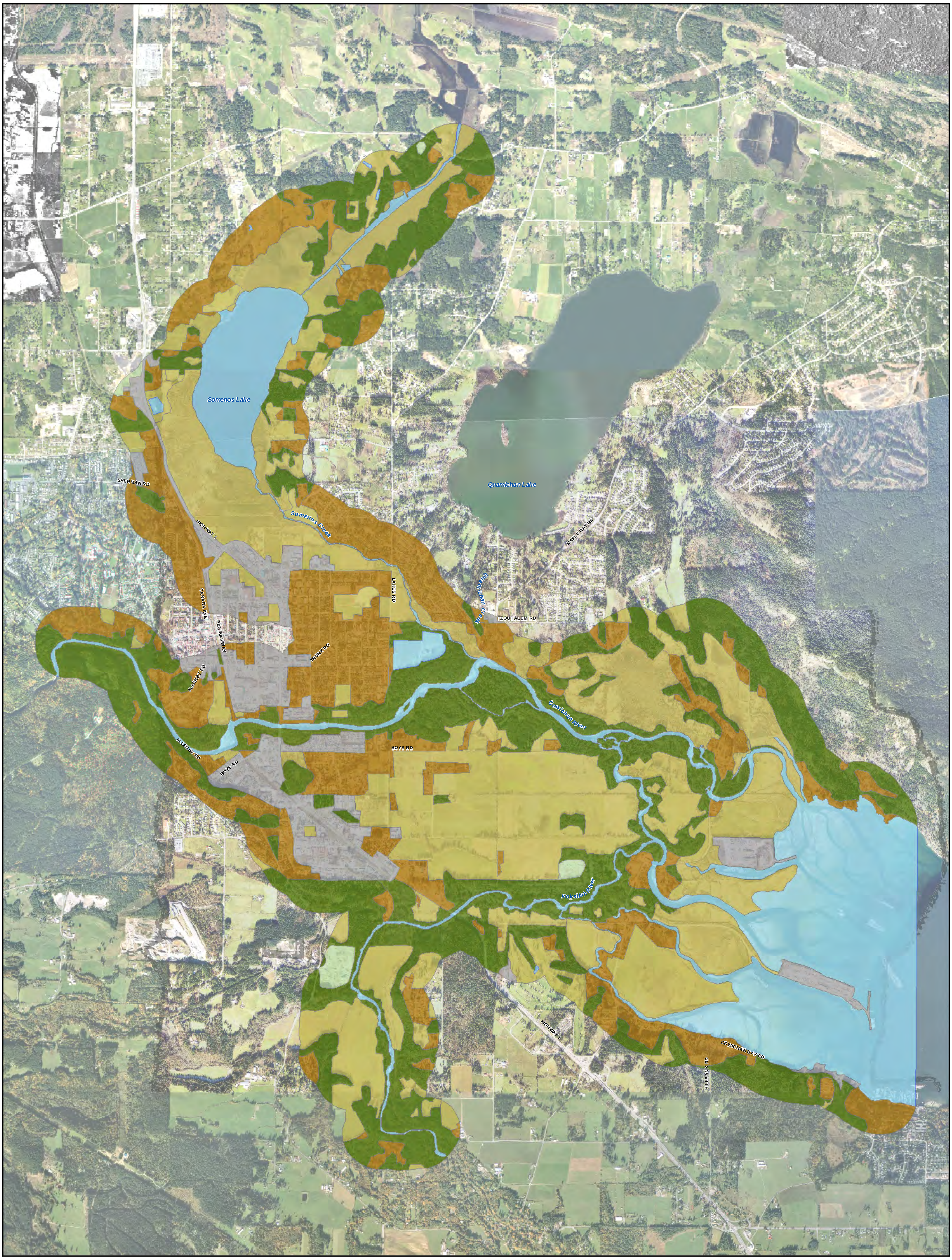
The City of Duncan, Cowichan Valley Regional District, District of North Cowichan and Cowichan Tribes all have jurisdiction within the floodplain. Table 2.1 summarizes the approximate area of the floodplain in each jurisdiction. The floodplain extent is based on the original floodplain mapping carried out by the BC Ministry of Environment (MELP 1997).

Table 2.1: Floodplain Area in Each Jurisdiction

Jurisdiction	Area of Floodplain (km^2)	Percent of Floodplain
Cowichan Valley Regional District	6.5	30
District of North Cowichan	6.0	28
City of Duncan	0.6	3
Cowichan Tribes	8.4	39
Total	21.5	100

The floodplain areas constitute only small portions of the District of North Cowichan and Cowichan Valley Regional Districts (3% and 10% respectively), whereas the floodplain takes up nearly 36% of the Cowichan Tribes lands and 35% of City of Duncan.

The Cowichan River is a Heritage River, recognized for its highly valuable and productive fish habitat. The river supports seven species of salmon and trout including important stocks of chinook, coho and chum salmon, as well as steelhead, brown, rainbow and cutthroat trout.



Legend

Landuse

- Agriculture
- Forest
- Rural
- Urban
- Water
- Other

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Land Use based on 2005 Terra RS Orthophotos

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Flood Management Planning Area
Land Use

Scale - 1:35,000

1 0.5 0 1 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

JXD, X:\34878 Cowichan FPM\GIS_PhaseTwo\34878_JXD_LandUse.mxd

Figure 2.1

2.2 PHYSIOGRAPHY

2.2.1 WATERSHEDS

Figure 2.2 shows a map of the Cowichan-Koksilah River watershed. The Cowichan River has its headwaters at Hooper Mountain (el. 1490 m) near the western end of Cowichan Lake. From Cowichan Lake to just upstream of Duncan, the river flows in a narrow valley, then opens up on to a wide floodplain until reaching Cowichan Bay. The drainage area near Duncan is 826 km^2. Downstream of Duncan, Somenos Creek drains into the Cowichan River from the north. A number of smaller tributaries enter the Somenos system (Bings, Averill, Richards, Quamichan and Tzouhalem creeks and an unnamed creek).

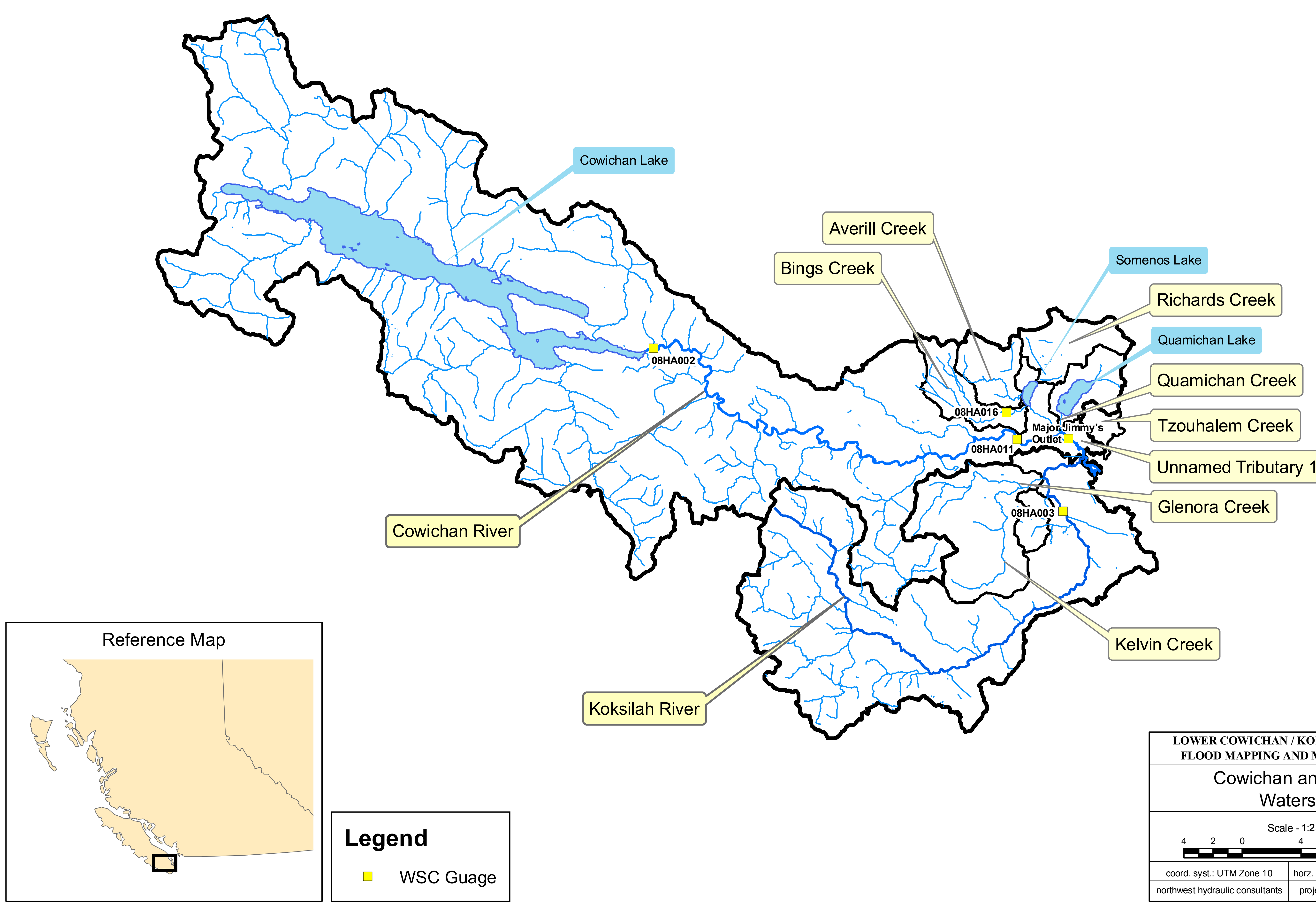
The Koksilah River has its headwaters at Waterloo Mountain (el. 1072 m) and joins the south branch of the Cowichan River approximately 1.5 km upstream of Cowichan Bay. The drainage area of the Koksilah River at Cowichan Station is 209 km^2. Glenora Creek and Kelvin Creek join the Koksilah River about 1.5 km upstream of the Trans-Canada Highway.

2.2.2 TOPOGRAPHY

The Cowichan/Koksilah floodplain covers an area of 21.5 km^2, based on original mapping by the BC Ministry of Environment (MELP 1997).
shows the updated floodplain topography, as determined from 2005 surveys. The Cowichan River exits from a narrow entrenched valley at the upstream limit of the study area, and then spreads over a broad, low-gradient alluvial fan, sloping gently towards the northeast, east and southeast. Without dikes or roadways, overbank flow would be free to spread in all three directions. The elevation of the floodplain is approximately El. 12.5 m where the Trans-Canada Highway crosses the Cowichan and slopes down to El. 1.5 m near Cowichan Bay at an average gradient of 0.002 (0.2 %). By comparison, the Koksilah floodplain at the Trans-Canada Highway is at El. 5 m and its average slope is approximately 0.001 (0.1%).

2.2.3 CHANNEL STABILITY

The river system has undergone significant changes as a result of both natural processes and engineering works. Figure 2.4 compares channel banklines in 1867 and 1946 with the present alignment. The earliest maps show the Cowichan River and Koksilah River flowing across the floodplain in a network of inter-connected channels. Flow from the Cowichan River was directed southwards, joining the Koksilah River just upstream of the present-day Trans-Canada Highway. By 1946 the two southern branches were closed. Figure 2.5 shows subsequent changes that occurred between 1946 and 1962. During construction of the Trans-Canada Highway Bridge, the main channel was shifted north to its present location and the former channel was cut off and abandoned. Significant natural channel changes also took



LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Cowichan and Koksilah Watersheds

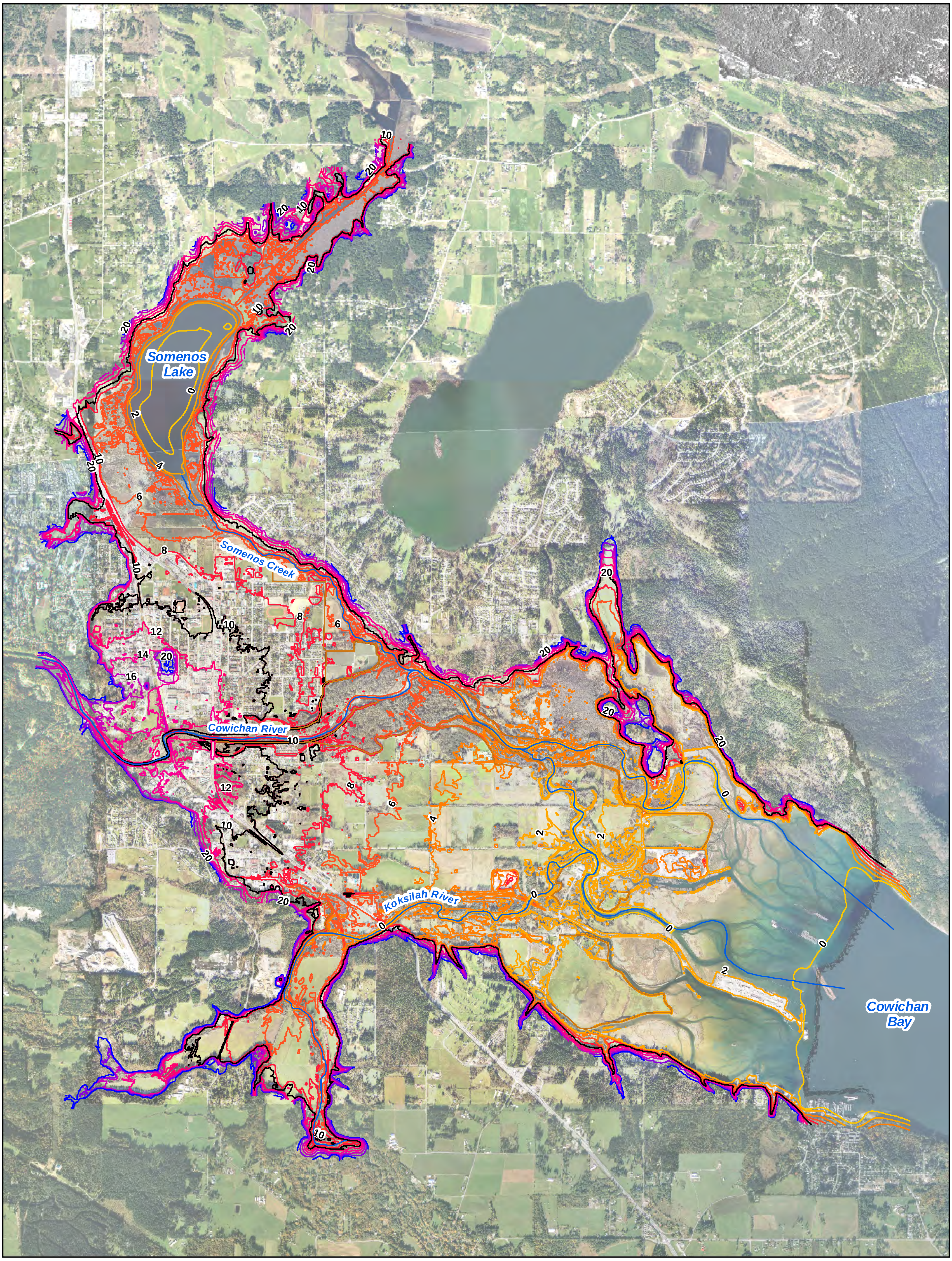
Scale - 1:250,000

4 2 0 4 8 Kilometres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

JXD, X:\Linux\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_DrainageBasins_11X17_R1.mxd

Figure 2.2



Legend

- Cowichan Stream Network
- Dikes
- 10M Contour

Contours (m GSC)

0 2 4 6 8 10 12 14 16 18 20

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Contours generated from: 2005 LIDAR

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Flood Management Planning Area
Topography

Scale - 1:35,000

0.5 0.25 0 0.5 1 1.5 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

Figure 2.3

JXD, X:\34878 Cowichan FPM\GIS_PhaseTwo\34878_Cowichan_JXD_TopographicMap_R1.mxd place downstream near the Somenos Creek confluence. An avulsion through the left bank floodplain created a new island, effectively truncating 600 m of lower Somenos Creek.

As a result of these modifications and dike construction (described further in 2.4.2), a significant proportion of the Cowichan River has been channelized. Most (more than 80%) of the right bank of the Cowichan River is continuously confined by riprap from above the E&N Rail Bridge down to the Tzouhalem Road Bridge, while left bank and North Branch is confined by riprap on about two thirds of its length.

Figure 2.6 summarizes recent channel changes along the lower Cowichan River. Notable channel shifting has occurred at several locations including:

- near the JUB outfall;
- at Somenos Creek confluence;
- near bifurcation of the North and South branches;
- upstream of the Pimbury Bridge on Tzouhalem Rd.

Bank erosion is frequently associated with log/debris jam formation and gravel aggradation. Woody debris on the Cowichan ranges from individual logs found on channel bars to large jams (up to several logs thick) that span the entire channel. A log jam on the Cowichan River in November 2006 triggered up to 100 m of bank erosion near the JUB sewage lagoons (Figure 2.6).

Historic channel surveys from 1977, 1990 and 2008 were analyzed to develop an overall sediment budget of the lower Cowichan River. The analysis was used to provide estimates of gravel deposition rates along the river downstream of the Allenby Bridge. Details of the analysis are contained in Volume 2 – Technical Investigations and is summarized below.

The analysis indicates that the lower Cowichan River is aggrading in the reach extending downstream from the Trans-Canada Highway Bridge to the Pimbury Bridge. Gravel deposition occurs mainly near abrupt changes in channel width (flow expansions) or in sections where the channel slope flattens out. Deposition volumes average in the order of 7000 m^3/year and the deposited material consists of cobbles, gravel and coarse sand. This sedimentation is apparently contributing to recent bank erosion and channel instability near the JUB outfall and lagoons. It may also account for at least some of the increase in flood levels in the area. The source of the gravel bedload is derived from eroding terraces and glacio-fluvial deposits that confine the river below Cowichan Lake (Figure 2.7).

The historic surveys and mapping show the Koksilah River has also undergone plan form change but to a lesser extent than the Cowichan River. Furthermore, there is no evidence of long term sediment aggradation problems on the lower Koksilah River. However, the river is subject to frequent log jams, which can trigger bank erosion, obstruct bridge openings and lead to local increases in flood levels. A major jam on the lower Koksilah River in 2005 blocked the entire channel and damaged the old railway trestle bridge downstream of Highway 1. Log jams provide and create critical habitat features throughout the year and stabilized jams or log accumulations may protect some banks from erosion.

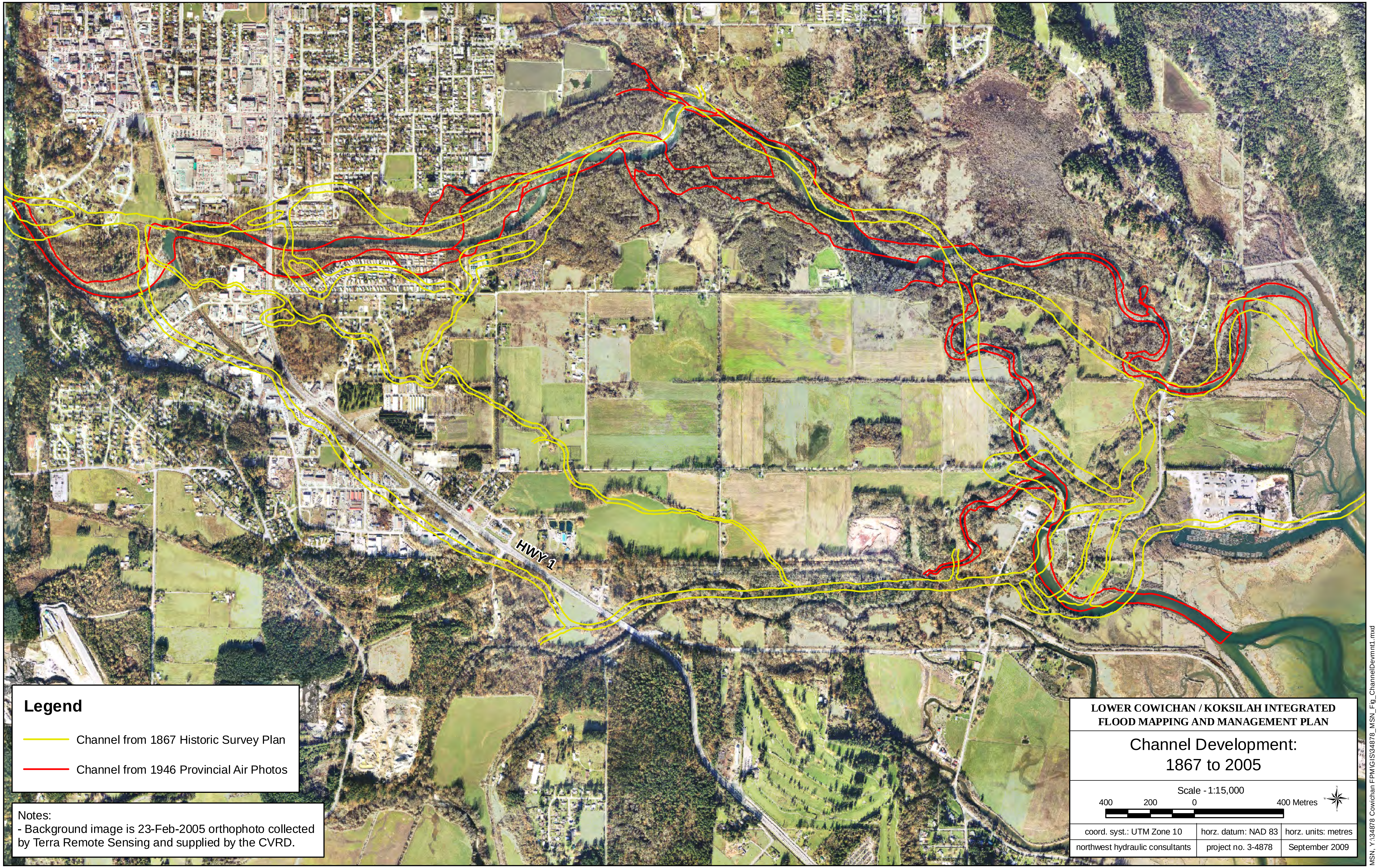

HWY 1
Legend
Channel from 1867 Historic Survey Plan
Channel from 1946 Provincial Air Photos
Notes:
- Background image is 23-Feb-2005 orthophoto collected by Terra Remote Sensing and supplied by the CVRD.
LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN
Channel Development: 1867 to 2005
Scale - 1:15,000
400 200 0 400 Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
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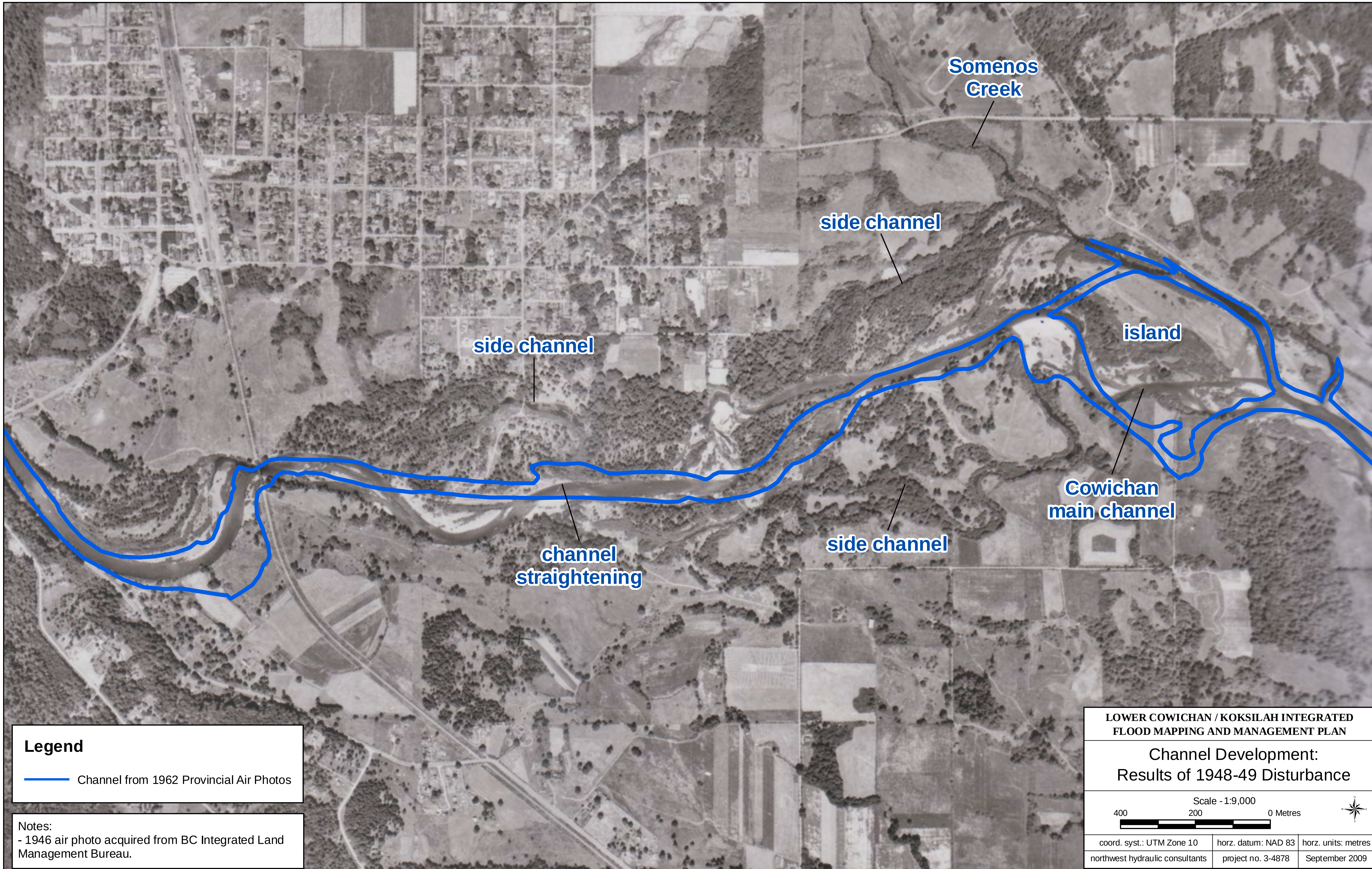
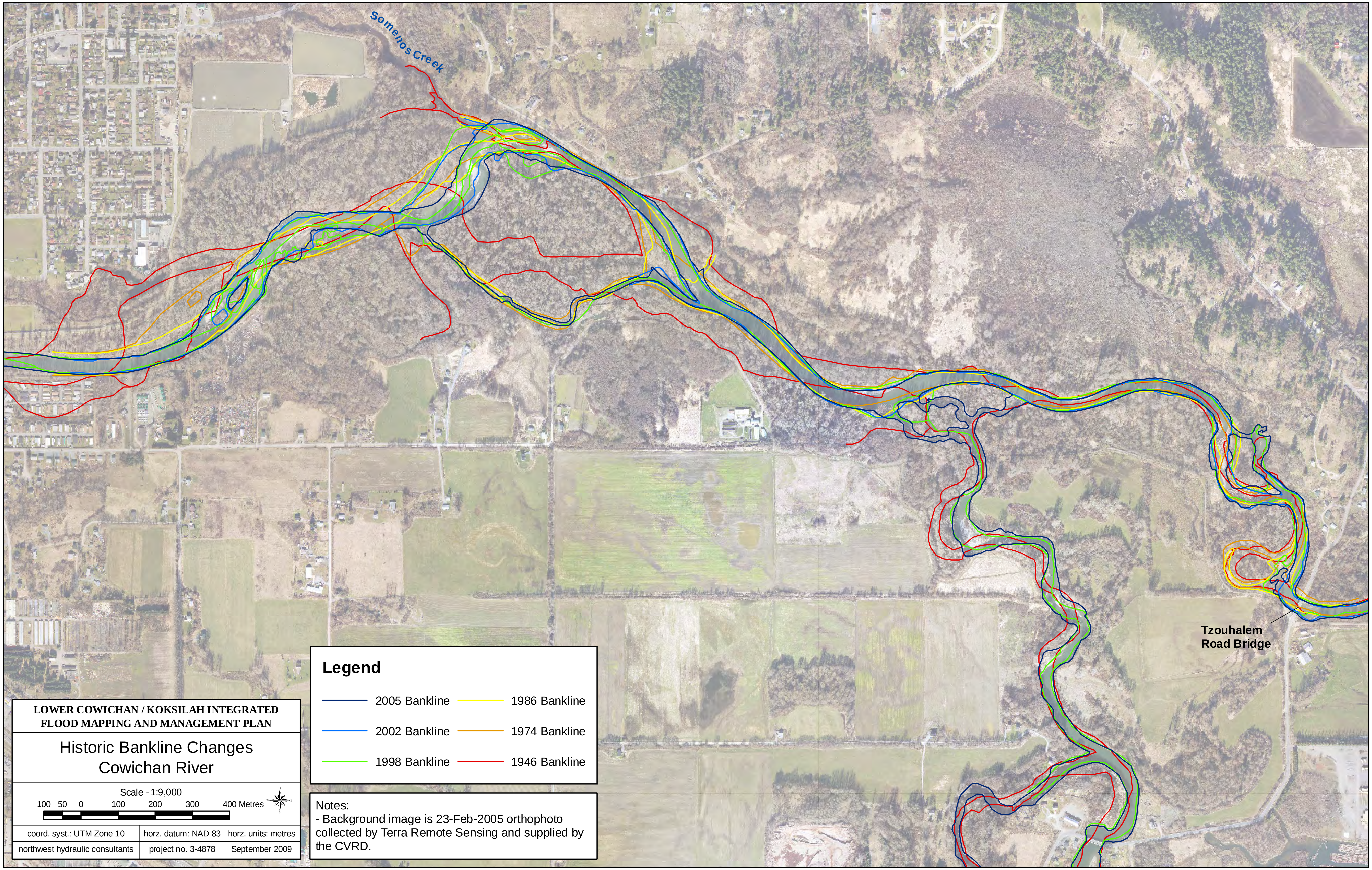
Figure 2.4



MSN, Y:\34878 Cowichan FPM\GIS\34878_JXD_Fig_ChannelDevmnt1948_11X17.mxd

Figure 2.5



MSN, Y:\34878 Cowichan FPM\GIS\34878_MSN_Fig_HistoricBanklineChanges1.mxd

Figure 2.6

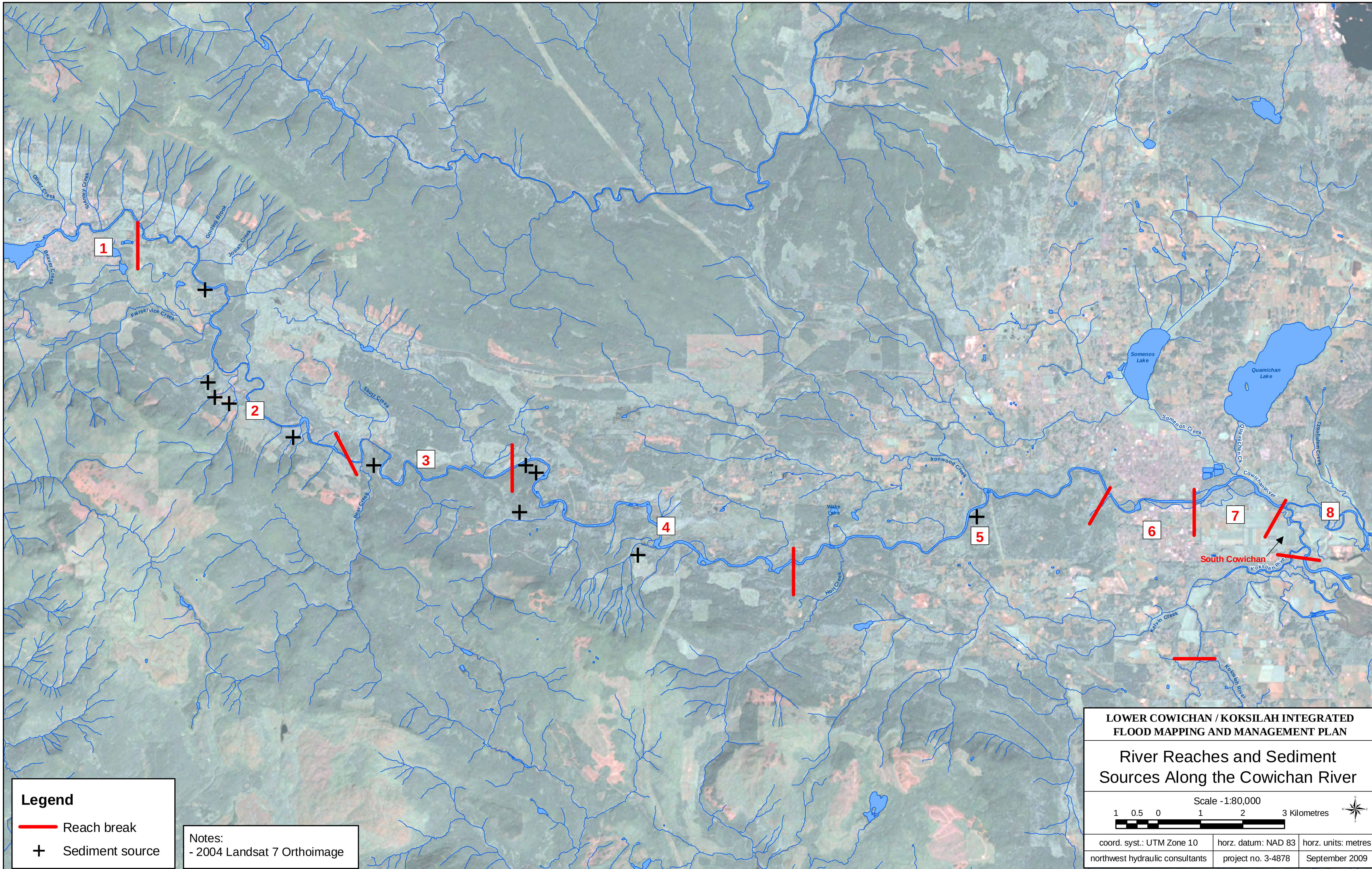


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Figure 2.7

2.3 HYDROLOGY AND OCEAN LEVELS

2.3.1 FLOOD HAZARDS

There are several distinct types of flood hazards on the Lower Cowichan/Koksilah River floodplain, including:

- Flooding on the mainstem rivers due to overtopping of banks and floodplain spills;
- Backwater-controlled flooding on tributaries such as Somenos Creek, where water levels in the Cowichan River control levels upstream in Somenos Creek;
- Flooding governed by high tides/storm surges in Cowichan Bay;
- Erosion, sedimentation and debris jamming which may lead to dike failures, bank breaching or major channel shifting (avulsions);
- Interior flooding and drainage behind dikes related to ponding and flow obstruction;
- Stormwater drainage issues related to urban/commercial development and other upstream landuse changes.

The most severe floods typically occur from November to March as a result of rain and rain-on-snow events, occasionally in combination with extreme high ocean levels. Flooding and bank erosion can be aggravated by debris jams and sediment deposition, so that the most severe flood damages may not necessarily correspond to the most severe hydro-meteorological events.

2.3.2 FLOOD RECORD

The Cowichan Valley has a long history of flooding. Table 2.2 describes 28 large floods between 1892 and 1982 (Septer 2000). Over this period, some degree of flooding occurred on average every three years.

Table 2.2: Historic Flooding Prior to 2000

Year	Date	Assoc. Max. Daily Flow (m^3/s)			Weather Conditions	Reported Flooding
		Cowichan Lake	Duncan	Koksilah		
1892	Dec. 11-21	-	-	-	Heavy rain mixed with snow	Four bridges in the area were washed out. A two-arch railway bridge was battered by logs in the Cowichan river and was destroyed. Cowichan Lake peaked at 2.7 m above normal and cabins on the lake were damaged. Timber waiting to be

Year	Date	Assoc. Max. Daily Flow (m^3/s)			Weather Conditions	Reported Flooding
		Cowichan Lake	Duncan	Koksilah		
						transported down the river was washed away. Total damage at the time was estimated at $0.25M.
1896	Jan. 4-8	-	-	-	Rapidly melting snow in combination with heavy rain	Large areas of Cowichan flats were under water. A Cowichan River wagon bridge (one of the best bridges on the Island) and the Koksilah railroad bridge failed.
1896	Nov. 12-13	-	-	-	Heavy rain	The Cowichan and Koksilah Rivers overflowed their banks.
1921	Oct. 24-29	-	-	-	Rain-on-snow	The Cowichan flats and Westholme areas were inundated. The Duncan wagon bridge was closed. Large quantities of woody debris endangered bridges.
1924	Jan. 28-31	-	-	-	Heavy rain	Cowichan River almost overflowed its banks. Logging operations were suspended.
1929	Dec. 25-30	-	-	-	Heavy rain	Cowichan Lake rose nearly 4.8 m in 5 days.
1930	Feb. 18-30	-	-	-	Heavy rain	The Island Highway was flooded south of Duncan.
1931	Jan. 22-31	-	-	-	Heavy rains for almost 30 days in combination with high tides	Koksilah River flooded a section of the Island Highway. Extensive damage to roads along Cowichan River. Two culverts burst in the Greendale and Lohenholmes areas.
1933	Dec. 19-20	-	-	-	Heavy rain and high winds	Cowichan Flats and Kelvin Creek areas were flooded. Many roads were impassable.
1935	Jan. 31	-	-	-	Rain-on-snow	Both the Cowichan and Koksilah Rivers damaged sections of the highway. Additional damage from mudslide. The Tzouhalem Indian Reserve was flooded.
1949	Feb. 15-23	-	-	-	Rain-on-snow	Logging was disrupted
1949	Dec. 25-29	255	-	-	Rain-on-snow in combination with high tides	Sections of Lake Cowichan Road were inundated by 1.5 m. The Cowichan River was backed up by high tides. The Island Highway was flooded for a distance of over 1.6 km.

Year	Date	Assoc. Max. Daily Flow (m³/s)			Weather Conditions	Reported Flooding
		Cowichan Lake	Duncan	Koksilah		
1951	Jan. 20-25	147	-	-	Rain-on-snow in combination with high tides	Low-lying areas at the mouth of Cowichan/Koksilah were flooded. The Indian Reserve was inundated. The highway was closed.
1957	Feb.22-24	98	-	-	Rain-on-snow	Extensive flooding on Indian Reserve. Many homes on Cowichan Bay Road and Tzouhalem Road were isolated. Some of the flooding resulted from Koksilah River floodwaters being impeded at two bridges.
1960	Jan. 24-29	139	255	157	Rain-on-snow in combination with high tides	A mudslide blocked the highway at Cowichan Bay. A total of eight slides were reported. Homes in Cowichan/Koksilah delta land were cut-off by high river flows. The highway was flooded.
1961	Jan. 9-17	309	558	190	Rain-on-snow in combination with high tides	Fifty families in the Duncan North Cowichan area were evacuated. Large quantities of logs were transported in the rivers. See description below.
62-63	Dec.30-Jan.2	177	306	133	Heavy rain	Cowichan River overflowed its banks. Residents used boats to get around in Duncan.
1963	Dec. 22-23	198	-	134	Heavy rain	The Cowichan spilled its banks in the lower reaches. Cowichan Bay Road was flooded by 0.6 m.
1966	Dec. 9-13	286	362	148	Rain-on-snow in combination with high tides	The Cowichan and Koksilah Rivers overflowed their banks. The Clem-Clem area between the two rivers was worst hit, two families were evacuated and many others stranded. Somenos Creek flood waters were pumped to prevent flooding of homes on Beverly Street. A small dam on the Cowichan River burst causing flooding at the Cowichan Indian Reserve.
1968	Jan. 12-20	326	450	182	Rain-on-snow	Boil water advisory. In Duncan several homes were evacuated due to failure of sewage system.
1971	Jan. 18-19	131	172	108	Rain-on-snow in	Cowichan Bay Road and Trunk Road at Duncan were closed.

Year	Date	Assoc. Max. Daily Flow (m^3/s)			Weather Conditions	Reported Flooding
		Cowichan Lake	Duncan	Koksilah		
					combination with high tides	
1972	Jan. 20-24	106	178	154	Rain-on-snow	The Cowichan and Koksilah Rivers overflowed their banks. The Koksilah River flooded the Cowichan Bay Road by a depth of 1.3 m for 1.6 km. Poor drainage caused flooding at Prevost and Beverly Streets.
1972	Dec. 15-22	129	195	164	Rain-on-snow in combination with high tides	The Cowichan overflowed its banks and flood roads in the valley. The Cowichan Bay and Tzouhalem Roads were closed.
1972	Dec. 25-26	234	425	183	Rain-on-snow in combination with high tides	Beverly Street was flooded; more than 50 families were forced to leave their homes. High tides damaged the docks. The Cowichan Bay area and the Indian Reserve were flooded.
1974	Jan. 12-15	220	343	183	Rain-on-snow in combination with high tides	Homes at Lake Cowichan were flooded by up to 1.2 m.
1975	Nov. 29-Dec.8	236	345	118	Rain-on-snow + earthquake	Mudslide crushed building in west Duncan.
1980	Dec. 23-27	275	385	207	Rain-on-snow in combination with high tides	Flooding of Cowichan Lake.
1982	Oct. 24-30	139	217	123	Heavy rain	The Cowichan River flooded 80 ha of farmland. The river was in the process of changing its course, threatening to wash out the highway. The area just west of Tzouhalem Road was flooded by water up to 1 m deep. An unfinished dike partly contained floodwaters.

Water Survey of Canada (WSC) maintains several hydrometric stations in the area (Figure 2.2). An updated flood frequency analysis for the Cowichan River and Koksilah River, carried out during this study, is described in Volume 2 – Technical Investigations.

The following sections highlight two large historic floods. Photos of a further flood in 1960 are presented at the end of the report.

Flood of 1961

This flood of record on the Cowichan River was estimated by WSC to have a maximum daily flow of 558 m^3/s. Septer (2000) provides a detailed description of the flood:

> *Following a lull in precipitation on January 13, it was hoped the floodwaters of the previous week would subside but on January 15, the Cowichan and Koksilah Rivers flooded their banks again. Overnight and in the early morning, over 150 mm of rain fell in the area. The two rivers swept through the south and southeast fringes of Duncan. A battalion of Princess Patricia's Light Infantry from Victoria was called in to battle floods in the area. It was feared that the hundreds of logs being carried down the Cowichan River might form a large logjam below Skutz Falls. The high tide at Cowichan Bay caused the water to back up south of Duncan. By 2 pm on January 15, hundreds of hectares near Cowichan Bay were flooded to depths of up to 1.5 m. Ted Robson's 120 ha farm was flooded. All the farm buildings were surrounded by water. Nearby Cowichan Bay Road leading off the Trans-Canada Highway was under 2 m of water.*
>
> *The Chevron gas station and the Tall Timbers Café had water up to the windows. According to the operators of the café, this was their 20th flood in the 13 years they had lived there. The last big flood had been in 1955 when similar conditions prevailed. After evacuation, the café operator was unable to check the house because the current was too strong. On January 16, all Duncan area schools were closed. A warning was issued to boil drinking water. In the flooded area 50 homes had been evacuated. Floodwaters were running within inches of the road surface at Allenby Road. The road which runs along the Cowichan River was threatened with closure. Though it remained open, for a short while it was partially blocked by a small landslide. Reservation properties were threatened and several of the homes were in knee-deep water. At the previous week's principal trouble spot, the Wall Street subdivision, water was again lapping at doors and flooding septic tanks. Near Duncan, Tzouhalem Road was flooded and closed to all traffic.*
>
> *In the Somenos Lake area, which usually flooded each year, floodwaters spread out over an area three times the normal size of the lake. The lowest part of the area to the southeast of the city, which was mostly Indian land, was hit hardest by the floodwaters. At least 30 families were evacuated from this area. Civil Defence crews sandbagged dikes at the foot of Beech Street in Duncan.*

In the 1961 flood, one man was believed to have drowned when his boat capsized in the Cowichan River near Duncan. In Duncan, damage to private property was estimated at

$50,000 (in 1961 dollars) and to public works $10,000. In Cowichan, private property damage was estimated at $28,000.

Flood of 2007

Three powerful Pacific storms hit the west coast over a period of five days in early December 2007. The first storm brought cold temperatures and approximately 50 cm of snow accumulation. The next day, the second much warmer storm passed over the valley. This storm along with the third system yielded high rainfall; 114 mm of rain was recorded at the Duncan Kelvin Creek gauge over three days. The temperatures in the valley increased over the course of the storm from below zero to a maximum of 14° C. The rainfall coupled with the increased temperatures caused the snow to melt rapidly, increasing water levels and flows in the Cowichan and Koksilah Rivers. The Koksilah flows were higher than the flows in 1961, but the Cowichan flows were lower and the resulting damage was less severe than in 1961.

This flood resulted in the evacuation of 17 families in the Cowichan area and a boil water advisory for the District of North Cowichan. The bridge abutment and E&N Railway line crossing the Koksilah River was damaged and was closed for three days for repairs. In addition to the closure of some secondary roads, the Island Highway and Cowichan Bay Road were both closed due to flooding. The Island Highway was shortly re-opened but the Cowichan Bay Road remained closed for two days, and the boil water advisory remained in effect for four days. The evacuees were allowed to return home after a few days. Significant flooding was noted in the Koksilah floodplain, immediately upstream of the Island Highway crossing and along Cowichan Bay Road immediately south of the highway. Removal of the major Koksilah log jam in the summer of 2006 reduced the extent of flooding in 2007.

2.3.3 DESIGN PARAMETERS

Design Flows

The 200 year instantaneous maximum flood discharge is commonly specified for assessing flood hazards and for preparing floodplain mapping in BC. A flood frequency analysis was carried out on the available WSC flow records to estimate 20, 50, 100 and 200 year return period flows. In general, the instantaneous flow records are shorter than the daily records and were extended using average ratios of observed maximum instantaneous to daily discharge. Design flows, estimated as described in the Volume 2 – Technical Investigations report, are summarized in Table 2.3.

Table 2.3: Updated Flood Frequency Estimates

Return Period (Years)	Cowichan R. near Duncan (08HA011)		Koksilah R. at Cowichan Station (08HA003)		Bings Creek near mouth (08HA016)	
	Maximum Daily (m^3/s)	Maximum Instantaneous (m^3/s)	Maximum Daily (m^3/s)	Maximum Instantaneous (m^3/s)	Maximum Daily (m^3/s)	Maximum Instantaneous (m^3/s)
20	440	560	230	380	14	21
50	490	620	250	410	14	21
100	520	660	260	430	14	22
200	540	700	270	450	15	23

The updated values on the Cowichan River are similar to the previous 1997 MOE estimates. However, on the Koksilah River the instantaneous values are substantially higher. The main reason is that only a few measurements of maximum instantaneous discharges were available on the Koksilah River at the time of the earlier study.

Design Ocean Levels

Extreme water levels in the lower estuary are a result of high tides and storm surges. An analysis of ocean water levels was conducted to determine appropriate tidal boundary conditions for hydraulic modelling and to provide an updated coastal flood construction level. This analysis is described in detail in Volume 2 – Technical Investigations.

Cowichan Bay is exposed to south-east winds and waves and is more affected by setup than the tide gauges at Fulford Harbour or Patricia Bay. An additional allowance was therefore made for wind and wave setup. The adopted ocean design levels are listed in Table 2.4.

Table 2.4: Estimated Coastal Flood Levels

Return Period (Years)	Ocean Level (m GSC)
25	2.3
50	2.3
100	2.4
200	2.5

2.3.4 EFFECT OF CLIMATE CHANGE

There is a general consensus that the climate in British Columbia is changing, but projections of future scenarios vary. In general, global climate models (IPCC 2007) down-scaled to British Columbia predict warmer and wetter winters in coastal areas, which could result in greater peak flows in the winter months. Some projections indicate the possibility of a 10% to 20% increase in winter precipitation by 2050 relative to mean values for the period 1961-

1990 (CIG 2008). However, predicting local changes to peak rainfall intensity during winter storms and corresponding peak discharges is much more difficult than predicting regional changes to average temperatures or precipitation. Therefore, this issue has been addressed primarily by conducting a sensitivity analysis (varying the peak discharge and determining the effect on the computed flood levels). The following future flow increases were assumed:

- Cowichan River near Duncan: peak flow of 800 m^3/s (15% above instantaneous 200-year event);
- Koksilah River near Cowichan Station: peak flow of 550 m^3/s (20% above instantaneous 200-year event).
- Tributary streams: peak flows increased by 20%.

Higher percentage increases were assumed for the smaller watersheds as they are more sensitive to environmental changes given the smaller areas over which to attenuate increased rainfall volumes.

Long-term sea level increases are also anticipated as a result of global changes in ocean volume caused by (i) melting icecaps and mountain glaciers, and (ii) changes to the temperature or salinity of ocean waters (Thomson et al. 2008). For the flood level sensitivity analysis, the 200-year design ocean level was increased by up to 1.5 m, reflecting upper bound estimates of projected increases by year 2100. The actual sea level rise over the next century may deviate substantially from this assumption. More detail on relevant literature and on this analysis are presented in Volume 2 – Technical Investigations.

2.4 INFRASTRUCTURE

Figure 2.8 shows the key infrastructure located on the floodplain in the study area. The floodplain extent is based on the previous floodplain mapping by the BC Ministry of Environment (MELP 1997).

JXD, X:\34878 Cowichan FPM\GIS_PhaseTwo\34878_Cowichan_JXD_InfrastructureFloodplain_11X17.mxd

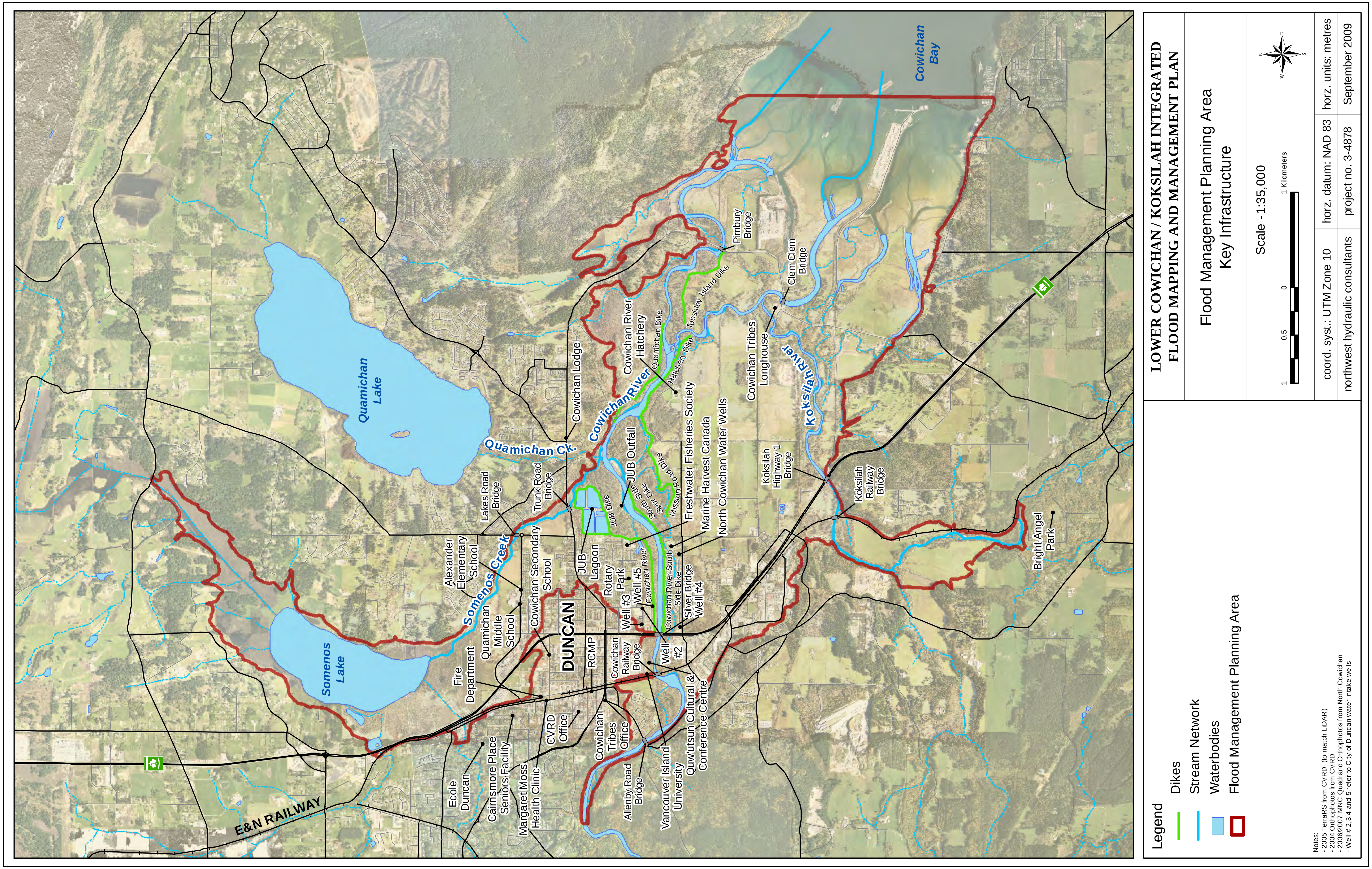


Figure 2.8

2.4.1 ROAD, RAIL AND MISCELLANEOUS INFRASTRUCTURE

The Trans-Canada Highway and the E&N Railway cross the west side of the floodplain and are aligned approximately NW-SE. Table 2.5 lists the main bridge crossings.

Table 2.5: Summary of Bridges in Study Area

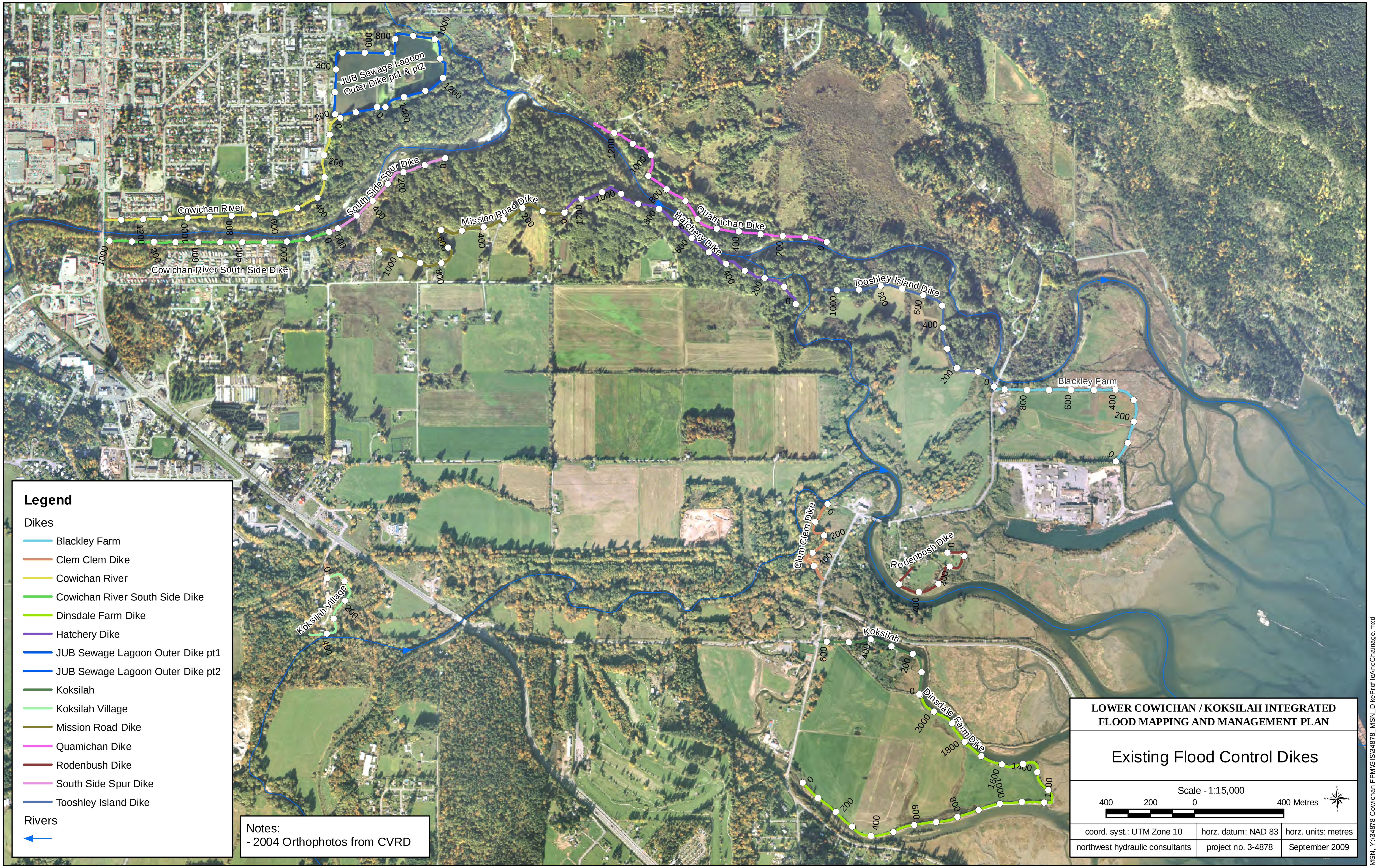
Bridge Name	River / Creek
Clem Clem Bridge (Tzouhalem Road)	Cowichan
Silver Bridge (Highway 1)	Cowichan
Cowichan Railway Bridge	Cowichan
Allenby Road Bridge	Cowichan
Koksilah Highway 1 Bridge	Koksilah
Koksilah Railway Bridge	Koksilah
Pimbury Bridge (Tzouhalem Road)	North Cowichan
Trunk Road Bridge	Somenos
Lakes Road Bridge	Somenos

Other critical infrastructure on the floodplain and immediately adjacent to the River includes:

- JUB sewage treatment lagoons and outfall on the north bank of Cowichan River;
- District of North Cowichan water wells on south bank of Cowichan River;
- Vancouver Island Trout Hatchery (Freshwater Fisheries Society) on the north bank of Cowichan River, raising steelhead, rainbow and cutthroat trout.

2.4.2 FLOOD CONTROL DIKES

Figure 2.9 shows existing flood control dikes, and Table 2.6 lists their governing authorities and lengths. Unfortunately, technical information and maintenance records for many of the structures are either incomplete or totally lacking. The total length of dikes in the area is 14.7 km, with nearly half located on land belonging to the Cowichan Tribes.



JUB Sewage Lagoon Outer Dike pt1 & pt2
Cowichan River
South Side Spur Dike
Mission Road Dike
Quamichan Dike
Hatchery Dike
Cowichan River South Side Dike
Tooshley Island Dike
Blackley Farm
Clem Clem Dike
Rodenbush Dike
Koksilah Village
Koksilah
Dinsdale Farm Dike
Legend
Dikes
Blackley Farm
Clem Clem Dike
Cowichan River
Cowichan River South Side Dike
Dinsdale Farm Dike
Hatchery Dike
JUB Sewage Lagoon Outer Dike pt1
JUB Sewage Lagoon Outer Dike pt2
Koksilah
Koksilah Village
Mission Road Dike
Quamichan Dike
Rodenbush Dike
South Side Spur Dike
Tooshley Island Dike
Rivers
Notes:
- 2004 Orthophotos from CVRD
LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN
Existing Flood Control Dikes
Scale - 1:15,000
400 200 0 400 Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
MSN, Y:\34878 Cowichan FPM\GIS\34878_MSN_DikeProfileAndChainage.mxd

Figure 2.9

Table 2.6: Dikes in Study Area

Name	Diking Authority	Length (km)
Tooshley Island Dike	Cowichan Tribes (CT)	1.08
Hatchery Dike	CT	1.15
Koksilah Village	CT	0.43
Mission Road Dike	CT	1.18
Quamichan Dike	CT	1.20
South Side Spur Dike	CT	1.18
Clem Clem	CT	0.47
Dinsdale Farm Dike	Ducks Unlimited Canada (DUC)	2.04
Rosenbush Dike	DUC	0.54
Cowichan River	City of Duncan	1.37
JUB Lagoons Dike	Joint Utility Board	1.54
Koksilah	Johnston, Ian M.	0.63
Blackley Farm	No Local Authority	0.94
Cowichan River South Side	District of North Cowichan	1.02

The 1,000 m long Cowichan River South Side Dike was constructed in 1983 along the right bank. It starts at the Trans-Canada Highway Bridge and cuts off the former main and side-channels (Figure 2.6). The dike is riprapped over most of its length, but although it is heavily overgrown by vegetation, portions are being actively eroded. The Cowichan South Dike transitions downstream to the South Side Spur Dike, which is lower in elevation, has a narrower crest width, and is generally not protected by riprap.

The Cowichan (City of Duncan) Dike was completed along the north (left) bank in 1987 and extends from the Trans-Canada Highway to the JUB sewage lagoons. This dike is protected by riprap and appears to have been maintained periodically. The perimeter dike around the JUB sewage lagoons is approximately 0.3 m lower than the main dike and is not riprapped.

The Quamichan Dike extends 1.3 km along the north branch of the Cowichan River on its left (north) bank. It is located within the jurisdiction of the Cowichan Tribes. The dike is generally not protected with riprap and is heavily overgrown with vegetation. Hatchery Dike, on the opposite side of the river, is continuously protected with riprap. An intake structure has been constructed through it to supply flow to side-channels for fisheries enhancement. The Quamichan and Hatchery Dikes together produce a noticeable constriction in the floodplain throughout this reach. For example, the width of the floodway between them is typically about 75 m, whereas the corresponding width between the Cowichan Dike (City of Duncan) and the South Side Dike varies from 110 m to 150 m.

Most of the remaining dikes in the region were built with only limited engineering input and have not been maintained over the years. Dikes such as the Tooshley Island Dike, Dinsdale Farm Dike, Koksilah Dike, Rodenbush Dike and Blackley Farm Dike have limited ability to function as flood control structures, since they are either very low or have openings that will allow flood water to enter.

2.5 HABITAT AND FISHERIES RESOURCES

2.5.1 HABITAT TYPES

There are several unique, sensitive and critical habitat types within the Cowichan Flood Management Area including intact riparian ecosystems, off-channel floodplain habitat, marsh and wetland complexes, and extensive estuarine habitat. The following section includes a summary of ecological values within these habitat types based on existing references as well as field observations. More detailed biophysical information is included in Appendix A. Key locations and features associated with fisheries and wildlife are shown in Figure 2.10.

Intact Riparian Ecosystems

Intact riparian habitat provides important features that support biological diversity, structure and function on a floodplain (Photo 2.1). They also provide important migration corridors as well as important nesting and foraging habitat for wildlife species (black tailed deer, black bears, furbearers), and numerous species of waterfowl, shorebirds, songbirds and raptors. For example, mature cottonwood trees within riparian habitat along the Cowichan River provide critical roosting habitat for bald eagles during the fall season as well as important nesting habitat during the late winter and spring.

Legend

- Dikes
- Stream Network
- Waterbodies

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Key Features Associated with Fisheries and Wildlife

Scale - 1:35,000

1 0.5 0 1 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

Figure 2.10

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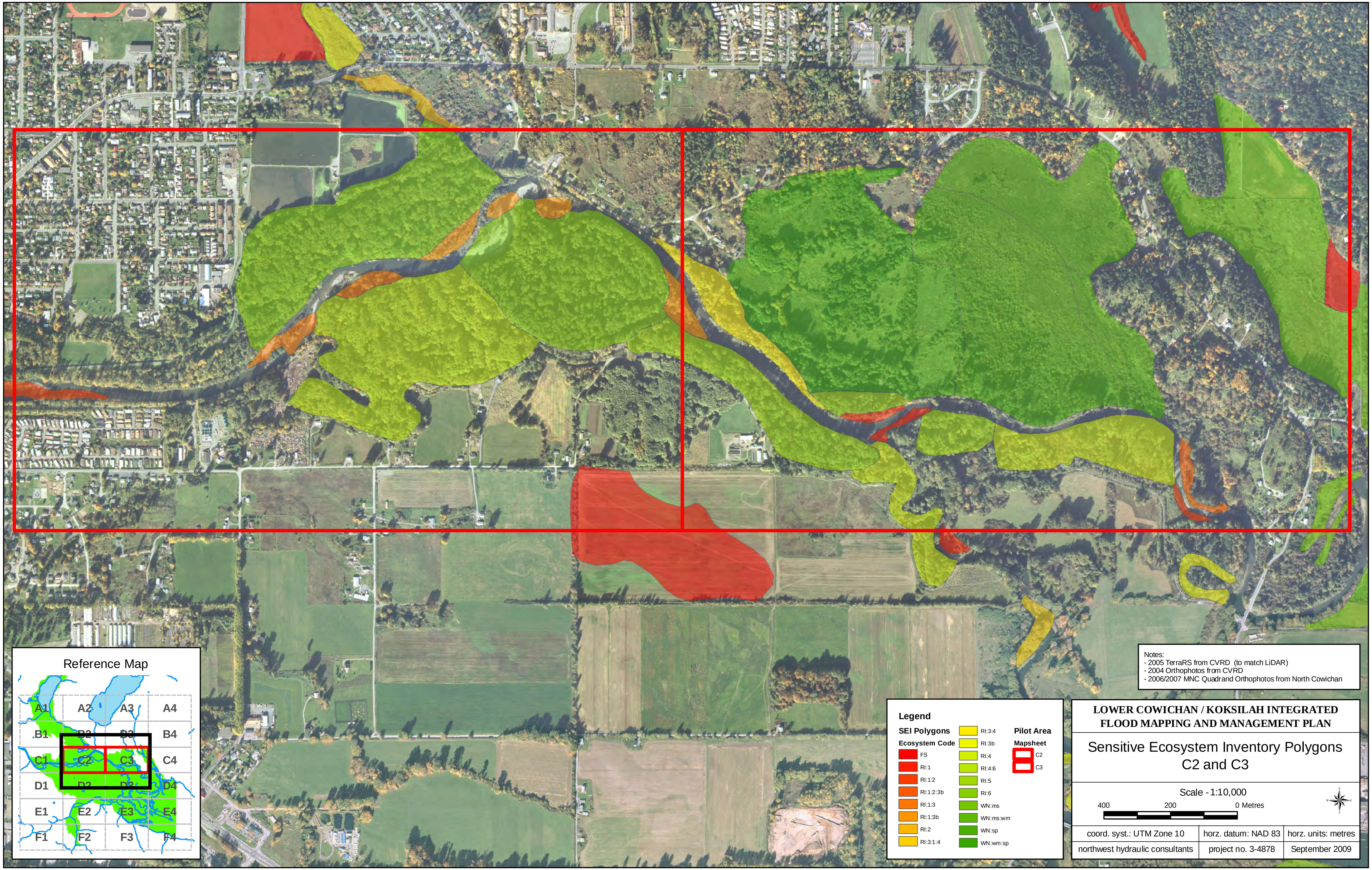


JXD, X:\34878 Cowichan FPM\GIS\GIS\34878_Cowichan_JXD_SEI_11X17.mxd

Figure 2.11

Photo 2.1: Aerial view of the Cowichan River mainstem illustrating mid channel bars at km 4.3 and 4.5 where gravel and debris accumulate and intact riparian habitat extends over both left and right banks with Quamichan Road in the foreground (May 08).

The high value of intact riparian habitat within the lower Cowichan and Koksilah Flood Management area has been recognized by the provincial BC Sensitive Ecosystem Inventory (SEI) program (Figure 2.11).

Off-channel Habitat

Off-channel habitat consists of a matrix of side-channels, backwatered channels, off-channel ponds and sloughs which provide high quality fish habitat. Off-channel fish habitat typically provides a high quality refuge area during peak flows as well as stable overwintering habitat when the mainstem is subject to high flow periods. During summer low flows, off-channel fish habitat offers refuge to juveniles that migrate into the well-vegetated and groundwater fed off-channel habitat (Photo 2.2 to Photo 2.5, and Figure 2.10).

Photo 2.2. Upstream view of Major Jimmy's side-channel where year round flows support high quality spawning and rearing habitat (June 08).

Photo 2.3: Downstream view of the Hatchery side-channel illustrating high value summer rearing habitat, intact riparian canopy with a bankfull width of 10 m and channel gradient of approx 0.5% (June 08).

Photo 2.4: Lateral view of one of the Five Fingers rearing ponds illustrating stable, high quality year round rearing habitat, with enhanced LWD cover as well as wildlife habitat enhancement including bird and bat nesting boxes (June 08).

Photo 2.5: Overbank flooding at right bank near km 5.1 and flooding into Fish Gut alley at discharge of 33 m^3/s. (February 17 09).

A total of 159 side-channels have been catalogued throughout the Cowichan River watershed and have been categorized according to 4 types: flood, back, active, and relic channels (Burns 2002, Burns et al. 1988). Active channels have high fisheries value as they support fish year round with sufficient year round flows that provide good quality spawning and rearing habitat. Relic channels represent historical locations of the mainstem and are typically isolated from the mainstem but often have high restoration potential (Burns et al. 1988). For example, Major Jimmy's Channel, Hatchery Channel and Fish Gut Alley are all active channels that currently support significant numbers of chum, coho and trout spawners.

Off-channel habitat within the Koksilah River is less abundant relative to the Cowichan River. The majority of these channels are seasonally wetted and provide good quality winter rearing habitat. Salmonid production within side-channel habitat is currently limited by low summer and early fall flows, fish access, adequate cover, and suitable spawning substrates. Wood debris is the most important cover type in off-channel habitat for both trout and coho (Fielden and Holtby 1987).

Estuarine Habitat

The complex ecology of the estuary provides the foundation for a critical food supply and unique, year round habitat for fish, shellfish, mammals and bird species (Law 2008). The estuary also provides valuable migration and year round rearing habitat for salmonids and trout species (Law 2008, MOE 1994).

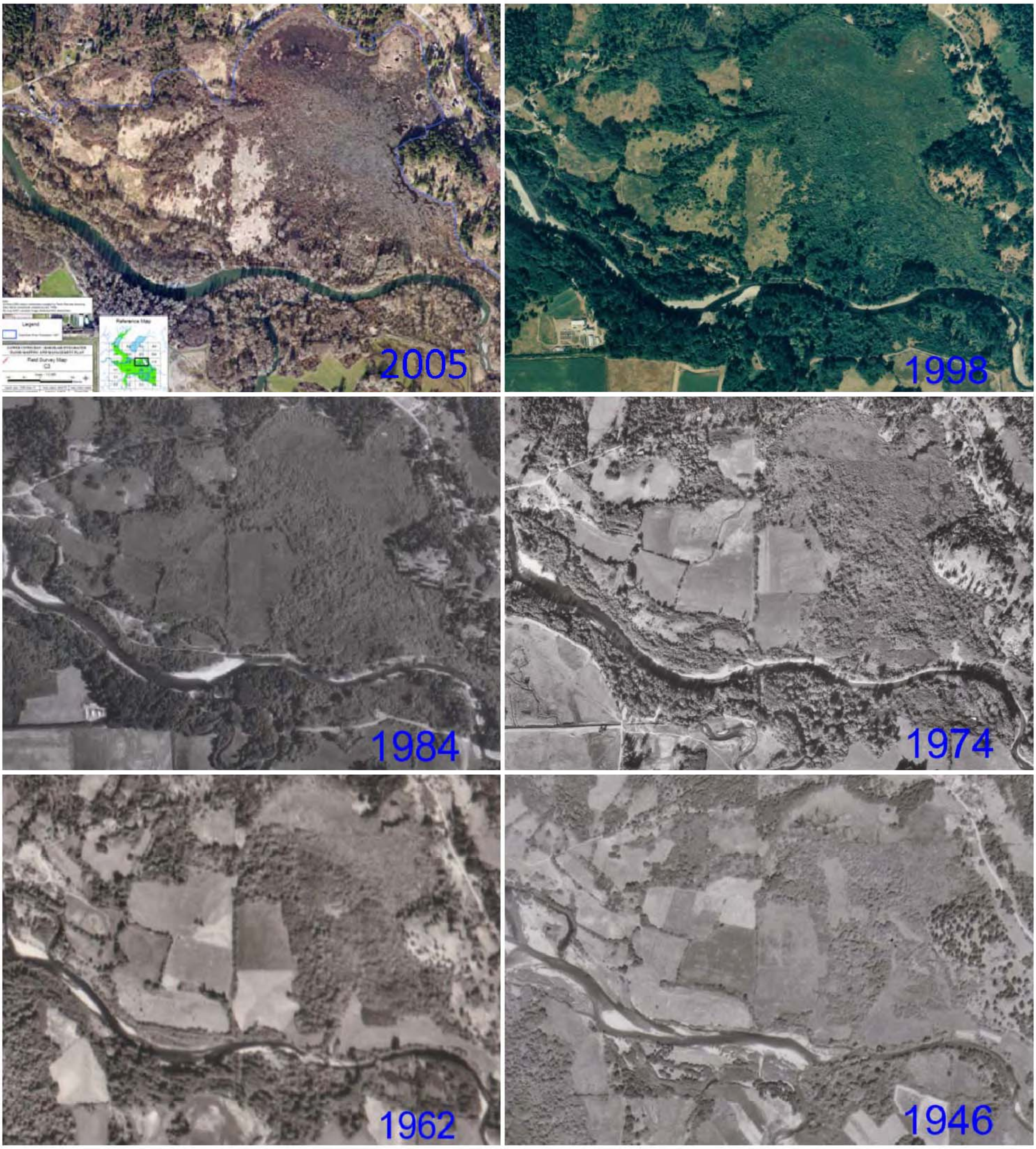
The Cowichan River estuary is one of the largest estuaries in BC encompassing approximately 4.9 km^2 with 277 hectares of intertidal area (Figure 2.10; CETF 1980, Williams and Langer 2002). The estuary provides a nursery area for many species of fish (including salmonids, sole, herring, sand lance, *Cottidae* species) and invertebrates during their early life stages.

The Cowichan estuary is a regionally important migratory bird staging area within Georgia Strait as well as an overwintering site for waterfowl that nest in Alaska and northern BC (MOE 1994). The estuary also supports at least 12 waterfowl species (loons, grebes, ducks, gulls, cormorants) as well as numerous shorebirds, herons and raptors on a year round basis. The estuarine habitat at Khenipsen Road also provides significant wildlife habitat for migrating waterfowl as well as an abundance of sites for breeding and nesting birds (Figure 2.10, Jones 2005).

Marsh and Wetland Habitat

A healthy marsh can support abundant life including grasses, birds, fish, and invertebrates. The estimated 62 ha Priest's Marsh supports abundant bird habitat and is known to provide year-round off-channel rearing for salmonids within the eastern portion where an estimated 5.1 ha of backwater channels occur (Burns 2002).

Based on reconnaissance level field sampling completed in 2008, soil and vegetation characteristics within Priest's Marsh are consistent with wetland ecosystems. In the early 1900s, farm settlement in the Priest's marsh area resulted in changes in landcover and drainage within the wetland (Figure 2.12). Priest's Marsh was historically dominated by facultative hydrophytes in the vegetation community and received seasonal inundation from



LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Historic Changes
Priest's Marsh

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 1946 air photo from BC Integrated Land Management Bureau.

northwest hydraulic consultants	project no. 3-4878	September 2009

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Figure 2.12

mainstem flooding. The most significant changes to the wetland ecosystem occurred between the 1940s and 1980s during agricultural development, which included wetland drainage alterations, clearing, and the construction of Quamichan Dike. Cessation of agricultural activity in Priest's Marsh occurred in the late 1980s.

2.5.2 FISHERIES RESOURCES

The Cowichan River is recognized as one of the most important and productive fish bearing rivers on Vancouver Island based on the abundance and variety of salmonid species.

Anadromous fish species present in the study area include a fall run of chinook salmon (*Onchorhynchus tshawytscha*), coho salmon (*O. kisutch*) and chum salmon (*O. keta*). There is a strong run of winter run steelhead (*O. mykiss*) and limited presence of sea run cutthroat trout (*O. clarki*) (Burns 2002). A small run of summer run chinook is present and both sockeye (*O. nerka*) and pink salmon (*O. gorbuscha*) are typically rare. However, during the fall of 2007, a small run of pinks were observed in the lower Cowichan River.

Indigenous resident fish species include rainbow trout (*O. mykiss*), cutthroat trout (*O. clarki*) and Dolly Varden char (*Salvelinus malma*). Brown trout (*Salmo trutta*) were introduced during the 1930s and have successfully colonized the system, but with limited presence in the lower reaches of the Flood Management Planning Area (LGL 2005). Landlocked sockeye (kokanee) are resident to Cowichan Lake (Burt and Wightman 1997). Introduced species within the study area include the pumpkinseed fish (*Lepomis gibbosus*), three spine stickleback (*Gasterosteus aculeatus*), prickly sculpin (*Cottus asper*) and various lamprey species (*Lampetra spp.*) (Hanelt 2002).

Fish habitat values are high or very high throughout the entire lower Cowichan/Koksilah flood management area due to the extensive system of accessible, low gradient channels that are interconnected with sloughs and backwatered ponds. The abundance of high quality mainstem and side-channel spawning habitat is primarily utilized by chum salmon, coho salmon and trout species with a small number of the chinook spawners in the mainstem Cowichan during some years as well.

There are four fish hatchery facilities located in the lower Koksilah/Cowichan Rivers and include the Vancouver Island Hatchery operated by the Freshwater Fisheries Society of BC adjacent to the EcoCenter, a Fisheries and Oceans Canada hatchery operated by the Cowichan First Nation and two private hatcheries raising Atlantic salmon (Figure 2.10).

The limiting factors to fish production in the Cowichan and Koksilah Rivers are associated with water quality and water quantity caused primarily by high water temperatures during the summer low flows and suspended sediment loads.

2.5.3 CONSERVATION AREAS

Several ecological parks and conservation areas have been established within the Cowichan Flood Management Area to sustain valuable and sensitive ecological features (Figure 2.10). To date, these include:

- **Cowichan Bay Farm:** In 1990, the Nature Trust and partners in the Pacific Estuary Conservation Program acquired the 51 ha farm. The goal of this managed farm is to improve wildlife habitat while providing the opportunity to farm to the local agricultural community. The seasonally flooded cultivated fields provide prime foraging opportunities for waterfowl during the critical migratory and wintering periods.
- **Maple Grove Park**: In 2002, the park was designated as a CVRD park in a management partnership between Nature Trust of BC, MWLAP, CVRD and the CB Improvement Project. Located on the Nature Trust Cowichan Bay Farm property, Maple Grove Park includes Koksilah Grove, a 2 ha park of old growth native Big Leaf Maple Trees (*Acer macrophyllum*).
- **Blackley Farm:** As an agricultural improvement, a dike was constructed around the farm in 1978
- **Somenos Marsh Wildlife Refuge:** In 2000, an IBA was established over an area of 2 km^2 including Somenos Lake, the lower reaches of 4 creeks as well as a wildlife refuge and heronry on the west side of the Trans-Canada Highway (IBA 2004). Managed by the Somenos Marsh Wildlife Society (since 1989), Nature Trust BC, and Ducks Unlimited (since 1994), the Somenos Lake, wetlands, marsh, and cultivated fields collectively provide high quality habitat for wildlife, birds and fish. As well, Somenos Marsh provides regionally significant foraging and staging habitat for waterfowl.
- **Somenos Garry Oak Protected Area:** Established to protect one of the most endangered ecosystems in Canada, the protected area is 10.5 hectares in size and located on the edge of Somenos Lake and Marsh, southwest of the lake outlet (Figure 2.10; Williams et al. 2003). Prior to the 1850s, Garry Oak ecosystems covered tens of thousands of acres in the Cowichan Valley. Restoration of Garry oak ecosystems is ongoing through partnership efforts between the Nature Conservancy of Canada, BC Parks and the Garry Oak Ecosystems Recovery Team.

2.5.4 KNOWN SPECIES AT RISK

According to the existing SARA and COSEWIC database maintained by Environment Canada (GOC 2009) and Williams et al. (2003), a minimum of 26 endangered species have been confirmed or are likely resident to the Cowichan Flood Management Planning Area. Detailed information on known species at risk is included in Appendix A.

2.5.5 ENVIRONMENTAL IMPACTS OF PAST LANDUSE ACTIVITIES

Resource development, flood management activities and landuse within the Cowichan Flood Management Area have altered natural flood characteristics as well as natural ecological features and function of the floodplain. Historical impacts of resource use on ecological values within the Flood Management Area include:

- ***Channelization and loss of flood capacity:*** Construction of standard engineered dikes (south side and north side dikes) as well as non-standard or orphan dikes (Quamichan, Hatchery dike) has resulted in channelization and a reduction of flood capacity of the Cowichan mainstem (Figure 2.10). Habitat complexity, connectivity and riparian function have been altered with the loss of floodplain connectivity affecting available stream flows and fish access to off-channel habitat. Within the lower Cowichan and Koksilah Rivers, there is an abundance of both isolated and connected off-channel and remnant channel habitat.
- ***Loss or alteration of sensitive estuarine habitat***: Since 1962, European settlers have constructed dikes for agricultural purposes and flood protection (Williams and Langer 2002). Diking and development of cultivated fields has altered natural flow patterns over the floodplain and tidal habitat. As early as the 1880s, there has been infilling for industrial and commercial development, log storage and booming activities (Law 2008). Long term log storage activities result in anoxic conditions and compacted sediments within the estuarine substrates that reduces the abundance and diversity of aquatic plants (i.e. eelgrass) and benthos, thereby decreasing the overall productivity of the estuary. The majority of log handling and storage activities occurred in the north estuary and may therefore have affected the colonization of high value eelgrass beds. A subtidal habitat study identified accumulations of organic debris where the presence of a sulphur reducing bacteria *Beggiatoa* was observed, indicating the presence of oxygen poor sediments (Clarke 2005). Estuarine habitat has also been infilled for land reclamation as well as dredged to sustain access to port facilities.
- ***Loss of functional riparian habitat:*** Historically, there has been a loss of functional riparian habitat within the Flood Management Area. Starting in the 1920s, the CN Railway line was constructed along the Koksilah River as well as the Westcan Terminal roadway constructed in later years to connect inland logging to the estuary (Law 2008). More recently, agricultural and rural residential development has altered natural riparian and shoreline habitat features by removal of the native riparian canopy for construction of roadways, flood protection dikes and other erosion control features. Loss of natural riparian habitat features reduces shade, food supply, and recruitment of LWD to the stream channel. Furthermore, nesting, foraging and roosting habitat for shorebirds, songbirds and raptors is lost and important migration and foraging habitat for deer, black bear and other furbearers is reduced. Over time, impacts to riparian habitat have recovered with a few permanent alterations within the Flood Management Area.
- ***Decreased water quality:*** Water quality within the mainstem Cowichan River and estuary has decreased as a result of high summer water temperatures, non point sources of pollution, runoff from agricultural areas, increased sediment

loads from upstream sources and potential impacts from sewage treatment facilities.

- ***Loss of channel stability, increased bank erosion:*** Channel stability along the mainstem Koksilah and Cowichan Rivers has been decreased due to increased peak flows from historical logging and agricultural development upstream of the Flood Management Area. In some cases, shoreline flood protection dikes have channelized stream sections and increased bank erosion downstream (LGL 2005).

2.5.6 HABITAT RESTORATION EFFORTS

Habitat restoration activities have been ongoing in the lower Cowichan floodplain area for several decades and are summarized in Table 2.7 according to six general habitat restoration categories. Restoration projects to date in the study area include five side-channels constructed by partnership groups including Cowichan Tribes, Federal, Provincial and Regional governments.

Table 2.7: Summary of Major* Habitat Restoration Projects by Category within the Cowichan Flood Management Planning Area.

System	Habitat Restoration Category					
	Flow Augment-ation	Off-channel Develop-ment	Bank Protection	Gravel/ debris Removal	Channel Excavation	Fish Passage Improvement
Cowichan Mainstem			2	2		
Cowichan Offchannel	3	5				
Somenos Mainstem					1	1
Koksilah Mainstem			2	2		
Koksilah Offchannel						
TOTAL	3	5	4	4	1	1

* Some projects that were undocumented or smaller scale may not be included in this summary table. Several estuarine restoration projects have been undertaken and are not included in this summary table.

Previous notable studies undertaken in the Cowichan-Koksilah Flood Management Planning Area describe fish habitat restoration opportunities, including Lill et al. (1975) and Burns (2002). Restoration concepts identified by these studies have been instrumental in the implementation and adaptation of projects carried out by ad hoc partnerships often including Cowichan Tribes. In 2004 Cowichan Tribes initiated the Cowichan Recovery Plan, which was completed by LGL in 2005. While the Cowichan Recovery Plan was intended to support ongoing treaty negotiations it has also served as an important planning tool as well as a starting point for a community partnership group known as the Cowichan Stewardship Round Table (CSRT).

Current habitat restoration strategies are typically coordinated by the CSRT, including Cowichan Tribes, government, industry and NGOs. The CSRT received the National River Conservation Award in 2009 for the three year river restoration project completed at Stoltz Bluffs, which is the largest instream restoration project on Vancouver Island to date.

Selection of Restoration Projects

Selection for habitat restoration projects is dependent on several factors including:

- Available funding sources
- Criteria established by various funding agencies depending on priority watersheds, target species, benefit/cost analysis or annual focus (i.e. water management planning, species enumeration, habitat assessments versus instream habitat restoration, fish passage, bank stabilization, etc.)
- Project rationale and relevance to ecologically based limiting factors for production
- For Ministry of Transportation funding, eligibility of a project is based on past environmental impacts of linear development at or near the proposed habitat restoration site or in compensation for another site impacted by linear development
- Requirement as compensation works for proposed development or maintenance works

Permitting Requirements

Agency permitting is required for all instream works including habitat restoration projects. Required permitting can involve a “Notification” to a Federal and Provincial Agency or similar representative, when the proposed works do not require an intensive agency review and approval process. These projects are typically endorsed or being managed by a government agency or First Nations group. Other habitat restoration projects may require a more formal review and an associated “Approval” for the proposed works to proceed, depending on the proponent as well as the nature of the proposed instream restoration works. Any proposed development within the estuary is subject to the environmental review process established through the Estuary Management Plan.

Proposed instream habitat restoration works are typically scheduled during the fisheries instream low risk window that takes place in the Cowichan and Koksilah Rivers between July 15 and September 15 annually. Chinook can migrate into the system as early as July but don’t typically spawn till early October (B. Rushton personal communication). Other salmonid species including pinks can migrate into the lower river prior to mid-September with mitigative measures undertaken to minimize risk and stress to the spawners as well as to facilitate uninhibited upstream migration.

The proposed project description, engineered drawings, construction plan and environmental plan are submitted and discussed with the following permitting agencies prior to submission of the permit requests for instream habitat restoration or flood protection works. Specific permitting requirements for each project are dependant on land ownership or jurisdiction, the nature of the proposed instream works, proponent and whether they have status as emergency measures. Some agencies will request an onsite inspection to review details of the project prior to issuing the permit. The following table illustrates potential permitting requirements for proposed works in the Cowichan River.

Table 2.8: Permitting Requirements for Instream Works

Agency	Permit Type
Fisheries and Oceans Canada (FOC), Duncan	Fisheries Act Authorization or Letter of Advice
Cowichan Valley Regional District	Permission for Works Permit
Min Water, Land and Air Protection (MWLAP), Nanaimo	Section 9 Approval or Notification
Min of Environment	Watershed Stewardship
Min of Environment	Environmental Protection
District of North Cowichan	Permission for Works
Cowichan Tribes	Permission for Works
City of Duncan	Permission for Works
Transport Canada, NWPD	Navigable Waters
Permit & Authorizations Services Bureau	Fish collection permit

3 ASSESSMENT OF FLOOD HAZARDS

3.1 NUMERICAL MODELLING METHODOLOGY

The program MIKE FLOOD developed by the Danish Hydraulic Institute (DHI) was used to model the complex river-floodplain system in the study area. MIKE FLOOD is a comprehensive modelling package that can integrate floodplains, streets, rivers and sewer/storm water systems into one comprehensive numerical model. The program has been widely adopted in Europe and the USA and has been approved by the US Federal Emergency Management Authority (FEMA) for regulatory and flood insurance investigations.

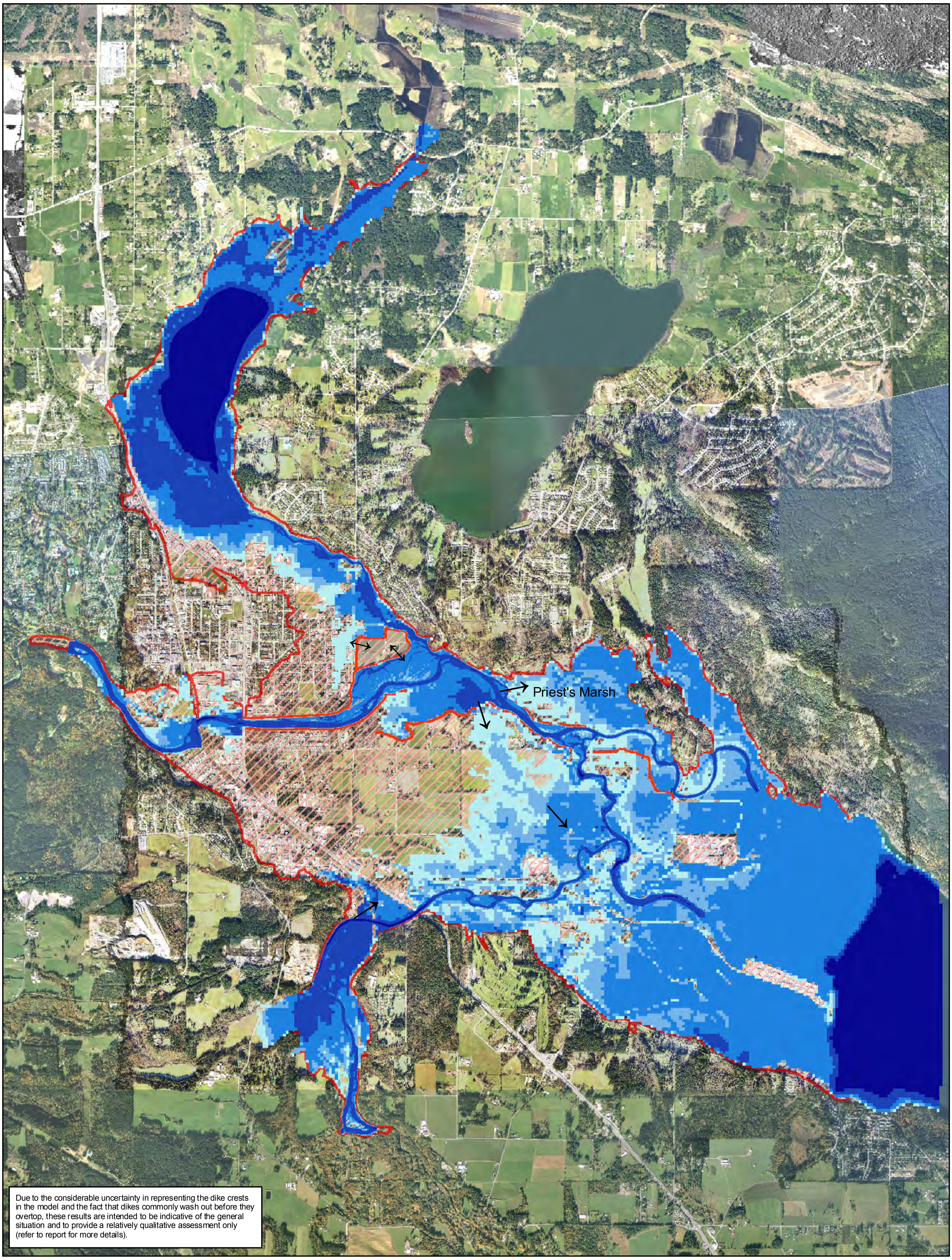
The program incorporates a combination of one-dimensional (MIKE 11) and two-dimensional (MIKE 21) numerical routines. The MIKE 11 model was used for simulating discharges, water levels and other hydraulic parameters in confined sections of the river or when flows remain below bankfull stage. This model simulates the branched network of channels that form the entire Cowichan/Koksilah River system and its tributaries. It also simulates tidal effects in the lower reaches and unsteady flow variations during flood events. However, it is not possible to simulate overbank flooding on wide, complex floodplains with localized spills and bank breaching in any one-dimensional model. These floodplain processes were modelled with the two-dimensional MIKE 21 model. The two models are inter-connected by the MIKE FLOOD software, and the results can be integrated with ArcGIS software and viewed in other spatial mapping products including Google Earth.

Volume 2 – Technical Investigations summarized the field survey program, development, testing, calibration and verification of the model, and also described the various flood scenarios that were assessed over the course of the study. This present chapter provides a brief overview of the key findings.

3.2 PRESENT CONDITIONS

Initial simulations were made of various flood events using existing dike conditions. There is considerable uncertainty in attempting to specify the actual discharge capacity of the existing dikes. Topographic surveys showed that many dikes have irregular profiles with localized low spots caused by road crossings, past erosion or settlement, or openings for trails. Also, the accuracy of the LiDAR surveys was affected by heavy overhanging vegetation that obscured the ground in some locations. The capacity problem is compounded by the fact that dikes commonly wash out before they overtop, particularly if a flood is of long duration (Nagy 2008). Therefore, these initial runs were intended to be indicative of the general situation and to provide a relatively qualitative assessment. The principal results are described below.

Figure 3.1 shows simulated maximum water depths over the duration of a 200-year flood event, with the existing dikes in place. The calculated water level overtops the crest of the



Legend

Channelized Flows and Overbank Spilling

Flood Depth (m) - Freeboard not included

- 0.15 - 0.6: most houses are dry; walking in moving water is potentially dangerous
- 0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
- 1.0 - 2.0: ground floor flooded; residents evacuate
- 2.0 - 5.0: first floor and often roof covered by water; residents evacuate
- > 5.0
- Dikes
- Flood Management Planning Area - Potential Inundation and Ponding

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation folder name: C_nhc_D_200a_1.couple

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Modelling Results - Existing Conditions
200 Year Flood Water Depth

Scale - 1:35,000

1 0.5 0 1 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

Figure 3.1

JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_200_a (existing).mxd

JUB lagoon dike, which would result in a breach of the lagoons into the City of Duncan. The Mission Road Dike is overtopped and spills water across the floodplain, which eventually flows back into the channel near the junction of the South Cowichan and the Koksilah rivers. The Quamichan Dike is overtopped, allowing water to spill towards Priest's Marsh. General inundation occurs on both sides of the Tooshley Island Dike, but the Cowichan South Side Dike and Cowichan (City of Duncan) Dike[1] contain the flow.

Major spills occur along the Koksilah River both upstream and downstream of the Trans-Canada Highway. Portions of the E&N Rail line are overtopped, as is the Koksilah Village dike at its upstream end. The Trans-Canada highway is also overtopped north of the Koksilah Bridge. Backwater-induced flooding occurs in the lower end of Kelvin Creek. Since widespread spilling occurs over the river banks and between dikes, the floodplain conveys a significant portion of the total flood discharge.

3.3 EXISTING INFRASTRUCTURE

Table 3.1 summarizes the overall condition of the main dikes in the study area using three main criteria:

- Flood capacity of the dike with adequate (1 m) freeboard;
- Risk of erosion;
- General maintained condition of the dike, with "fair" or lower indicating maintenance is required.

Dike locations and stations are shown in Table 3.1.

Table 3.1 : Summary of Dike Conditions

Dike	Dike Capacity Return Period (Years)	Erosion Risk	General Maintenance Condition
Cowichan (City of Duncan)	25 (~ 400m section D/S of Hwy 1 bridge) 100 (rest of dike)	low	moderate to good
JUB Sewage Lagoons	< 25	moderate	moderate
Cowichan South Side	25	moderate	fair
Quamichan	< 25	high	fair to poor
Hatchery	< 25	moderate	moderate
Mission Rd.	25	low	poor
Tooshley Island	200 (if tied into high ground)	low	moderate
Koksilah Village	< 25	high	fair to poor
Clem Clem	< 25	low	fair to poor

[1] Field inspections indicate there is actually a small opening between the end of the Cowichan (City of Duncan) Dike and the JUB Dike, which would allow water to spill. This was not represented in the model.

Note: The dike flood capacity was determined assuming that a flood of the stated return period would leave a minimum freeboard of 1 m to the dike crest level.

3.4 DIKE BREACH SCENARIOS

The impacts of dike failures were investigated through a series of scenarios whereby breaches of single dikes were simulated to isolate the effects of individual structures, while at the same time all other dikes were hypothetically raised to remain intact and fully confine the flow. The five simulated scenarios are summarized in Table 3.2, and the resulting flood spills are shown in Figure 3.2 through Figure 3.6. Key results from two of the five simulations are described below.

Table 3.2: Dike Breach Scenarios

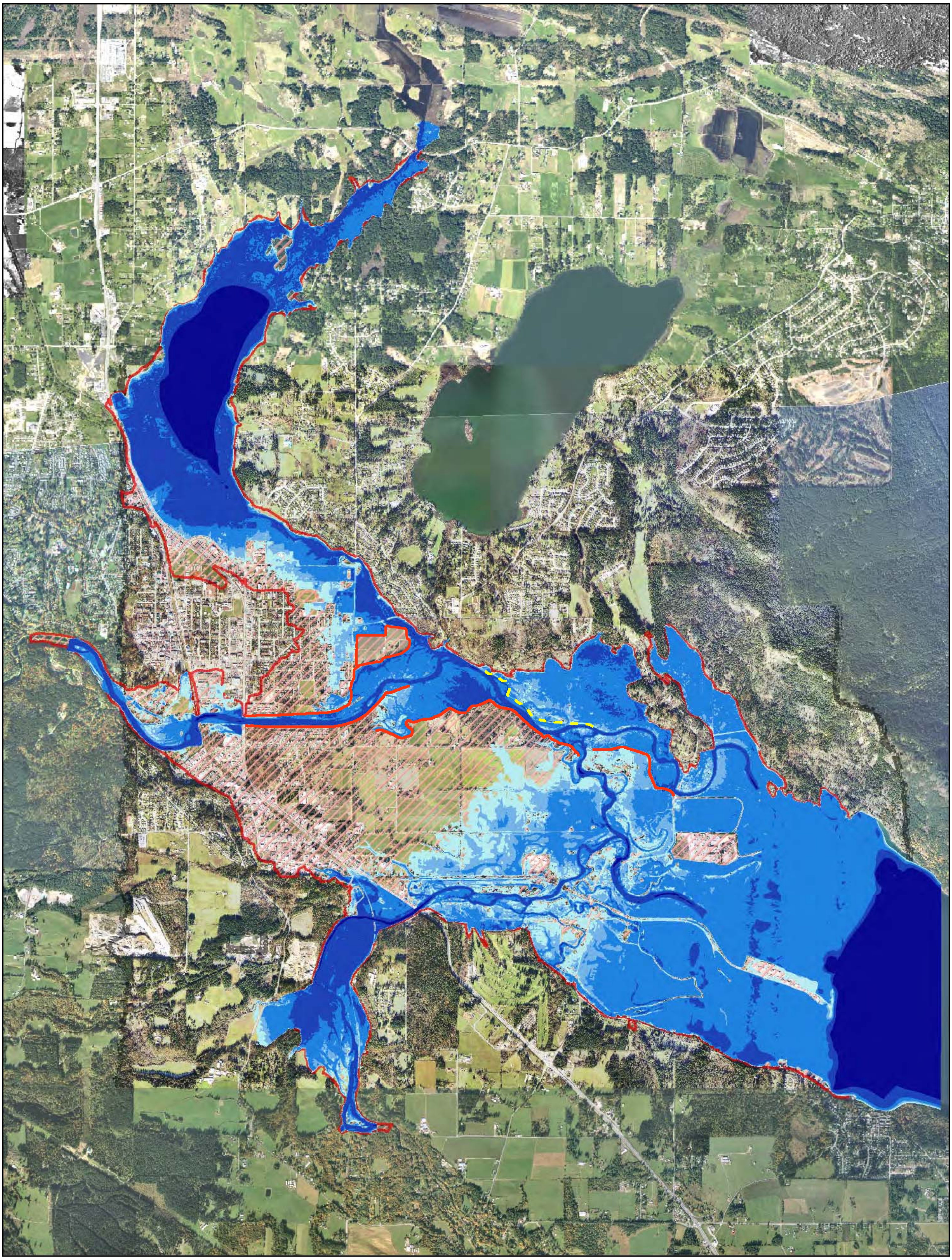
Scenario Number	Dike Breached	Figure Number
201	Quamichan	Figure 3.2
301	JUB Sewage Lagoon	Figure 3.3
401	South Side Spur + Mission Rd + Hatchery	Figure 3.4
601	Cowichan (City of Duncan)	Figure 3.5
701	Cowichan South Side and South Side Spur Dike	Figure 3.6

3.4.1 BREACH OF JUB LAGOON DIKE

Figure 3.3 shows the water depth and extent of flooding caused by a breach of the JUB lagoon dike. The simulation did not include any additional volume contained within the sewage lagoons at the time of the failure. The proposed Lakes Road Dike along the south side of Somenos Creek was included in this run, since this dike will affect flow interaction between Cowichan River spills and Somenos Creek. In a simulated 200-year flood event, water flows into the City of Duncan through the breach and is then prevented from flowing north by the Lakes Road Dike. This results in a greater extent of flooding into Duncan. The breach causes slight lowering of water levels on the Cowichan River upstream of the breach, over a distance of about 550 m.

3.4.2 BREACH OF COWICHAN SOUTH SIDE DIKE

Figure 3.6 shows the water depth and extent of flooding caused by a breach in the Cowichan South Side Dike. The breach allows water to overtop the right river bank and flow into a former channel that was blocked off when the dike was originally constructed. This channel conveys flows to the east for roughly 600 m before they spill onto the floodplain and continue in a southeast direction towards the Koksilah River. Under this scenario most of the floodplain between the Cowichan and Koksilah Rivers is inundated. A small region near



Legend
- Dikes
- Quamichan Dike (Breached)

Channelized Flows and Overbank Spilling

Flood Depth (m) - Freeboard not included
- 0.15 - 0.6: most houses are dry; walking in moving water is potentially dangerous
- 0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
- 1.0 - 2.0: ground floor flooded; residents move to upper floors or evacuate
- 2.0 - 5.0: first floor and often roof covered by water; evacuate
- > 5.0
- Flood Management Planning Area - Potential Inundation and Ponding

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Modelling Results - Quamichan Dike Breached
200 Year Flood Water Depth

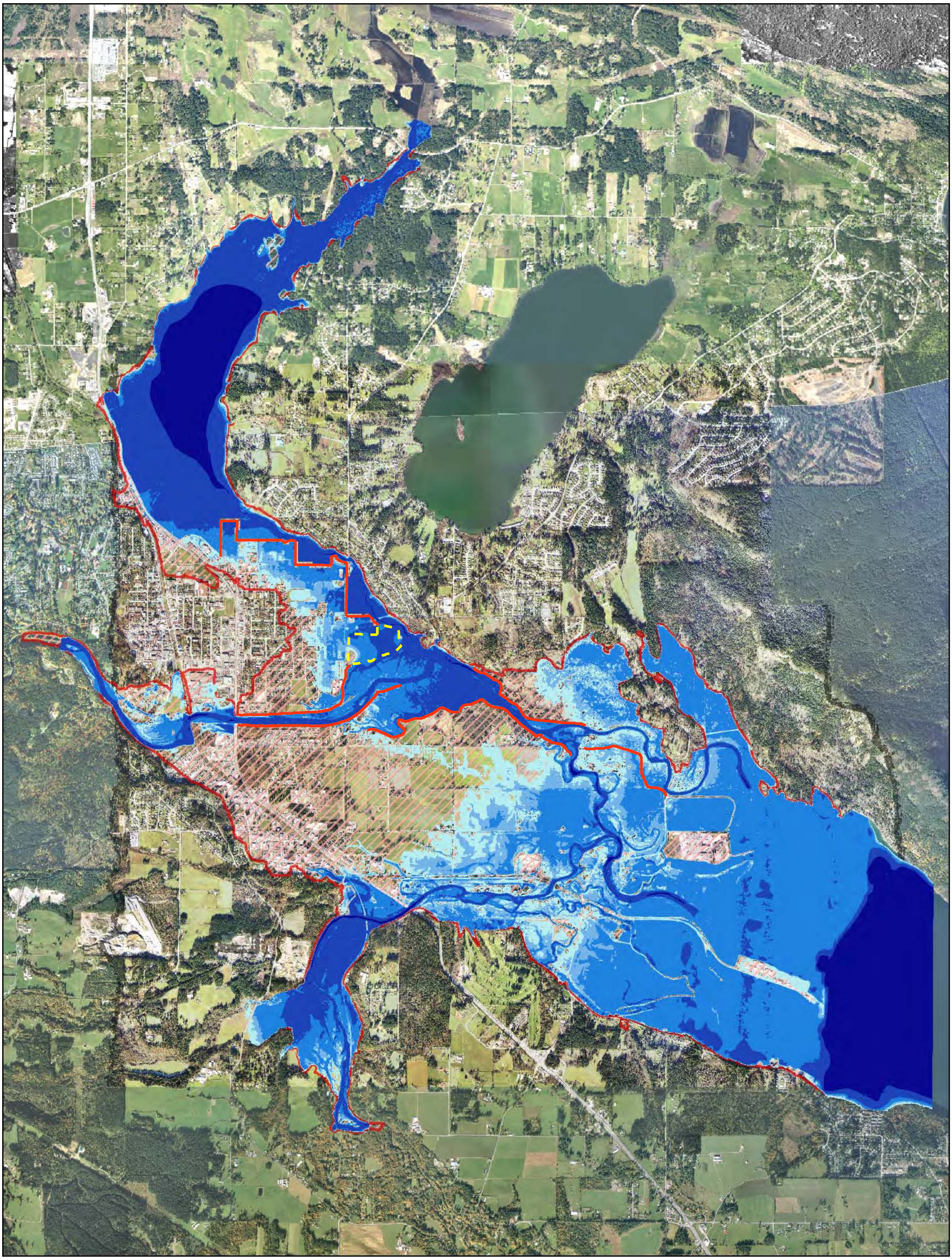
Scale - 1:35,000

1 0.5 0 1 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

Figure 3.2

JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_200_201.mxd



Legend

- Dikes
- JUB Sewage Lagoon Dikes (Breached)

Channelized Flows and Overbank Spilling

Flood Depth (m) - Freeboard not included

- 0.15 - 0.6: most houses are dry; walking in moving water is potentially dangerous
- 0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
- 1.0 - 2.0: ground floor flooded; residents move to upper floors or evacuate
- 2.0 - 5.0: first floor and often roof covered by water; evacuate
- > 5.0
- Flood Management Planning Area - Potential Inundation and Ponding

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation folder name: C_nhc_D_200_301_1.couple

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Modelling Results - JUB Lagoon Dike Breached
200 Year Flood Water Depth

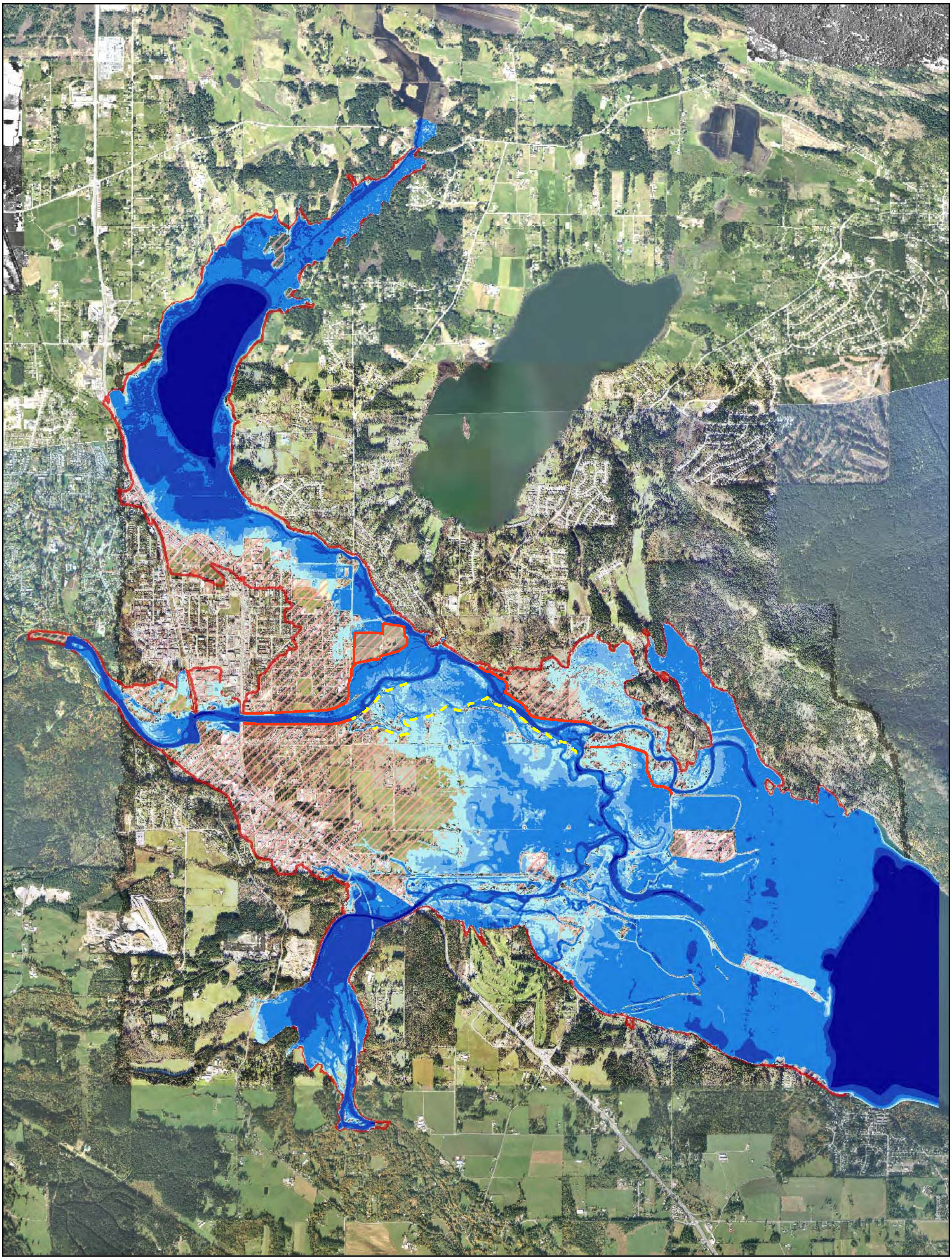
Scale - 1:35,000

1 0.5 0 1 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_200_301.mxd

Figure 3.3



Legend

Dikes

Hatchery, Mission, and South Side Spur Dike (Breached)

Channelized Flows and Overbank Spilling

Flood Depth (m) - Freeboard not included

- 0.15 - 0.6: most houses are dry; walking in moving water is potentially dangerous
- 0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
- 1.0 - 2.0: ground floor flooded; residents move to upper floors or evacuate
- 2.0 - 5.0: first floor and often roof covered by water; evacuate
- > 5.0

Flood Management Planning Area - Potential Inundation and Ponding

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation folder name: C_nhc_D_200_401_1.couple

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Modelling Results - Hatchery, Mission and South Side Spur Dikes Breached
200 Year Flood Water Depth

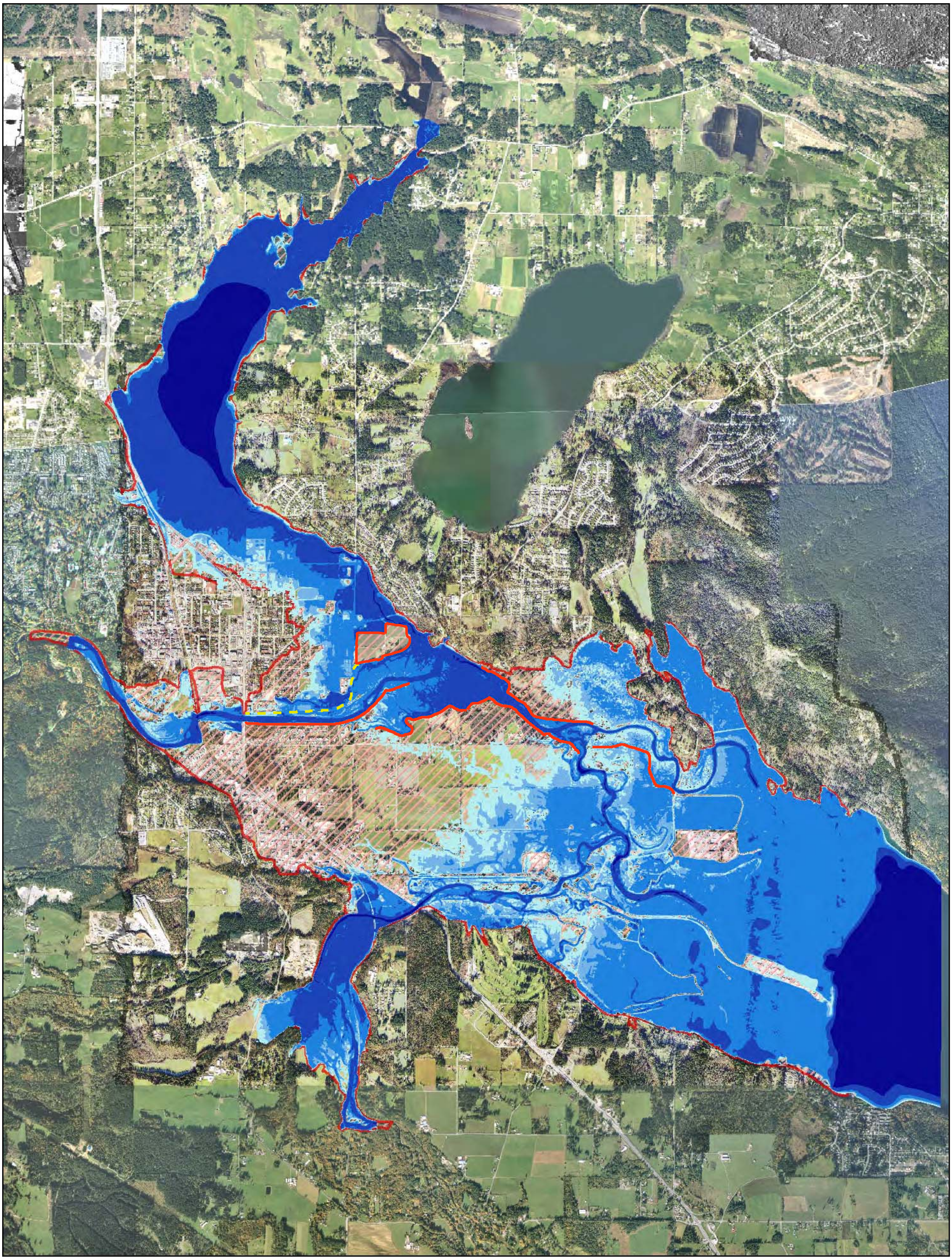
Scale - 1:35,000

1 0.5 0 1 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

Figure 3.4

JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_200_401.mxd



LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Modelling Results
Cowichan (City of Duncan) Dike Breached
200 Year Flood Water Depth

Scale - 1:35,000

1 0.5 0 1 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

Legend

- Dikes
- Cowichan (City of Duncan) Dike (Breached)

Channelized Flows and Overbank Spilling

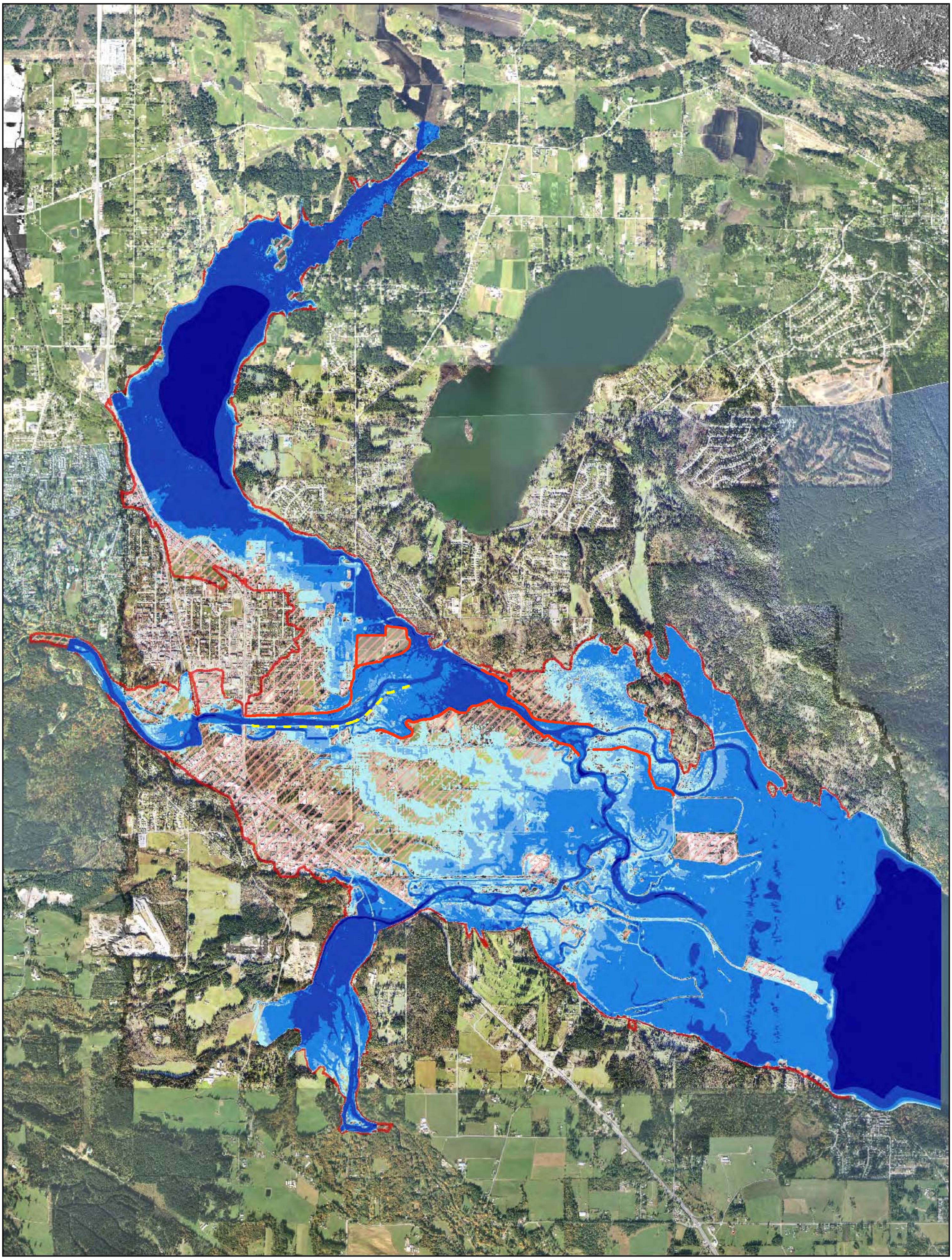
Flood Depth (m) - Freeboard not included

- 0.15 - 0.6: most houses are dry; walking in moving water is potentially dangerous
- 0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
- 1.0 - 2.0: ground floor flooded; residents move to upper floors or evacuate
- 2.0 - 5.0: first floor and often roof covered by water; evacuate
- > 5.0
- Flood Management Planning Area - Potential Inundation and Ponding

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation folder name: C_nhc_D_200_601_1.couple

JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_200_601.mxd

Figure 3.5



Legend

- Dikes
- Cowichan South Side and South Side Spur Dikes (Breached)

Channelized Flows and Overbank Spilling

Flood Depth (m) - Freeboard not included

- 0.15 - 0.6: most houses are dry; walking in moving water is potentially dangerous
- 0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
- 1.0 - 2.0: ground floor flooded; residents move to upper floors or evacuate
- 2.0 - 5.0: first floor and often roof covered by water; evacuate
- > 5.0
- Flood Management Planning Area - Potential Inundation and Ponding

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation folder name: C_nhc_D_200_701_1.couple

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Modelling Results - Cowichan South Side and South Side Spur Dikes Breached
200 Year Flood Water Depth

Scale - 1:35,000

1 0.5 0 1 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_200_701.mxd

Figure 3.6

Highway 1 with higher ground elevations remains dry. The breach does not raise water levels in the downstream channels. As expected, it causes a general decrease in water levels through all reaches of the main channels.

3.5 EXISTING DIKES RAISED SCENARIO

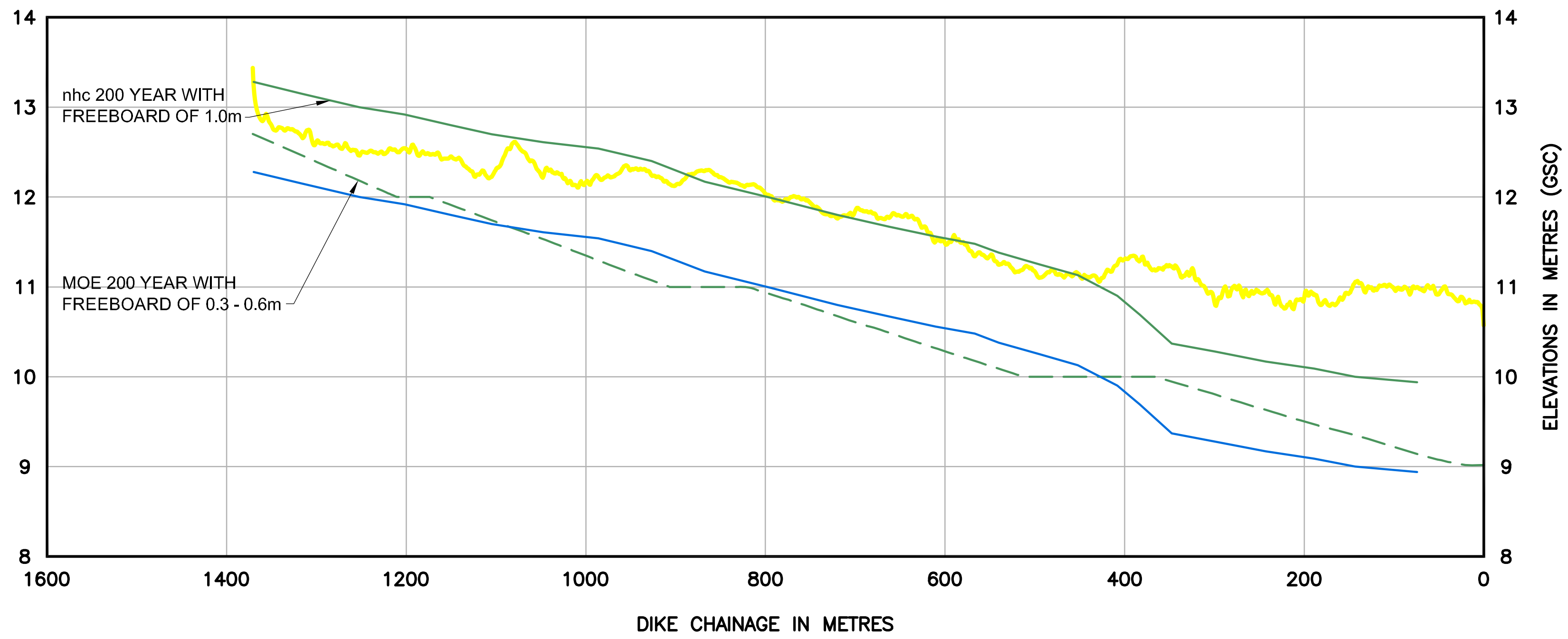
A further simulation was conducted with all existing dikes raised, thereby confining all flows to the floodways between dikes. This scenario is similar to the assumption used by MOE (1997) when developing the original floodplain mapping. It eliminates dike breaching or overtopping, maximizes spills and overbank flows at non-diked areas of the floodplain, and produces the highest water levels along the rivers. Therefore, this scenario was used to determine dike crest elevations that would be required to prevent overtopping.

Figure 3.7 through Figure 3.11 show simulated 200-year flood profiles at the various dikes, together with higher profiles incorporating 1 m of freeboard to represent required design crest levels; additional information on freeboard assessments is presented in Volume 2 – Technical Investigations). The 1997 MOE flood construction levels are also plotted for comparison - these values include MOE's adopted freeboard, which varied from 0.3 to 0.6 m.

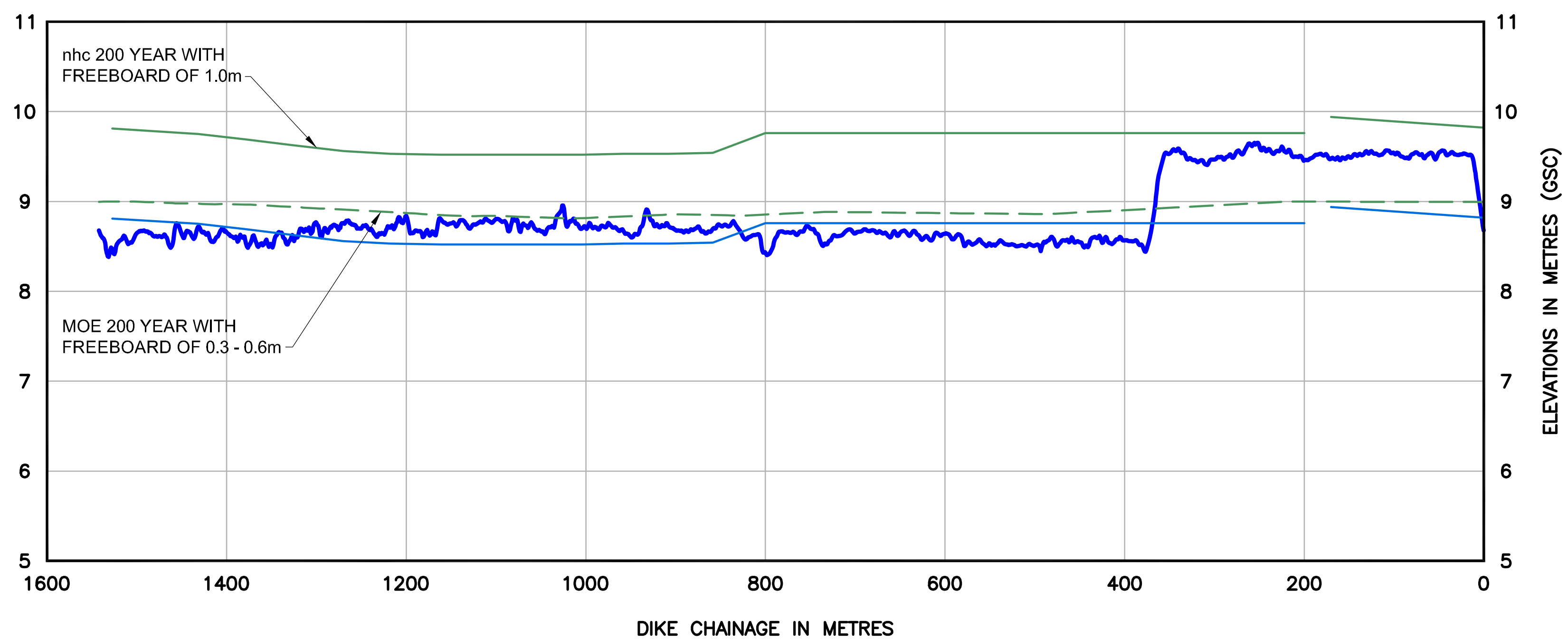
The estimated 200-year flood levels in the rivers and design crest levels determined in this study are mostly higher than the MOE (1997) results, as summarized below:

- Typically 0.5 m higher than MOE between Quamichan Dike and Hatchery Dike and near the confluence with Somenos Creek.
- Slightly higher than MOE at the JUB sewage lagoons and farther upstream past the Trans-Canada Highway Bridge.
- Generally lower than MOE along portions of the North Branch, except at the upstream end near the bifurcation with the South Branch.
- Approximately 1 m higher than MOE along Somenos Creek and at Somenos Lake.
- Up to 0.75 m higher than MOE along the Koksilah River upstream of the Trans-Canada Highway Bridge. Downstream of the bridge the two profiles are similar.

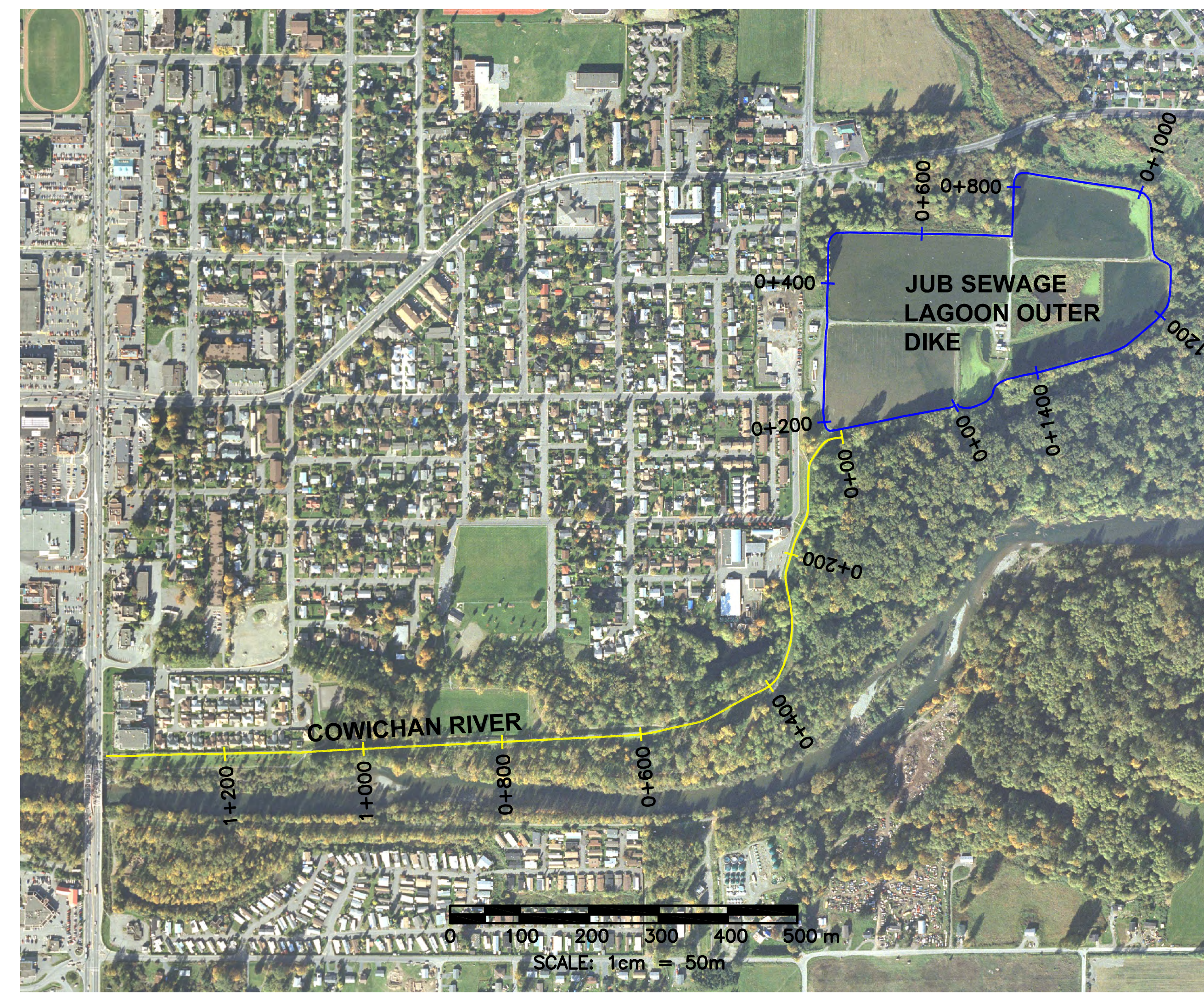
Table 3.3 lists vertical clearances from simulated 200-year flood levels to the low chords of the existing bridges. Present-day practice is to provide at least 1.5 m clearance on bridges that may experience log jams, but only the Pimbury Bridge has this much clearance. Three bridges are shown with negative clearance, that is, they would surcharge in a 200-year flood. This means that most of the bridges are liable to trap debris and log jams during floods, which can cause higher flood levels and increased risk of channel erosion. This factor needs to be considered when determining freeboard requirements for adjacent dikes.



COWICHAN RIVER DIKE



JUB SEWAGE LAGOON OUTER DIKE



NOTES:

1. DIKE CHAINAGES ESTABLISHED BY NHC.
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. WATER SURFACE PROFILES WERE COMPUTED USING EXTREME TIDES WITH THE SAME RETURN PERIOD AS THE FLOOD EVENTS.
4. WATER SURFACE PROFILES DO NOT INCLUDE FREEBOARD UNLESS INDICATED OTHERWISE. A FREEBOARD OF AT LEAST 0.6m SHOULD BE ADDED TO THE WATER ELEVATIONS SHOWN.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM LiDAR (23-FEB-2005) BY TERRA REMOTE SENSING AS PROVIDED BY CVRD. ACCURACY OF INDIVIDUAL LiDAR DATA POINTS IS IN AS THE ORDER OF ±0.3m.
6. MAXIMUM INSTANTANEOUS FLOWS USED FOR THE DESIGN FLOODS ARE REFERRED IN TABLE.
7. MIKE FLOOD SIMULATION NAME: C_nhc_D_25_101_1.couple C_nhc_D_100_101_1.couple C_nhc_D_50_101_1.couple C_nhc_D_200_101_1.couple

RETURN PERIOD	COWICHAN RIVER AT DUNCAN (08HA011)	KOKSILAH RIVER AT COWICHAN (08HA003)
YEARS	(m^3/s)	(m^3/s)
25	572	390
50	620	410
100	660	430
200	700	450

LEGEND

- COWICHAN RIVER DIKE
- JUB SEWAGE LAGOON OUTER DIKE
- 200 YEAR WATER LEVELS
- 1997 MOE 200 YEAR LEVELS WITH FREEBOARD
- nhc 200 YEAR LEVELS WITH FREEBOARD

No.	REVISIONS Description	By	Date	Designer: VFO	Project Number: 34878	Drawing Scale:
				Drafter: BH	Drawing Date: SEPT 2009	Original Drawing Scale: 0—20mm
				Reviewer: TSL	Drawing File Name: 34878-002.dwg	

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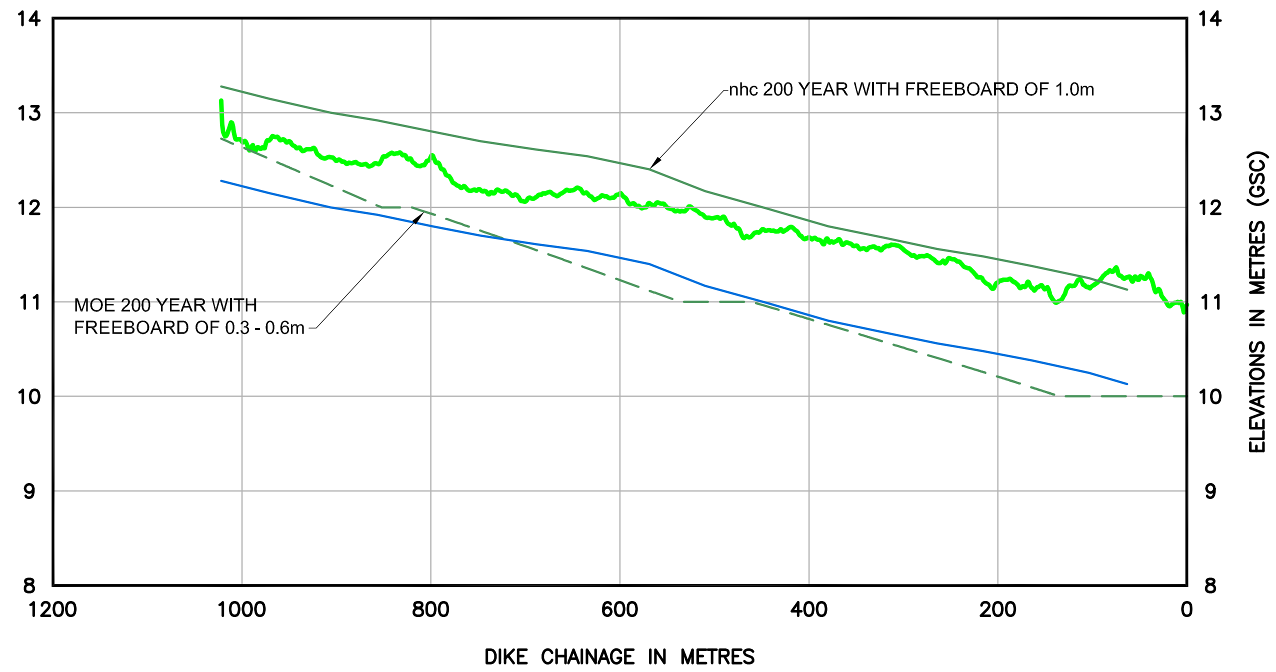
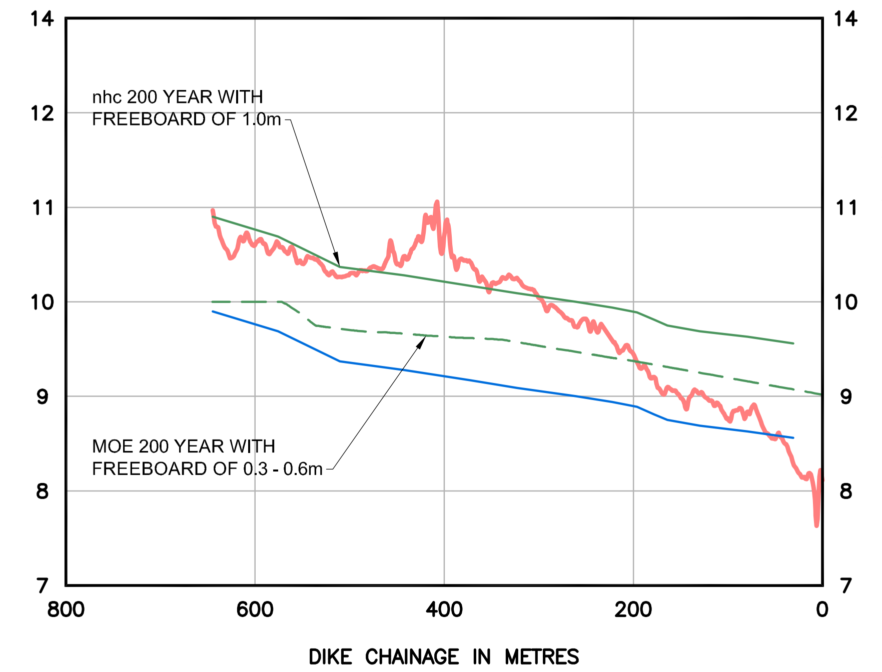
Modelling Results - Confined Flow:
Cowichan River and JUB Sewage Lagoon Dikes
and Flood Profiles

Sheet Reference Number
FIGURE 3.7



COWICHAN RIVER SOUTH SIDE DIKE



SOUTH SIDE SPUR DIKE

NOTES:

1. DIKE CHAINAGES ESTABLISHED BY NHC.
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. WATER SURFACE PROFILES WERE COMPUTED USING EXTREME TIDES WITH THE SAME RETURN PERIOD AS THE FLOOD EVENTS.
4. WATER SURFACE PROFILES DO NOT INCLUDE FREEBOARD UNLESS INDICATED OTHERWISE. A FREEBOARD OF AT LEAST 0.6m SHOULD BE ADDED TO THE WATER ELEVATIONS SHOWN.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM LiDAR (23-FEB-2005) BY TERRA REMOTE SENSING AS PROVIDED BY CVRD. ACCURACY OF INDIVIDUAL LiDAR DATA POINTS IS IN AS THE ORDER OF ±0.3m.
6. MAXIMUM INSTANTANEOUS FLOWS USED FOR THE DESIGN FLOODS ARE REFERRED IN TABLE.
7. MIKE FLOOD SIMULATION NAME: C_nhc_D_25_101_1.couple C_nhc_D_100_101_1.couple C_nhc_D_50_101_1.couple C_nhc_D_200_101_1.couple

RETURN PERIOD	COWICHAN RIVER AT DUNCAN (08HA011)	KOKSILAH RIVER AT COWICHAN (08HA003)
YEARS	(m^3/s)	(m^3/s)
25	572	390
50	620	410
100	660	430
200	700	450

LEGEND

- COWICHAN RIVER SOUTH SIDE DIKE
- SOUTH SIDE SPUR DIKE
- 200 YEAR WATER LEVELS
- 1997 MOE 200 YEAR LEVELS WITH FREEBOARD
- nhc 200 YEAR LEVELS WITH FREEBOARD

No.	REVISIONS Description	By	Date

Designer: VFO | Drafter: BH | Reviewer: TSL

Project Number: 34878 | Drawing Date: SEPT 2009 | Drawing File Name: 34878-002.dwg

Drawing Scale: | Original Drawing Scale: 0—20mm

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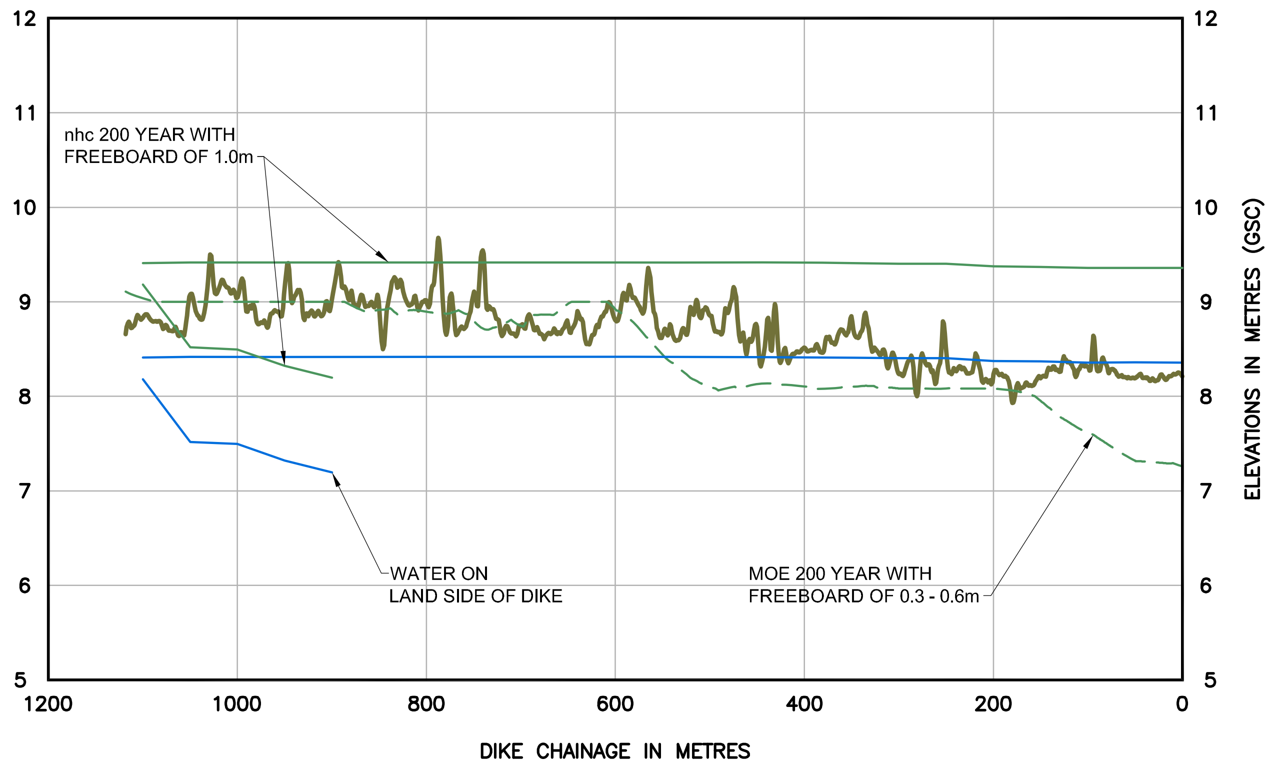
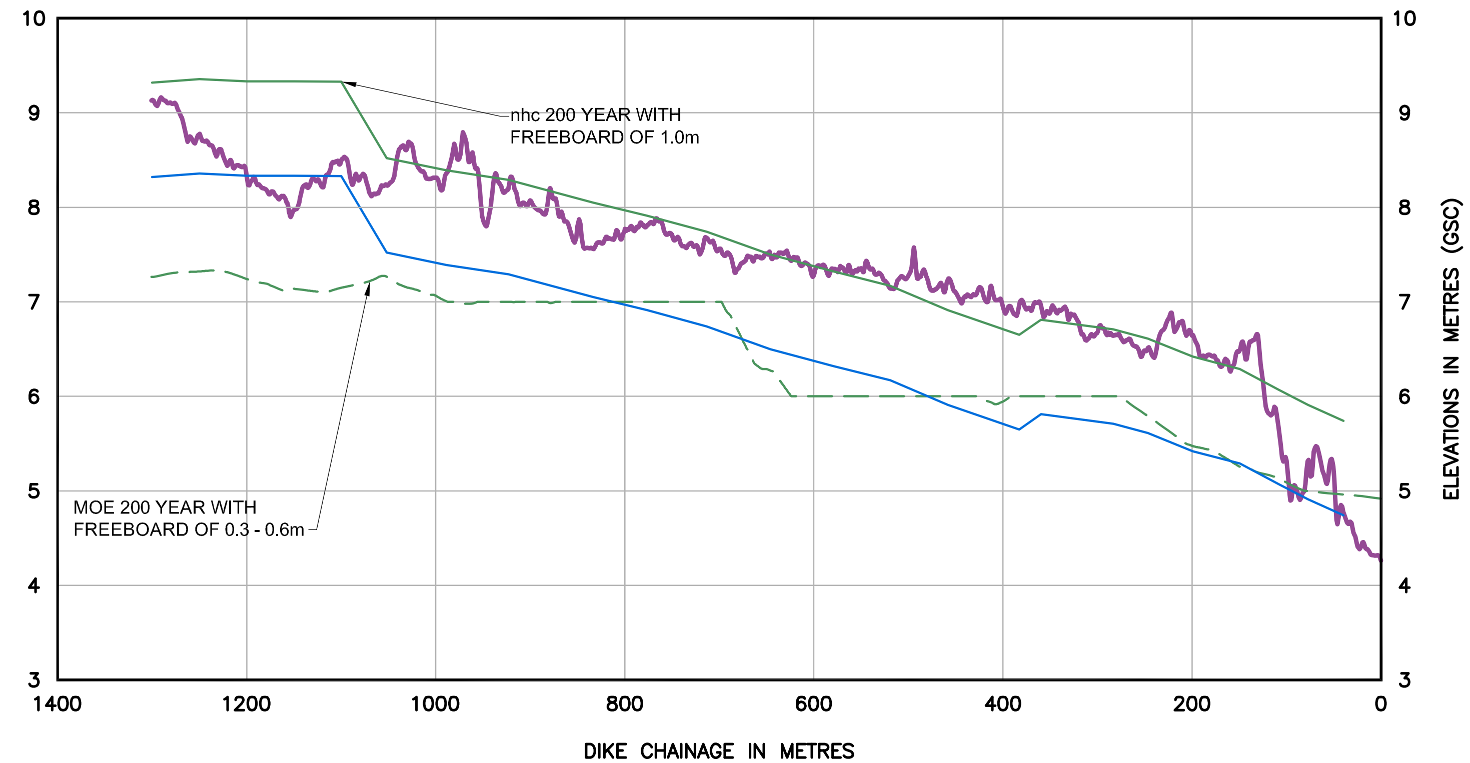
Modelling Results - Confined Flow:
Cowichan River South Side and South Side Spur Dikes
and Flood Profiles

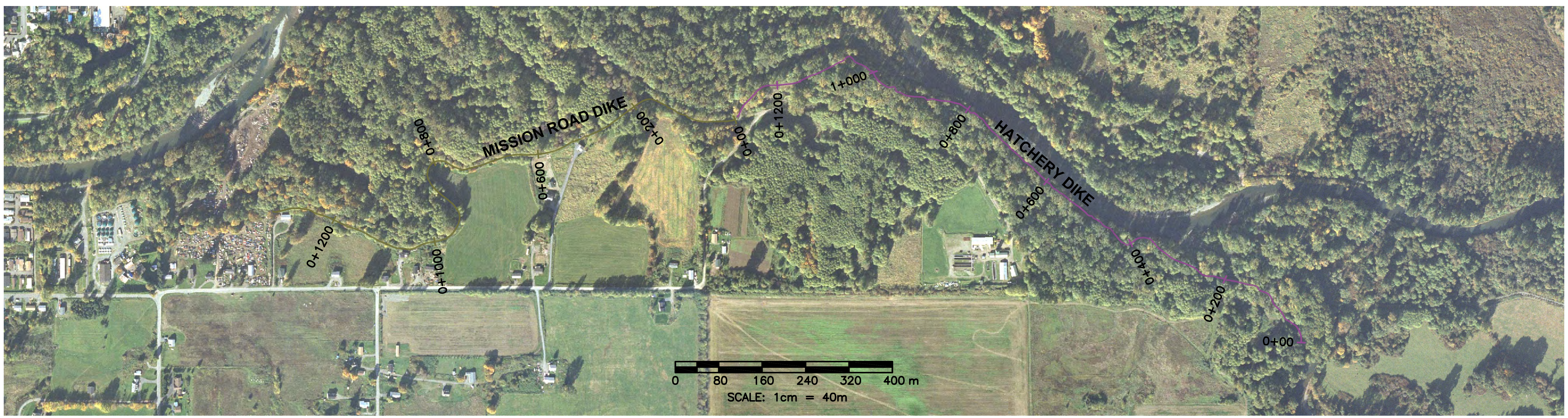
Sheet Reference Number
FIGURE 3.8



MISSION ROAD DIKE



HATCHERY DIKE



NOTES:

1. DIKE CHAINAGES ESTABLISHED BY NHC.
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. WATER SURFACE PROFILES WERE COMPUTED USING EXTREME TIDES WITH THE SAME RETURN PERIOD AS THE FLOOD EVENTS.
4. WATER SURFACE PROFILES DO NOT INCLUDE FREEBOARD UNLESS INDICATED OTHERWISE. A FREEBOARD OF AT LEAST 0.6m SHOULD BE ADDED TO THE WATER ELEVATIONS SHOWN.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM LiDAR (23-FEB-2005) BY TERRA REMOTE SENSING AS PROVIDED BY CVRD. ACCURACY OF INDIVIDUAL LiDAR DATA POINTS IS IN AS THE ORDER OF ±0.3m.
6. MAXIMUM INSTANTANEOUS FLOWS USED FOR THE DESIGN FLOODS ARE REFERRED IN TABLE.
7. MIKE FLOOD SIMULATION NAME: C_nhc_D_25_101_1.couple, C_nhc_D_50_101_1.couple, C_nhc_D_100_101_1.couple, C_nhc_D_200_101_1.couple

RETURN PERIOD	COWICHAN RIVER AT DUNCAN (08HA011)	KOKSILAH RIVER AT COWICHAN (08HA003)
YEARS	(m^3/s)	(m^3/s)
25	572	390
50	620	410
100	660	430
200	700	450

MISSION ROAD DIKE
HATCHERY DIKE
200 YEAR WATER LEVELS
1997 MOE 200 YEAR LEVELS WITH FREEBOARD
nhc 200 YEAR LEVELS WITH FREEBOARD

No.	REVISIONS Description	By	Date

Designer: VFO
Drafter: BH
Reviewer: TSL
Project Number: 34878
Drawing Date: SEPT 2009
Drawing File Name: 34878-002.dwg
Drawing Scale:
Original Drawing Scale: 0 20mm

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North Vancouver, B.C., Canada V7M 3G3
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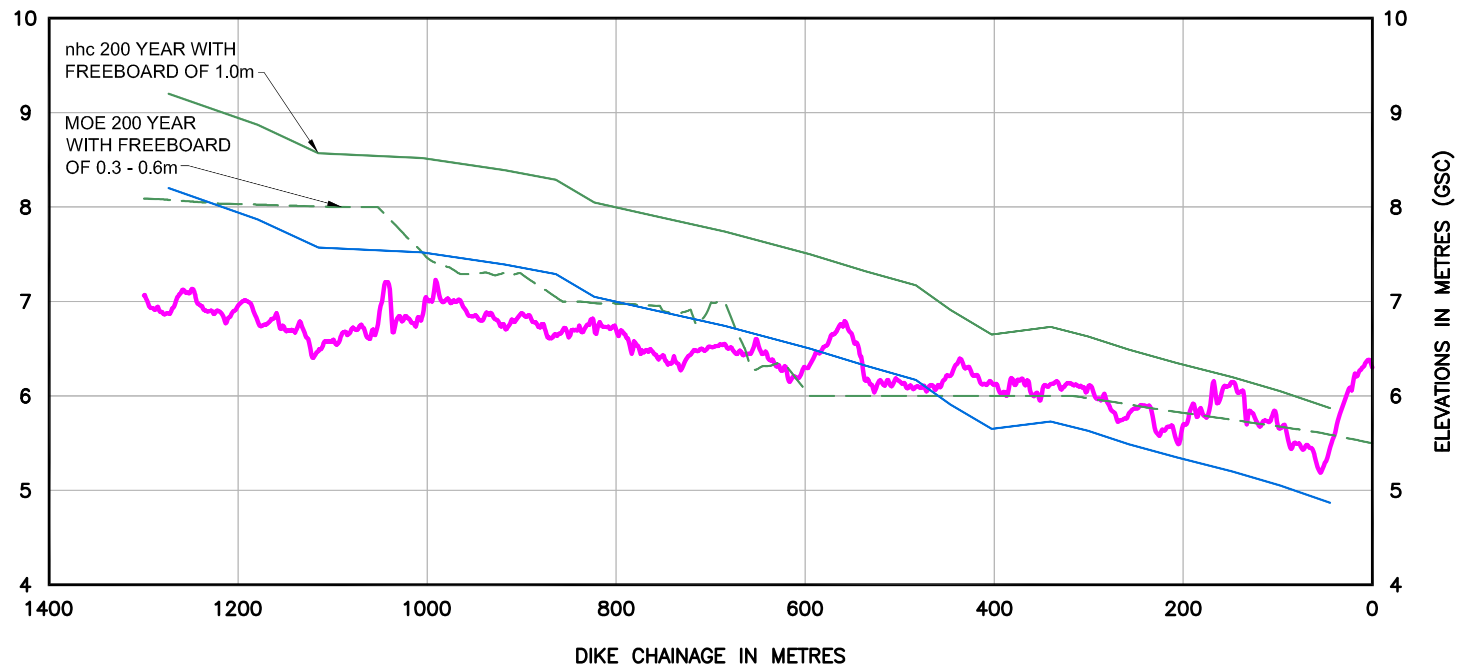
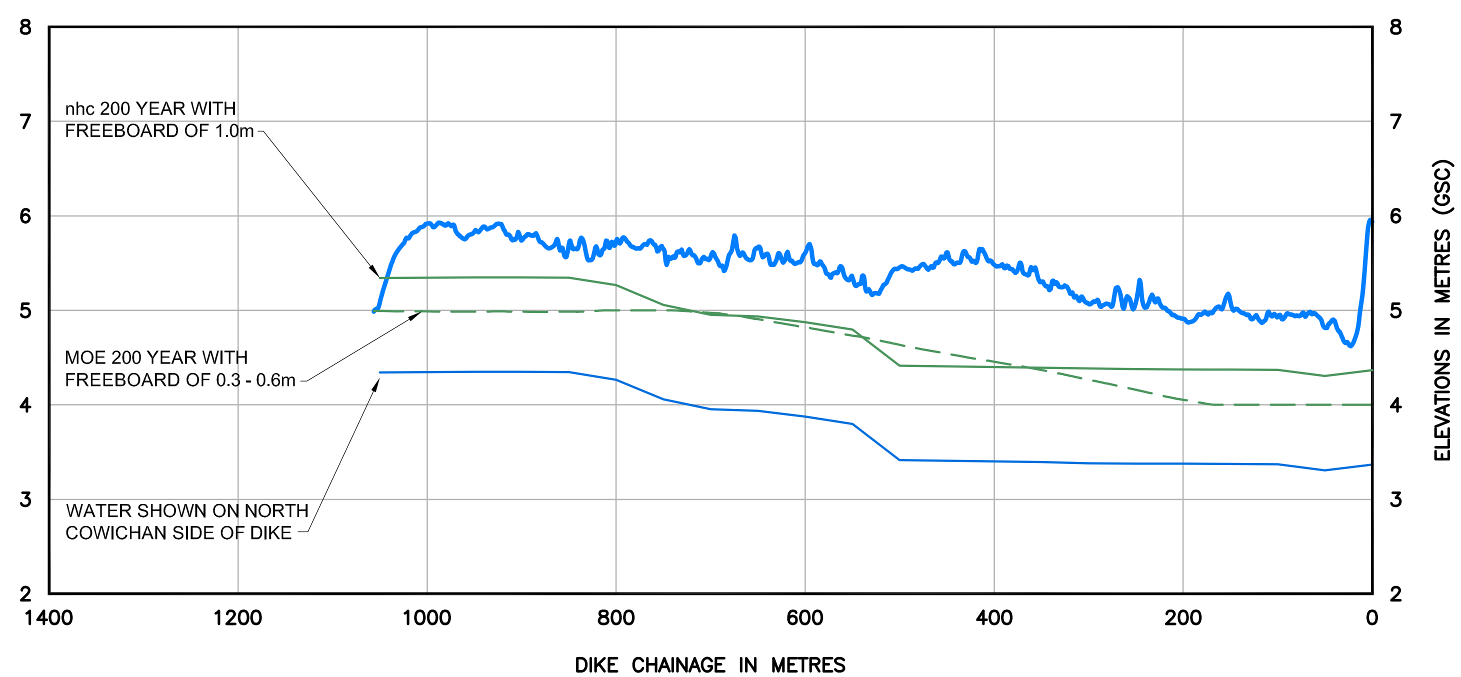
Modelling Results - Confined Flow: Mission Road and Hatchery Dikes and Flood Profiles

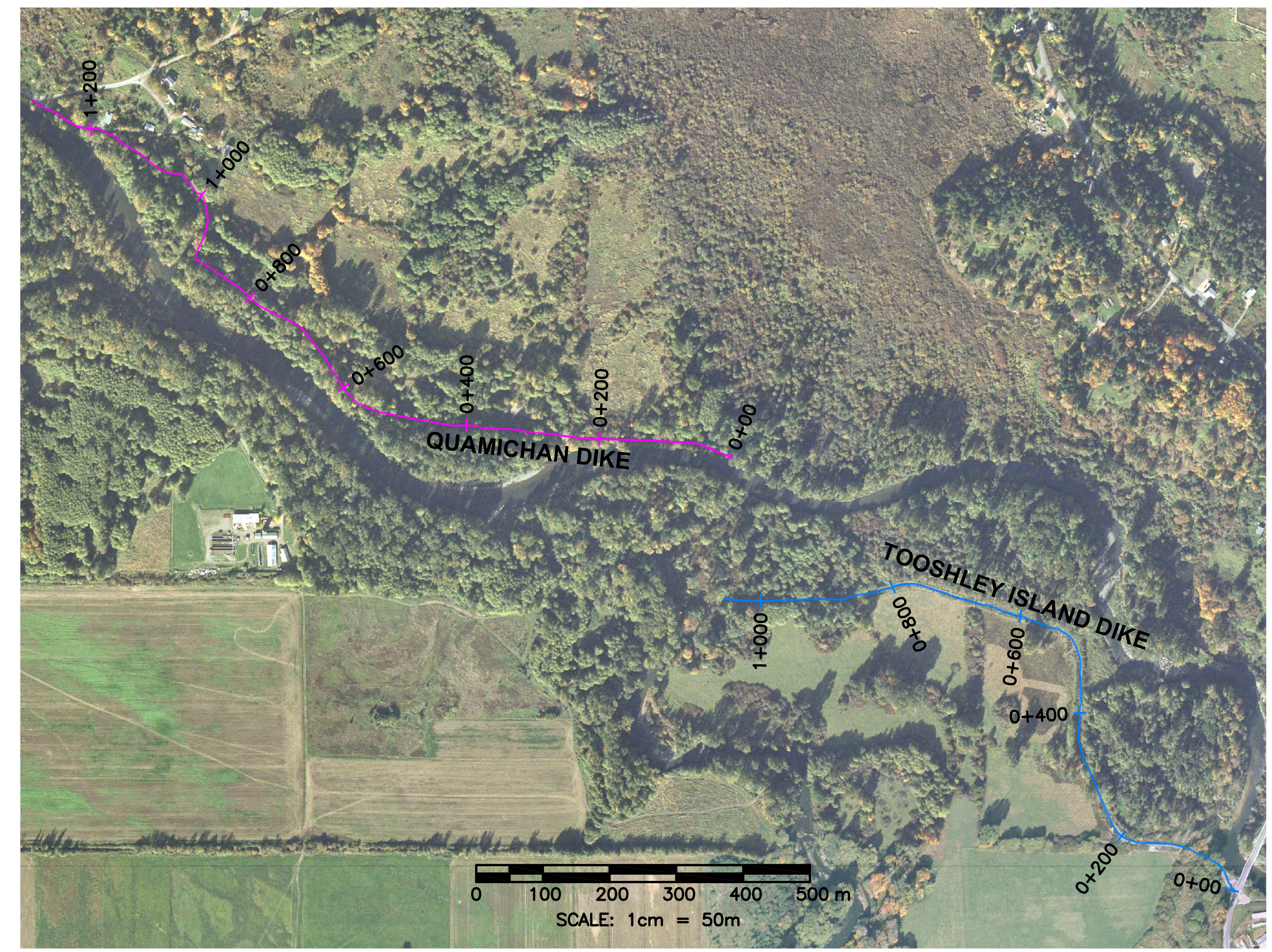
Sheet Reference Number
FIGURE 3.9



QUAMICHAN DIKE



TOOSHLEY ISLAND DIKE



NOTES:
1. DIKE CHAINAGES ESTABLISHED BY NHC.
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. WATER SURFACE PROFILES WERE COMPUTED USING EXTREME TIDES WITH THE SAME RETURN PERIOD AS THE FLOOD EVENTS.
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7. MIKE FLOOD SIMULATION NAME: C_nhc_D_25_101_1.couple, C_nhc_D_50_101_1.couple, C_nhc_D_100_101_1.couple, C_nhc_D_200_101_1.couple

RETURN PERIOD	COWICHAN RIVER AT DUNCAN (08HA011)	KOKSILAH RIVER AT COWICHAN (08HA003)
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25	572	390
50	620	410
100	660	430
200	700	450

LEGEND

- QUAMICHAN DIKE
- TOOSHLEY ISLAND DIKE
- 200 YEAR WATER LEVELS
- 1997 MOE 200 YEAR LEVELS WITH FREEBOARD
- nhc 200 YEAR LEVELS WITH FREEBOARD

No.	REVISIONS Description	By	Date

Designer: VFO	Project Number: 34878	Drawing Scale:
Drafter: BH	Drawing Date: SEPT 2009	Original Drawing Scale: 0–20mm
Reviewer: TSL	Drawing File Name: 34878-002.dwg	

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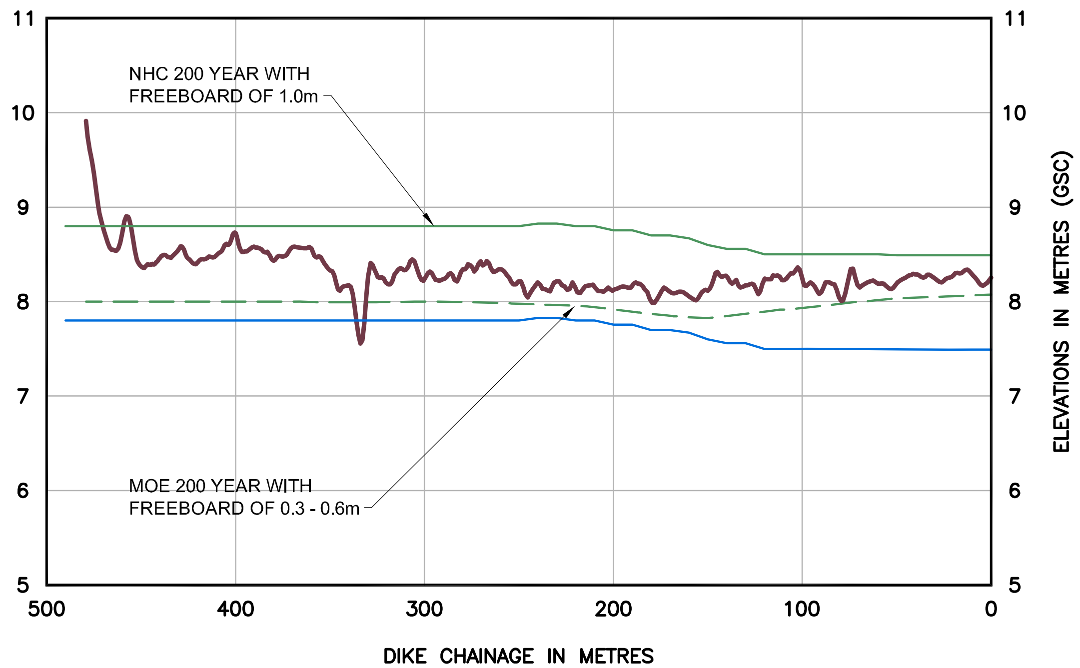
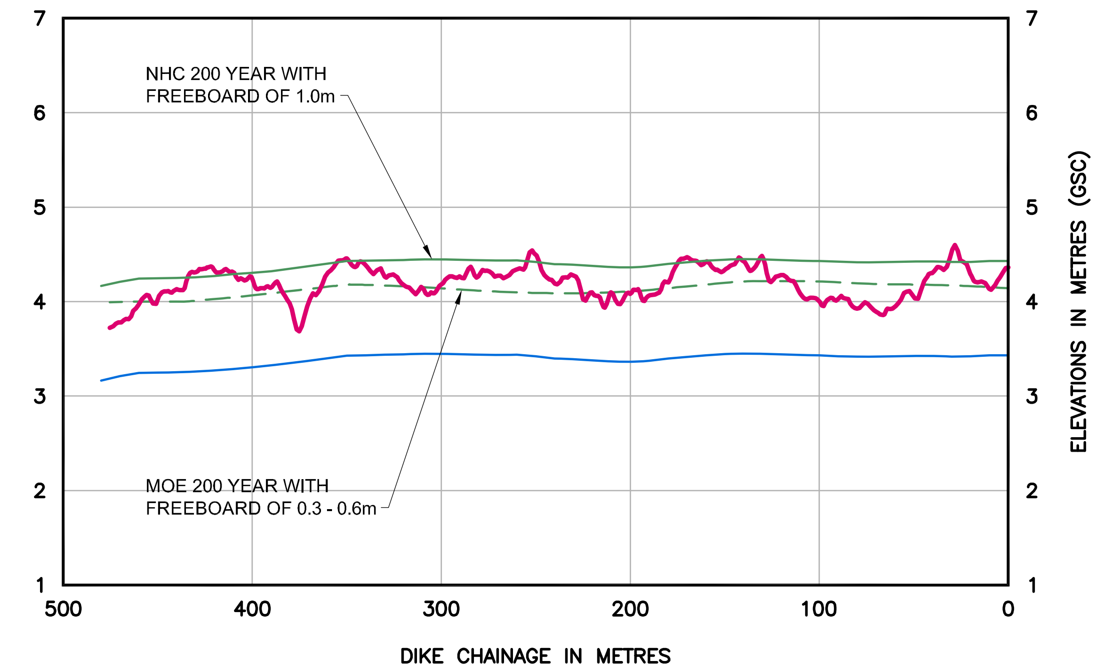
Modelling Results - Confined Flow:
Quamichan and Tooshley Island Dikes
and Flood Profiles

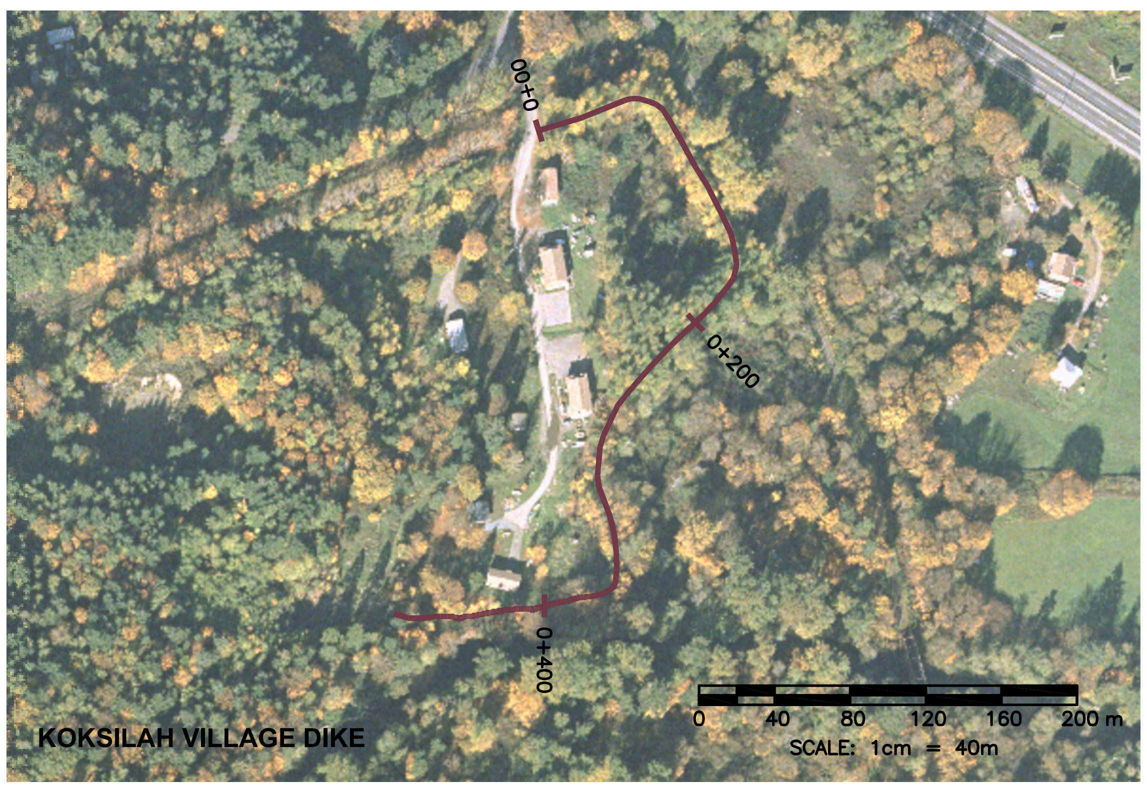
Sheet Reference Number
FIGURE 3.10

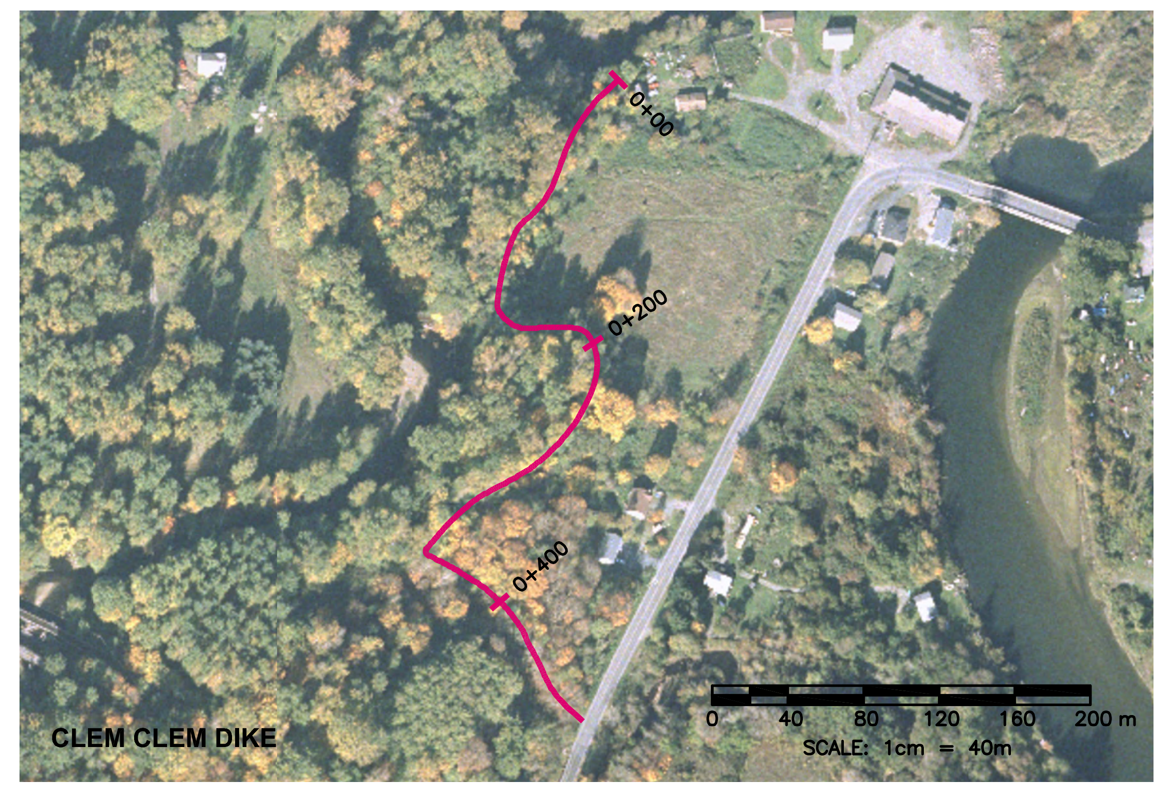


KOKSILAH VILLAGE DIKE



CLEM CLEM DIKE





NOTES:
1. DIKE CHAINAGES ESTABLISHED BY NHC.
2. ALL ELEVATIONS ARE TO GEODETIC DATUM.
3. WATER SURFACE PROFILES WERE COMPUTED USING EXTREME TIDES WITH THE SAME RETURN PERIOD AS THE FLOOD EVENTS.
4. WATER SURFACE PROFILES DO NOT INCLUDE FREEBOARD UNLESS INDICATED OTHERWISE. A FREEBOARD OF AT LEAST 0.6m SHOULD BE ADDED TO THE WATER ELEVATIONS SHOWN.
5. DIKE CREST ELEVATIONS WERE DERIVED FROM LiDAR (23-FEB-2005) BY TERRA REMOTE SENSING AS PROVIDED BY CVRD. ACCURACY OF INDIVIDUAL LiDAR DATA POINTS IS IN AS THE ORDER OF ±0.3m.
6. MAXIMUM INSTANTANEOUS FLOWS USED FOR THE DESIGN FLOODS ARE REFERRED IN TABLE.
7. MIKE FLOOD SIMULATION NAME: C_nhc_D_200_101_1.couple

RETURN PERIOD	COWICHAN RIVER AT DUNCAN (08HA011)	KOKSILAH RIVER AT COWICHAN (08HA003)
YEARS	(m^3/s)	(m^3/s)
25	572	390
50	620	410
100	660	430
200	700	450

LEGEND
- KOKSILAH VILLAGE DIKE
- CLEM CLEM DIKE
- 200 YEAR WATER LEVELS
- 1997 MOE 200 YEAR LEVELS WITH FREEBOARD
- nhc 200 YEAR LEVELS WITH FREEBOARD

No.	REVISIONS Description	By	Date

Designer: VFO | Project Number: 34878 | Drawing Scale:
Drafter: BH | Drawing Date: SEPT 2009 | Original Drawing Scale: 0 20mm
Reviewer: TSL | Drawing File Name: 34878-003.dwg

nhc
Northwest Hydraulic Consultants Ltd
30 Gostick Place
North Vancouver, B.C., Canada V7M 3G3
Office: (604) 980-6011 Fax: (604) 980-9264

Modelling Results - Confined Flow:
Koksilah Village and Clem Clem Dikes
and Flood Profiles

Sheet Reference Number
FIGURE 3.11

Table 3.3: Vertical Clearance above 200-Year Flood at Bridges

Bridge Name	Clearance (m)
Clem Clem Bridge (Tzouhalem Road)	0.44
Silver Bridge (Highway 1)	0.68
Cowichan Railway Bridge	1.20
Allenby Road Bridge	0.75
Koksilah Highway 1 Bridge	1.17
Koksilah Railway Bridge	-0.04
Pimbury Bridge (Tzouhalem Road)	1.87
Trunk Road Bridge	-1.22
Lakes Road Bridge	-1.04

3.6 EFFECT OF NEW AND MODIFIED DIKES

3.6.1 SET-BACK DIKE ON SOUTH SIDE OF COWICHAN RIVER

An additional simulation was done by modifying the dikes on the south side of the Cowichan River. The overall purpose of these modifications was to try to lower the flood levels in the main channel of the Cowichan River and to eliminate the spill around the upstream end of the Mission Road Dike. The dike modifications included:

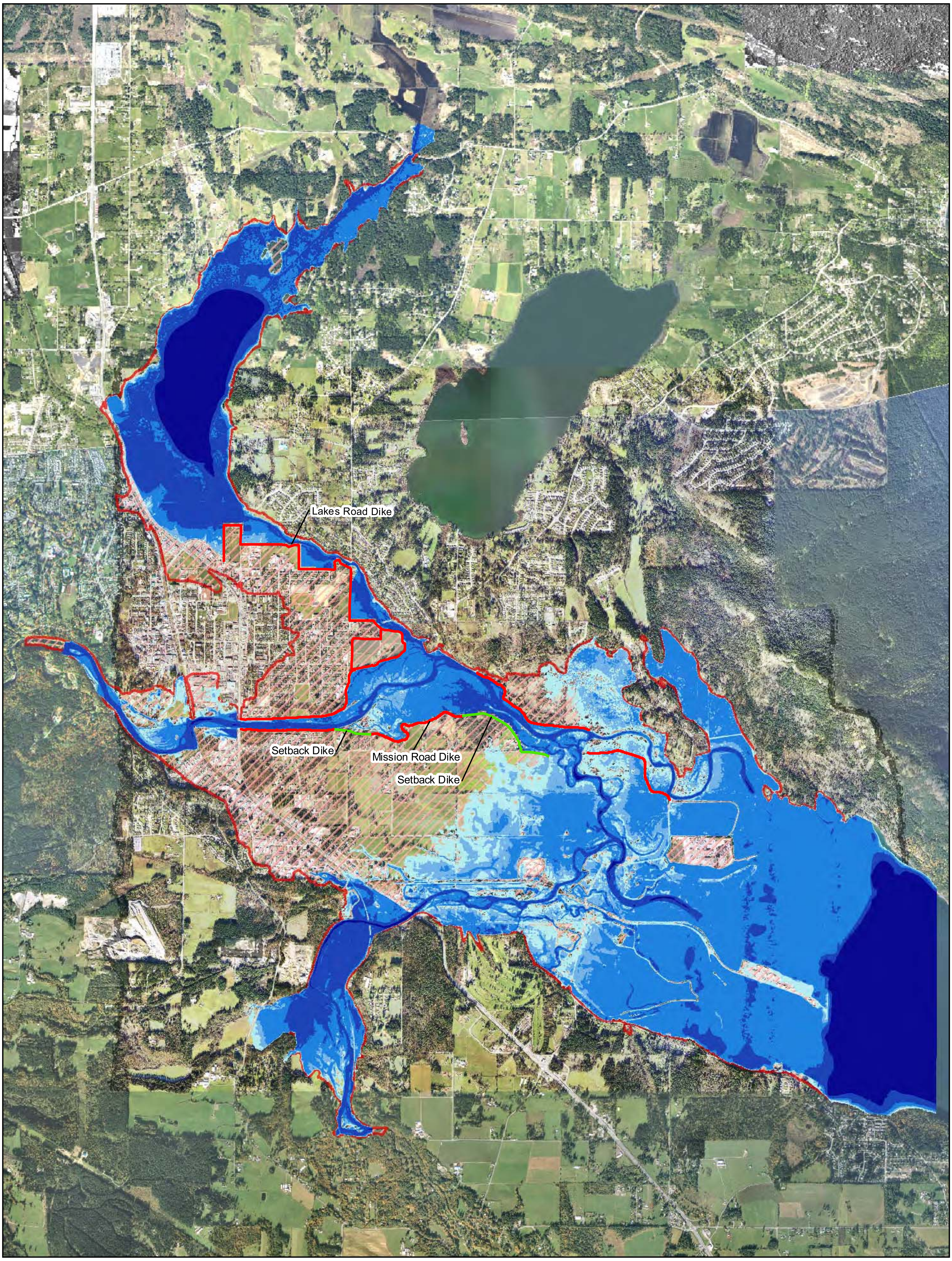
- Extending the Mission Road Dike upstream so that it ties-in to the South Side dike in order to prevent water from spilling around the end of the existing dike;
- Removing the South Side Spur Dike to allow more flow onto the floodplain;
- Setting back the Hatchery Dike by about 100 m to the existing road in order to allow more flow onto the floodplain.
- The Lakes Road Dike was assumed to be in place based on the assumption that it would be constructed if any set-back dikes were constructed.

The modified layout and results of the simulated 200-year flood are shown on Figure 3.12.

The estimated 200-year flood level in the channel was significantly lowered:

- 0.4 m at Cowichan River junction of North – South branches;
- 0.8 m at Somenos Creek junction and 0.6 m decrease at Cowichan Lake
- 0.5 m near downstream end of South Side Spur Dike
- Negligible change at downstream end of Cowichan South Side Dike.

The modified dike arrangement stopped flow from entering the floodplain between the South Side Spur and Mission Road Dikes but the south and east sides of the floodplain were still inundated, since the modification did not prevent flood waters from spilling over the floodplain from the Koksilah River or from the Cowichan River downstream of the Hatchery Dike.



Legend

Channelized Flows and Overbank Spilling

Flood Depth (m) - Freeboard not included

- 0.15 - 0.6: most houses are dry; walking in moving water is potentially dangerous
- 0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
- 1.0 - 2.0: ground floor flooded; residents move to upper floors or evacuate
- 2.0 - 5.0: first floor and often roof covered by water; evacuate
- > 5.0
- Flood Management Planning Area - Potential Inundation and Ponding

Dikes

- Dike
- Setback Dike

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation folder name: C_nhc_D_200_801_1.couple
- Added New Somenos Dike, Mission and South Setback Dike,

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Modelling Results
Set-Back Dike on South Side of Cowichan
200 Year Flood Water Depth

Scale - 1:35,000

1 0.5 0 1 Kilometers

N E S W

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_200_801.mxd

Figure 3.12

3.6.2 NEW LAKES ROAD DIKE

The purpose of the Lakes Road Dike was to reduce flooding in the north and east sections of City of Duncan. The dike is set back from Somenos Creek, starting at the sewage lagoons, then following Lakes Road, Beverly Street, wrapping around development at the north end of Duncan, following York Road (Figure 3.13).

The dike was largely effective in reducing flooding of Duncan. However, some inundation still occurred at the northwest corner of the city, since the high ground at the end of the dike is not sufficient to completely prevent flooding. Water levels in the Somenos system were increased by a maximum of about 0.1 m as a result of the dike. Water levels in other parts of the river system were unaffected.

3.6.3 NEW KOKSILAH RIVER DIKE

The left bank of the Koksilah River downstream of Highway 1 is low-lying and is very susceptible to flooding. A model simulation was made to see if the flood extent could be reduced by installing a dike along the abandoned railroad bed from the highway down to the former railway trestle bridge (Figure 3.14).

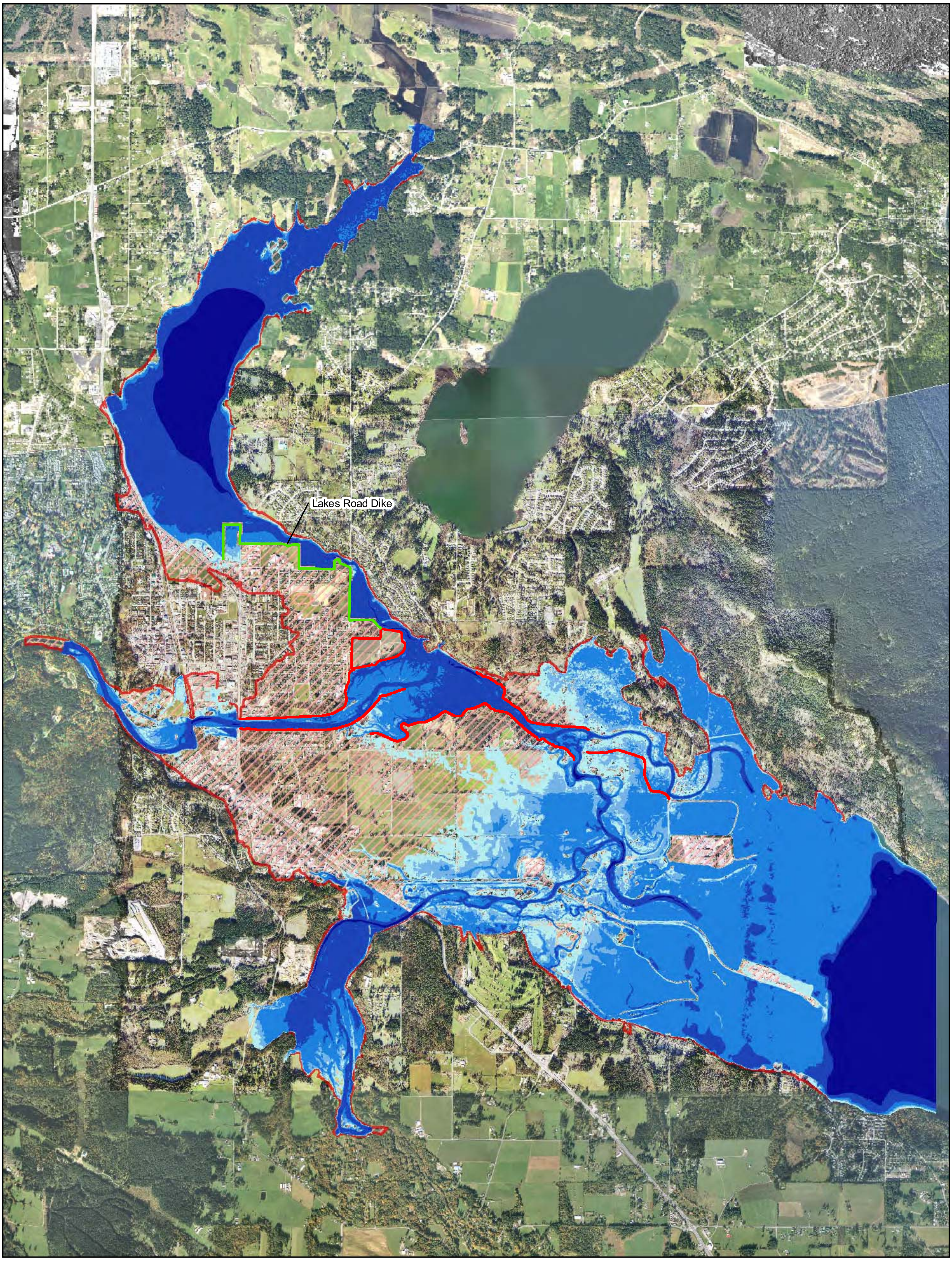
The new dike reduced the extent of flooding on the left bank downstream of the highway but did not completely prevent it. The dike caused flood waters to back up on the upstream side of the highway, then flow across the highway and flood parts of the area behind the dike. The new dike increased flood levels in the Koksilah River by a maximum of 0.3 m near the Highway. At the Koksilah/Cowichan confluence, water levels were slightly reduced since more flow was directed through a distributary channel to the estuary.

3.7 EFFECTS OF CLIMATE CHANGE

The Climate Impacts Group (CIG 2008) recommended that the application of climate change predictions in decision making should depend on the specific location, time frame and risk tolerance. Decision makers with long timelines and low risk tolerance (in design of critical infrastructure for example), should consider low-probability, upper-bound projections.

Two model simulations were conducted with the following future scenarios:

- An increase in the 200-year ocean level by 1.0 m, with no change in 200-year river discharges;
- The same increase in 200-year ocean level, with a simultaneous increase in peak discharges of 15% on the Cowichan River and 20% on the Koksilah River and all tributaries in the floodplain area.



Legend

Channelized Flows and Overbank Spilling

Flood Depth (m) - Freeboard not included

- 0.15 - 0.6: most houses are dry; walking in moving water is potentially dangerous
- 0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
- 1.0 - 2.0: ground floor flooded; residents move to upper floors or evacuate
- 2.0 - 5.0: first floor and often roof covered by water; evacuate
- > 5.0
- Flood Management Planning Area - Potential Inundation and Ponding

Dikes

- Dike
- Lakes Road Dike

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation folder name: C_nhc_D_200_501_1.couple

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Modelling Results
New Lakes Road Dike
200 Year Flood Water Depth

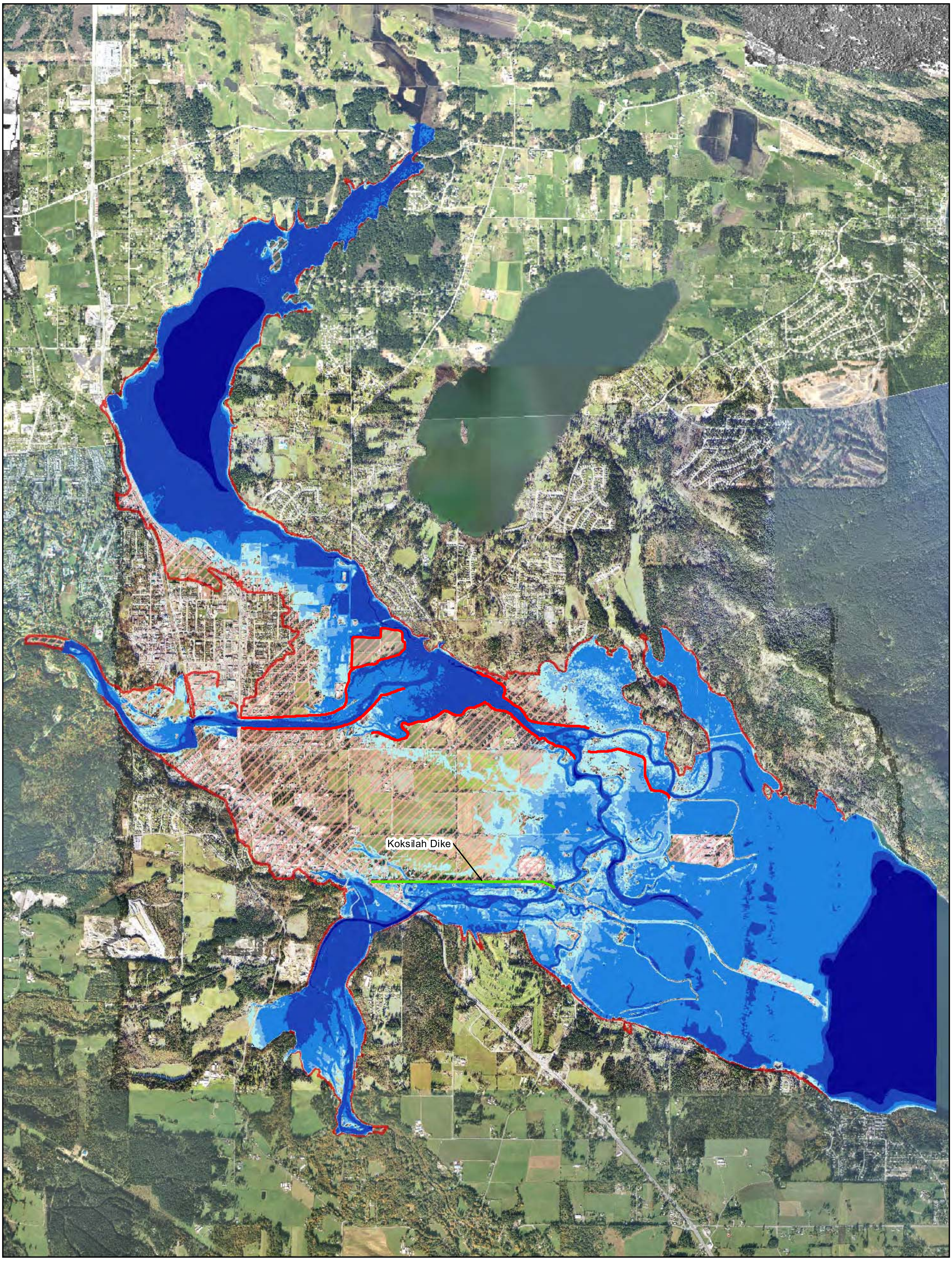
Scale - 1:35,000

1 0.5 0 1 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_200_501.mxd

Figure 3.13



Legend

Channelized Flows and Overbank Spilling

Flood Depth (m) - Freeboard not included

- 0.15 - 0.6: most houses are dry; walking in moving water is potentially dangerous
- 0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
- 1.0 - 2.0: ground floor flooded; residents move to upper floors or evacuate
- 2.0 - 5.0: first floor and often roof covered by water; evacuate
- > 5.0
- Flood Management Planning Area - Potential Inundation and Ponding

Dikes

- Dike
- Koksilah Dike

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation folder name: C_nhc_D_200_901_1.couple

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Modelling Results
New Koksilah Dike
200 Year Flood Water Depth

Scale - 1:35,000

1 0.5 0 1 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_200_901.mxd

Figure 3.14

3.7.1 EFFECTS OF INCREASED OCEAN LEVEL ONLY

Water level increases greater than 0.5 m are limited to the area downstream of the Pimbury Bridge on the north branch of the Cowichan River and the Clem Clem Bridge on the Cowichan River. The rise in floodplain gradient upstream of these two bridges significantly limits the impacts of increased ocean level. There is no detectable change in flood levels at the mouth of Somenos Creek on the Cowichan River, or at the Trans-Canada Highway Bridge on the Koksilah River.

3.7.2 EFFECTS OF INCREASED OCEAN LEVEL AND PEAK DISCHARGES

Figure 3.15 shows the effect of an increase in the 200-year peak flood combined with a 1 m higher ocean flood level. Cowichan flows overtop the right bank upstream of the Railway and Highway 1 Bridges. Flows spill overbank in a south-easterly direction on both sides of Highway 1 before joining flows from the Koksilah River. The left bank between the Railway and Highway 1 Bridges is also overtopped, with flow spilling north towards Somenos Lake. This flow path falls outside the 1997 floodplain extent as defined by MOE.

Figure 3.16 highlights the increases in water depths due to these climate change assumptions, compared to the previous 200-year results. In general, the assumed flow increases raise water levels by 0.1 to 0.25 m in Somenos Creek and near the JUB lagoons. Upstream of the Highway 1 Bridges on both the Cowichan and Koksilah Rivers, water depths increase by 0.25 to 0.5 m. It therefore appears that the extent of flooding on the floodplain is more sensitive to an increase in peak discharge than to an increase in ocean levels. The effect of a 1 m rise in ocean levels is restricted to the lower end of the floodplain, whereas the increase in discharge affected a broader area.

3.8 RELATION BETWEEN CHANNELIZATION AND HABITAT

Impacts of channelization on fisheries values include an overall reduction in species diversity and abundance relative to a non-channelized system. A study on pickerel in North Carolina indicated that channelization can reduce fish productivity up to 90% with similar implications to salmon and trout habitat in BC (Bayless and Smith 1967, as cited in Lill et al. 1975). Channelization for flood control creates an enlarged and straight channel with the capacity to sustain most of the floodwaters, but the adjacent floodplain is typically drained with the loss of seasonal inundation necessary to sustain the ecology of floodplain vegetation (Lill et al. 1975).

Specific habitat related impacts of river channelization in low gradient habitat within the Cowichan Flood Management Planning Area include the loss of natural meander patterns and associated pool/riffle sequences. The loss of vertical and lateral complexity reduces the frequency of protected alcoves, undercut banks, accumulation of stable large woody debris as

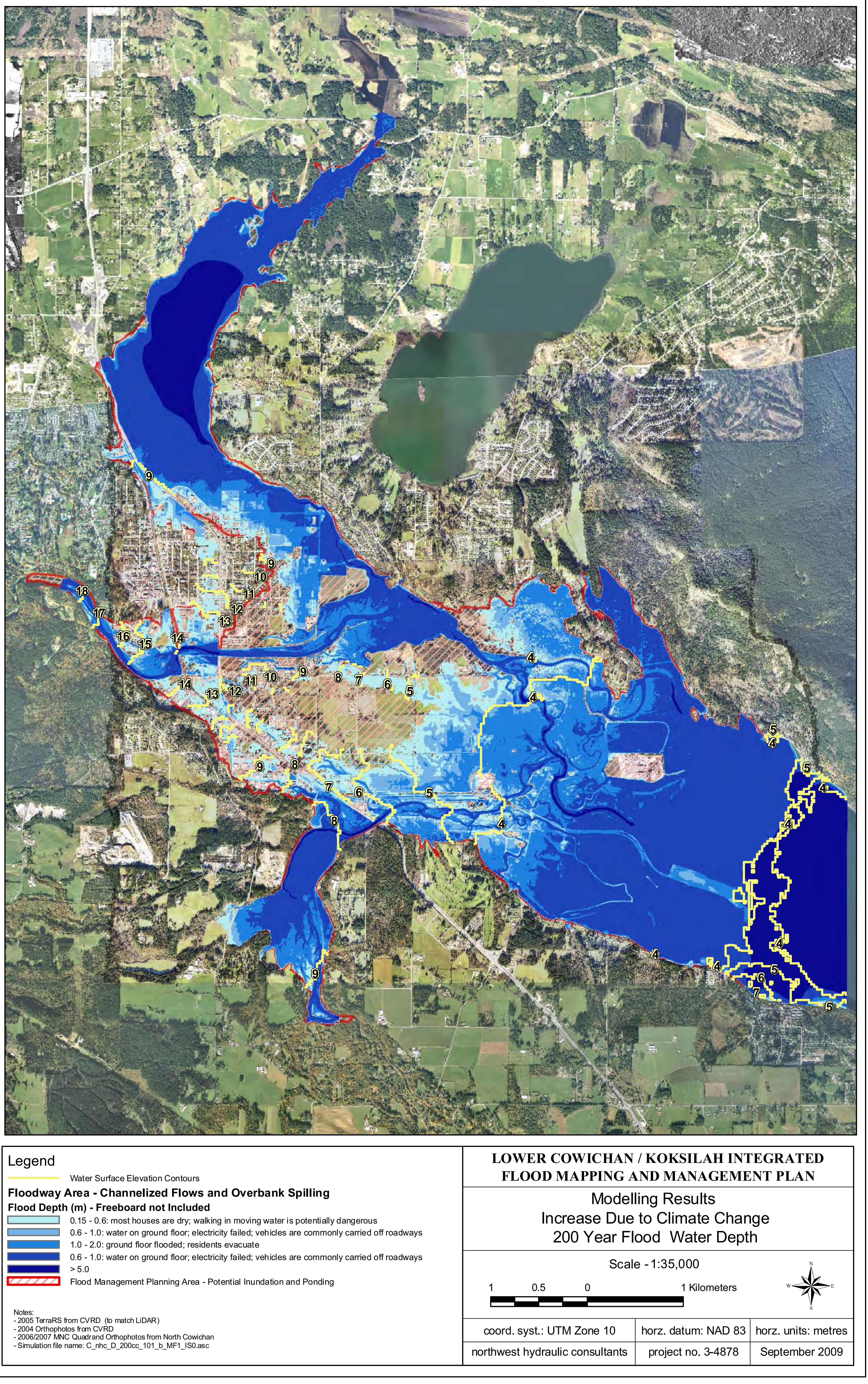


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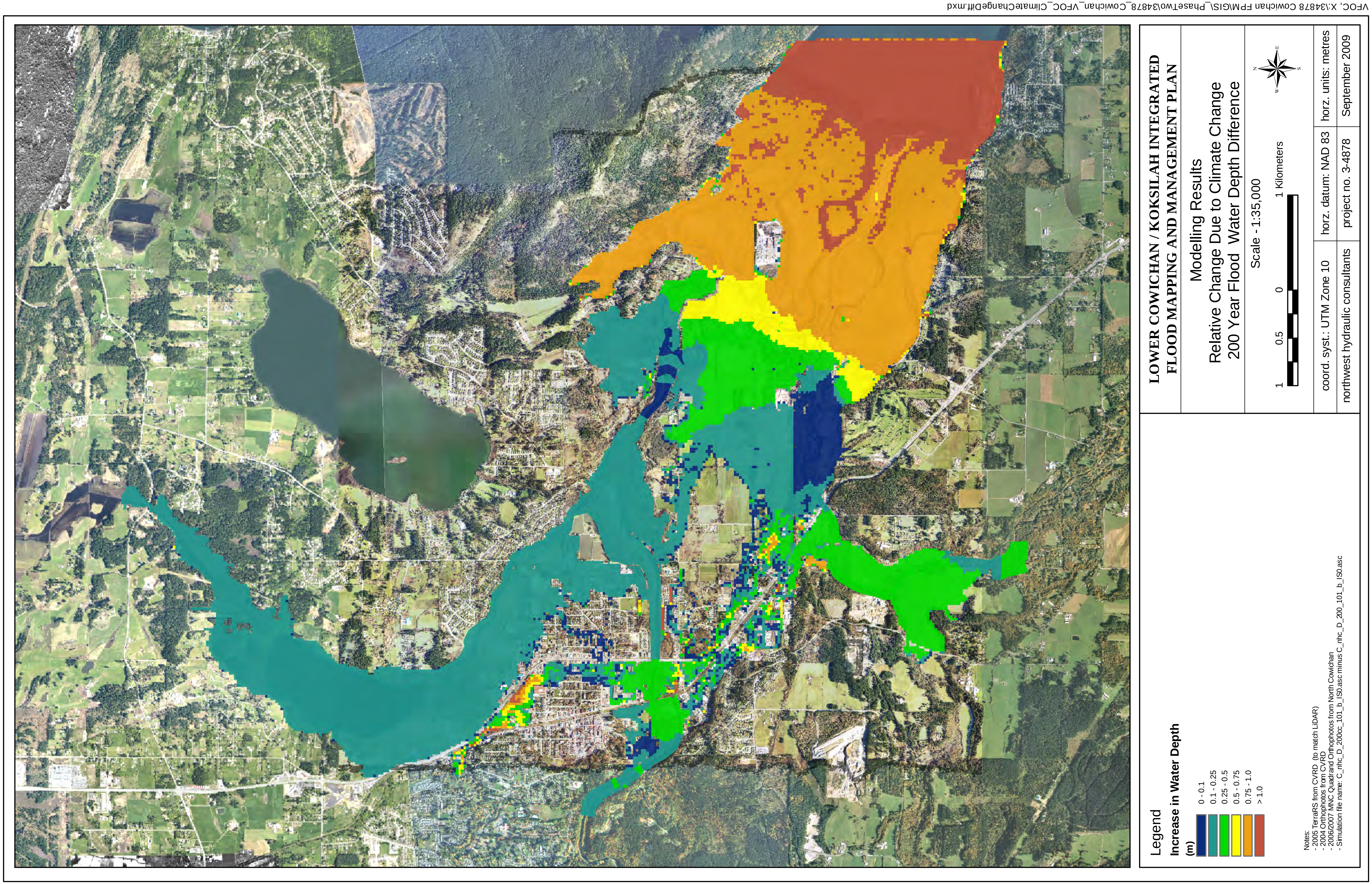
Figure 3.15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LOWER COWICHAN / KOKSILAH INTEGRATED
FLOOD MAPPING AND MANAGEMENT PLAN
Modelling Results
Relative Change Due to Climate Change
200 Year Flood Water Depth Difference
Scale - 1:35,000
1 0.5 0 1 Kilometers
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
Legend
Increase in Water Depth (m)
0 - 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1.0
> 1.0
Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation file name: C_nhc_D_200cc_101_b_IS0.asc minus C_nhc_D_200_101_b_IS0.asc

Figure 3.16

well as stable substrates. The removal of instream cover (LWD, boulders, rooted aquatic plants) can be the most significant factor affecting fish production in channelized streams (Tarplee 1971, as cited in Lill et al. 1975). The loss of instream features results in the reduction of invertebrate production, depth and frequency of lateral pools as well as the loss of refuge habitat for juvenile salmonids. The channelized Cowichan mainstem reach immediately downstream of the Highway 1 Bridge is characterized by homogenous and deep, extensive glide/riffle. This illustrates the loss of a natural pool/riffle ratios and natural frequency of LWD and riparian habitat that were likely present prior to the diking and channelization.

Other impacts of channelization on fish and wildlife habitat typically include loss of natural riparian structure, function and complexity. Direct effects to fish habitat include the immediate loss of shade, food supply and overhead cover, increased stream temperatures during the summer season as well as the loss of a long term supply of LWD recruitment. For engineered shoreline dikes with a regular maintenance program, impacts to natural riparian features are permanent. Within the Cowichan River mainstem the lack of maintenance along the shoreline dikes has allowed for recovery of natural overstory canopy consisting of Black cottonwood, Pacific willow and Red alder as well as the robust recovery of shrub species including red osier dogwood and Scoulers willow.

3.9 SUMMARY OF FLOOD HAZARD ISSUES

Key conclusions from the analyses described above are as follows:

- None of the existing dikes have adequate freeboard for a 200-year flood over their entire length. Portions of the City of Duncan are vulnerable to flooding due to overtopping or breaching of the JUB lagoon dike, as well as from backwater flooding from Somenos Creek in the Lakes Road area. Critical infrastructure such as the JUB sewage lagoons and outfall are vulnerable to damage from flooding and bank erosion.
- Under 200-year flood conditions, large spills occur along both banks of the Koksilah River, resulting in overtopping of the Trans-Canada Highway. Deep and fast flow conditions occur on the floodplain, which could pose high erosion hazards to buildings or other structures on the floodplain.
- Flooding and bank erosion can be aggravated by log jams and sediment deposition, so that the most severe potential flood damages may not necessarily arise from the most severe hydro-meteorological events. The log debris and sediment originate in the headwaters of the watersheds, upstream of the study area.
- Flood levels and flood spills over the entire floodplain area are vulnerable to alterations in dike crest levels. Furthermore, raising roads on the floodplain can have a similar effect as raising dikes. Raising or extending a dike or road at one location may raise flood levels farther upstream. It appears many local dikes were constructed without assessing their effect on adjacent areas.

Further raising or extension of dikes should not be permitted unless it can be demonstrated there will be no net water level rise at other locations.

- The Cowichan River has been artificially straightened, re-located and confined by riprap dikes, producing a canal-like appearance over much of its length. This produces high velocities and scour through narrow sections, together with localized gravel deposition and channel instability in wider sections. This type of channelized river generally requires regular maintenance and repair. Also, it adversely impacts fisheries habitat by reducing complexity.
- Currently simulated 200-year flood levels on portions of the Cowichan River, portions of Koksilah River upstream of the Trans-Canada Highway, and all of Somenos Creek and Somenos Lake are generally higher than those predicted by MOE (1997). Most of the bridges in the study area appear to have inadequate clearance under open water conditions, and are therefore susceptible to trapping logs and floating debris and potential structural failure.

4 MAPPING TOOLS

A key component of this Flood Hazard Management Plan was the development of technical tools to aid in the planning process. Various flood hazard maps were developed from numerical models of the basin – the development of the model is detailed in Volume 2 – technical investigations and summarized here.

4.1 FLOOD HAZARD MAPPING

4.1.1 OVERVIEW

Floodplain mapping of the Cowichan Valley was initially completed in 1981. In 1997, the floodplain hazard maps were updated by the BC Ministry of Environment using topographic information from the 1980s. The methods used for producing the flood maps were based on techniques developed in the 1970s under the original Canada-BC floodplain agreement. NHC's September 2008 Scoping Report identified a number of advancements in floodplain mapping techniques that have been adopted in other jurisdictions in Canada, USA, Europe and Japan in recent years. Appendix C of this volume also highlights some of these developments. BC's Living Water Smart initiative indicates that BC's floodplain hazard mapping practices are being reviewed and will need to be updated to modern standards.

Based on study objectives as stated in the terms of reference for the study, the updated floodplain maps were developed using current best management practices. The updated floodplain maps and flood construction levels were utilized a number of recent advances:

- New topographic surveys of the channel in 2008 and comprehensive LiDAR mapping of the floodplain in 2005;
- The MIKE-FLOOD model which represents the entire network of channels and floodplain and allows realistic simulations of spills and overtopping of banks and dikes;
- GIS mapping techniques for representing flood spill paths, flood inundation depths as well as critical infrastructure and sensitive habitat;
- Representing varying degrees of flood hazards by defining a higher hazard "floodway" zone subject to high velocities and deep flows and a lower hazard "flood fringe" zone. This is intended to guide planners to better landuse practices on the floodplain.

It should be noted that the updated floodplain management boundary (extent of inundation) defined in this study is virtually the same as the floodplain extent shown on the 1997 maps except in a few local areas. For the most part, the overall floodplain limits have not changed appreciably. However, flood construction levels within the boundaries have changed in some locations. Typically, flood construction levels (FCL) adjacent to the main river channels are higher than in 1997, while FCLs away from the channels on the floodplain are lower.

4.1.2 METHOD OF APPROACH

The MIKE-FLOOD model of the entire lower valley was used to estimate 25, 50, 100, and 200-year flood levels to simulate both ideal conditions, where all existing structures performed well, and realistic conditions where some dikes were assumed to breach

A series of dike breach scenarios were simulated in order to isolate the effects of individual structures on flooding during an extreme flood event. The dike breach scenarios were focused on determining the maximum extent of inundation area caused by one or more dikes failing. This approach is consistent with methods developed by FEMA for floodplain mapping in the USA. The results are of value to this study because they demonstrate the localized extent of specific failures during an extreme flood event. A detailed description of the analysis is described in Volume 2 of this study. Information on individual simulations is also summarized in Chapter 3 of Volume 3 (this present report). Table 4.1 outlines the scenarios used in the analysis.

Table 4.1: Summary of Model Simulations to Determine FCL

Flood Event (years)	**Scenario Number**	**Dikes Removed\Breached**	**Dikes Added**
200	101	None-all dikes raised	
200	201	Quamichan Dike	
200	301	JUB Lagoon Dikes	Proposed Somenos Dike along Lakes Road
200	401	Hatchery Dike Mission Road Dike South Side Spur Dike	
200	601	Cowichan River Dike	
200	701	Cowichan South Side Dike	

4.1.3 FLOOD CONSTRUCTION LEVELS

The flood construction level (FCL) is used for regulating development on the floodplain and in British Columbia is generally based on the 200-year flood plus an allowance for freeboard. The FCL is used to establish the elevation of the underside of the wooden floor system or top of concrete slab for habitable buildings. Provincial guidelines (MELP 2001) state the following:

> *Areas used for habitation, business or storage of goods damageable by floodwaters shall be established within any building at an elevation such that the underside of the floor system thereof is no less than the flood construction level.*

In this study the FCL was computed as follows:

200-year instantaneous maximum water level + 0.6 m of freeboard

The adopted 200-year maximum instantaneous water level was determined by finding the maximum water level at each grid point from each of the simulations indicated in Table 4.1. The maximum water depth grid (MaxDepth) and GIS tools were used to establish FCL contours and floodplain extents for the Cowichan and Koksilah Rivers, as shown on Map 1. The floodplain extents varied only slightly from the extents delineated in 1997 with the exception of an additional inundated area in the City of Duncan between the Trans-Canada Highway and the railroad. This newly identified area would be inundated following the failure of the Cowichan River dike.

The updated FCL contours were compared with MOE's 1997 contours, which are based on a more conservative approach. In the main channels of the Cowichan River and most of the Koksilah River, the updated FCLs are generally higher than the corresponding 1997 levels. In the Somenos system, the FCL increased from 8.8 m to 9.7 m. However, the updated FCLs on the floodplain are generally lower than the corresponding MOE levels, with decreases of over one metre in some locations. This significant reduction in the floodplain FCL values can be attributed to the new modelling approach, which provides a more realistic representation of flow across the broad floodplain.

The FCL values shown on Map 1 do not include any specific provision for changes to hydrology or ocean levels induced by future climate change. There are no widely accepted guidelines available for incorporating hypothetical future hydrological changes into present-day floodplain maps. Sensitivity analyses were carried out to assess the effect of changes to the ocean level and peak discharge on flood levels. Based on the 100 year projections of sea level change in Thompson et al. (2008) and allowing for potential increases to flood flows of between 15 % to 20 %, the computed 200-year flood levels were found to have increased by approximately 0.4 m over most of the study area. Therefore, in order to provide a first step towards planning for the potential effects of climate change over the next century, the FCL values should be increased by 0.4 m over and above freeboard to account for wind set-up and modelling error. Further scientific investigations and research will require any projections to be updated periodically over the coming years.

4.1.4 FLOODWAY ZONE

A "floodway" represents the portion of the river channel and adjacent floodplain that conveys most of the flood flow and is subject to higher velocities deeper flows than other regions. Encroachments in the floodway (such as new buildings, elevated roads or fills) will cause increased flood levels upstream, since these developments will reduce the river's hydraulic conveyance. These encroachments will also be subject to potential erosion and have the potential to trigger erosion at other adjacent sites by changing flow paths or inducing local scour. By comparison the "flood fringe" represents the portion of the floodplain that may be subject to inundation and ponding but only contributes marginally to conveying the flood. An encroachment in the "flood fringe" area will still require floodproofing, but will have substantially less impact on adjacent flood levels than developments in the floodway. Further details on the use of floodway and flood fringe zones are found in Volume 1 – Scoping Report, and in Section 6.2.

In this study, the floodway was identified using the deep and fast flowing (DFF) floodway approach developed by the USBR (1988) and adopted by Pierce County in Washington State (NHC 2007a). The DFF floodway consists of areas within the floodplain that could, under the 200-year flood conditions, have water depths greater than 1 m, have velocities greater than 1 m/s, or have some combination of depth and velocity lying above the threshold shown in Figure 4.1. All active channels were included in the DFF floodway.

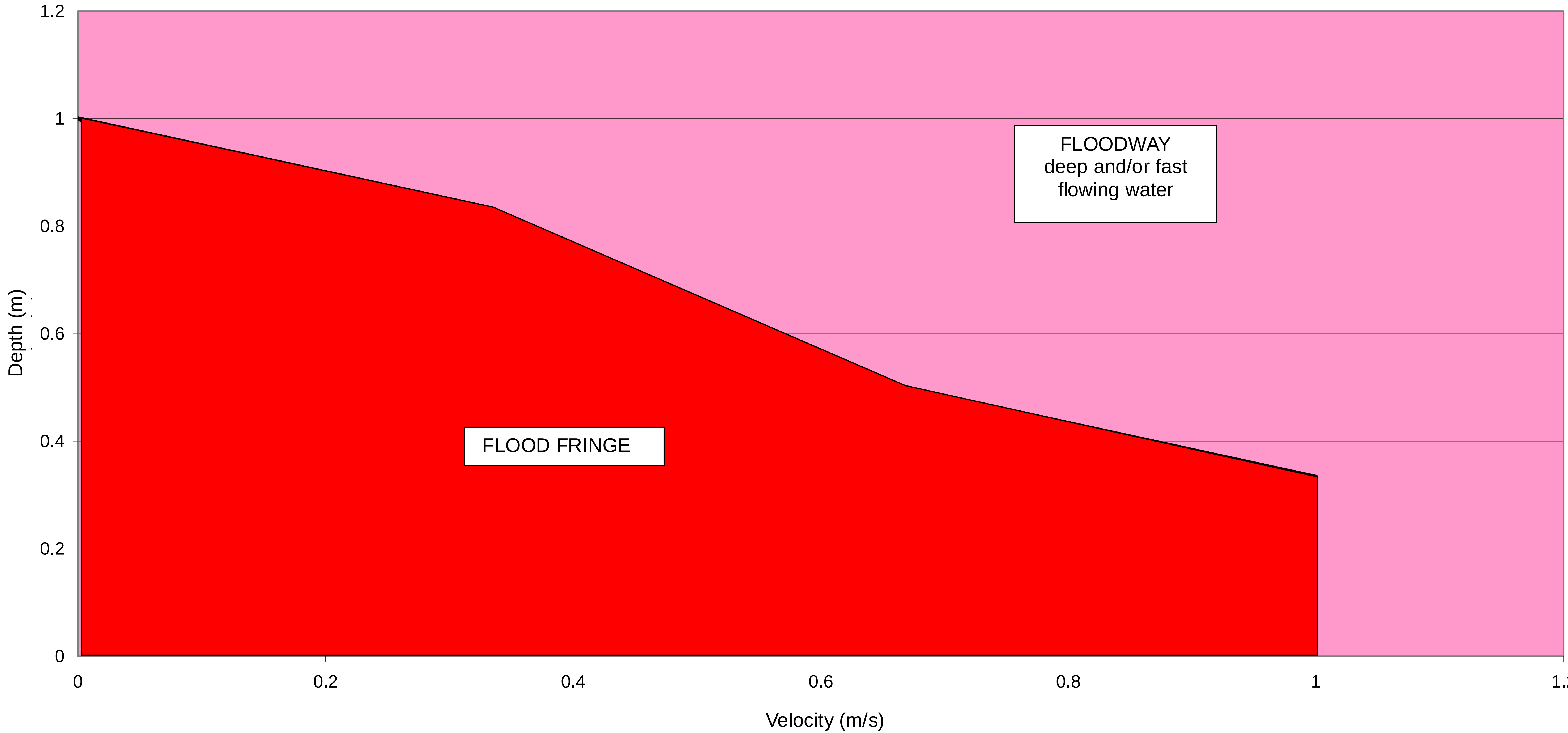
For each of the six simulations, a grid was generated containing only the maximum water depths computed at each grid point. In GIS, these six grids were combined into one grid, keeping only the greatest of the six maximum water depth values at each grid point. Similarly, a MaxVelocity grid was compiled and contained the maximum water velocities in the inundated area as a result of one or more dikes failing.

Once the three input files required for the DFF calculation (active channel shapefile, MaxDepth grid, and MaxVelocity grid) were generated, the methodology outlined in the Pierce County memo (NHC 2007a) was followed to yield a floodway polygon. Some post-processing (removal of small gaps and island) was required to obtain the final DFF floodway polygon shown on Map 1. The floodway covers a large portion of the floodplain on both sides of the Koksilah River and the lower half of the Cowichan River.

Although not included in the DFF analysis, it is known from previous simulations that the floodway will increase substantially if the peak discharge increases in the future as a result of climate change. In particular, new flood spills will occur upstream of the Trans-Canada Highway Bridge on both sides of the Cowichan River and hence increase the area of the DFF floodway.

4.1.5 LIMITATIONS OF MAPPING

1. The maps depict flood conditions at the time of the surveys. Changes to the channel and floodplain will affect the flood levels and render site-specific map information obsolete.
2. Floodplain maps are administrative tools which depict the minimum flood elevation and floodplain boundaries. Flooding may occur outside of the designated boundaries.
3. Floodplain maps do not provide information on site-specific hazards such as land erosion or sudden shifts in the water courses.
4. Other sources of water, roads, railways or other barriers can restrict water flow and affect local flood levels. Obstructions such as debris and log jams, sediment deposition, local storm water inflows, groundwater or other land drainage can cause flood levels to exceed those indicated on the map. Lands adjacent to a floodplain may be subject to flooding from tributary streams that are not indicated on the maps.
5. The accuracy of the location of a floodplain boundary as shown on this map is limited by the base mapping and orthophotos. The lines were not established by legal survey on the ground.
6. Professional assistance and detailed site-specific engineering analysis are required to address any of the above issues.



Deep and/or Fast Flowing (DFF) Floodway Classification is based on United States Bureau of Reclamation (1998).

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Flood Fringe and Floodway Classification

northwest hydraulic consultants	project no. 3-4878	September 2009

Figure 4.1

The updated floodplain mapping will be one of the key tools for flood management and is intended to be a component of the integrated flood management plan. The existing (1997) MOE maps should continue to be used until the new flood management plan is implemented.

4.1.6 FLOOD SCENARIO MAPS

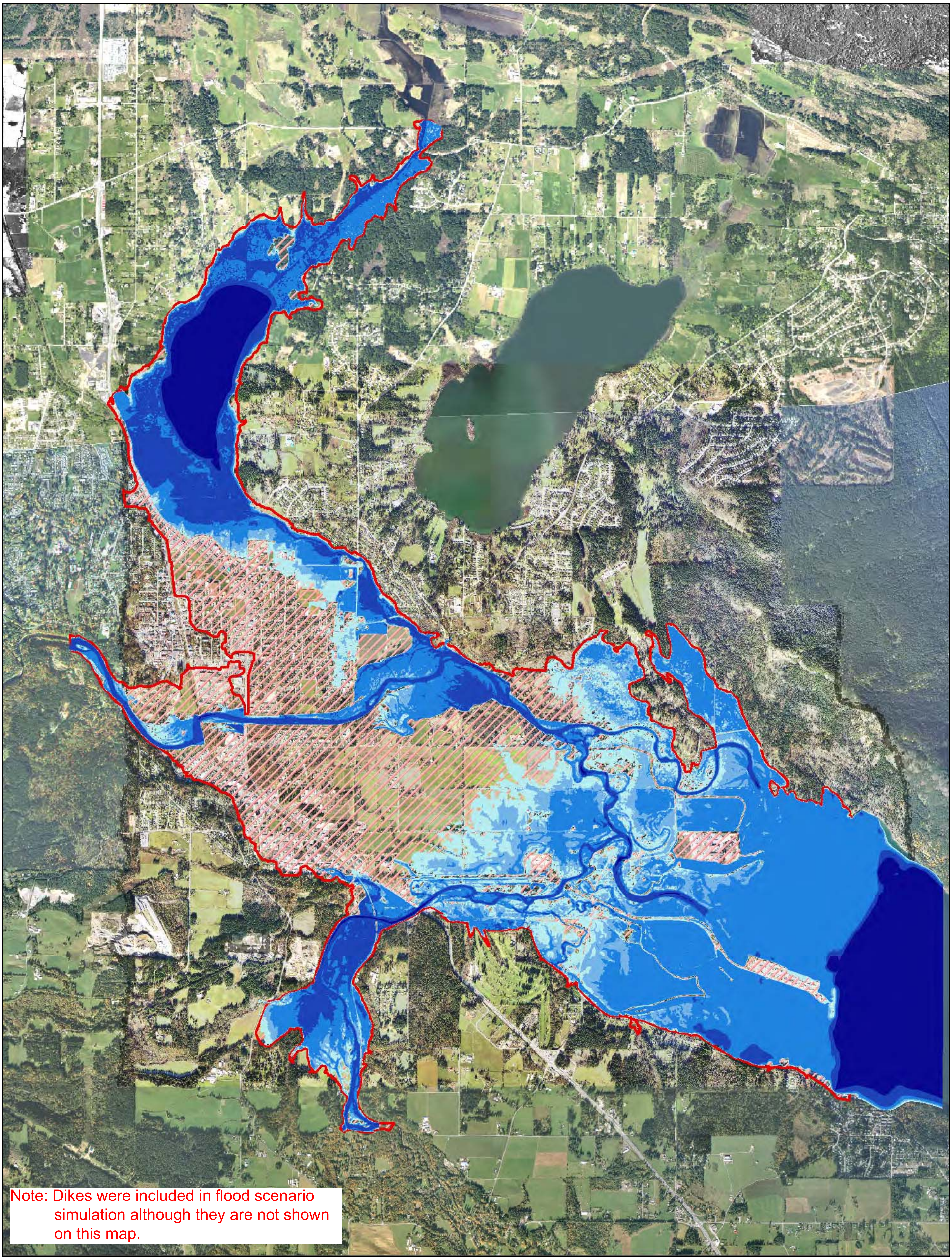
Flood extent and flood depth maps were generated for a wide range of scenarios, including existing conditions, with all existing dikes raised and with various dike breach scenarios. These maps were included and discussed in Volume 2 – Technical Investigations. Flood scenario maps for 25, 50, 100 and 200-year flood conditions are reproduced in this report. The simulations were done with the existing dikes raised so that all of the flow was confined within the floodway between the dikes. This eliminated dike overtopping but allowed spills and floodplain flows to occur at other non-diked areas. These scenarios produced higher water levels along the river and represent a conservative approach to determining appropriate dike crest levels that are required to prevent overtopping.

Flood depths shown on these maps (Figure 4.2 through Figure 4.5) do not include any freeboard. The maps are intended to assist in emergency response planning since they show a number of hypothetical flood spills and inundation zones during future events.

4.2 CHANNEL EROSION HAZARD MAPPING

4.2.1 OVERVIEW

Channel bank erosion can take a variety of forms, but most commonly includes meander migration, translation of existing bends downstream, channel widening during flood and avulsions. Woody debris jam accumulations are known to be additional triggers for both bank erosion and avulsions. In some rivers, the risk from erosion may be greater than the risk of flooding (FEMA 1999). Locations subject to potential erosion can include areas that are not subject to flooding, such as adjacent terraces. Erosion can also result in failure of flood protection structures and threaten property and infrastructure that is not subject to flooding. Channel erosion hazard mapping, therefore, provides land managers with an additional tool for planning development on floodplains. They may also provide guidance in reducing degradation and loss of aquatic and riparian habitats (Rapp and Abbe 2003). Although there is no standard approach for delineating areas susceptible to erosion hazards, the following discussion provides an example of an approach that has been developed for other rivers in British Columbia (cf. Ham and Schwab 1998).



Legend

Channelized Flows and Overbank Spilling

Flood Depth (m) - Freeboard not included

- 0.15 - 0.6: most houses are dry; walking in moving water is potentially dot includeangerous
- 0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
- 1.0 - 2.0: ground floor flooded; residents move to upper floors or evacuate
- 2.0 - 5.0: first floor and often roof covered by water; evacuate
- > 5.0
- Flood Management Planning Area - Potential Inundation and Ponding

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation folder name: C_nhc_D_25_101_1.couple

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Flood Scenario Map
25 Year Flood - Water Depth

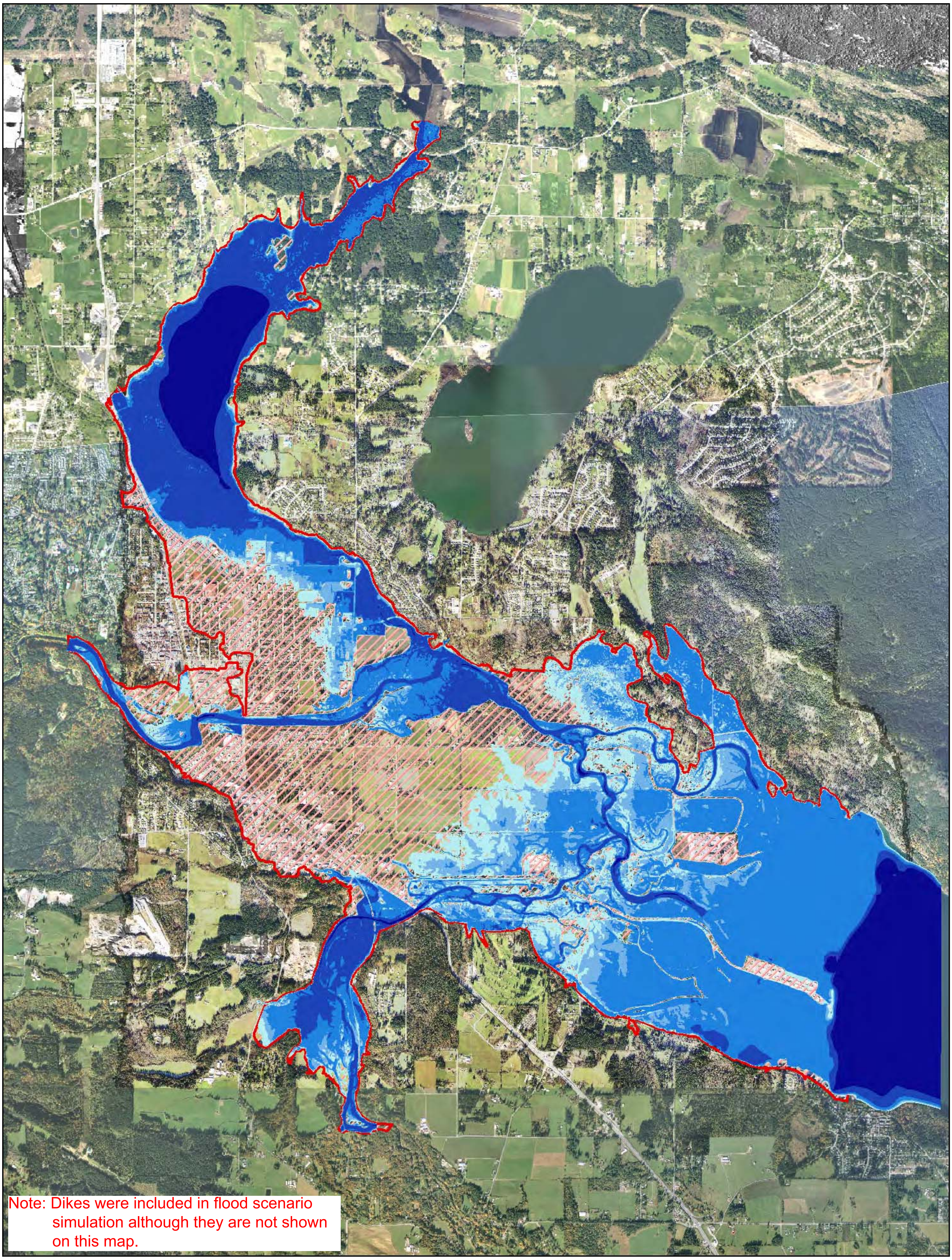
Scale - 1:35,000

1 0.5 0 1 Kilometers

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

Figure 4.2

JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_25_101.mxd



Legend

Channelized Flows and Overbank Spilling

Flood Depth (m) - Freeboard not included

- 0.15 - 0.6: most houses are dry; walking in moving water is potentially dangerous
- 0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
- 1.0 - 2.0: ground floor flooded; residents move to upper floors or evacuate
- 2.0 - 5.0: first floor and often roof covered by water; evacuate
- > 5.0
- Flood Management Planning Area - Potential Inundation and Ponding

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation folder name: C_nhc_D_50_101_1.couple

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Flood Scenario Map
50 Year Flood - Water Depth

Scale - 1:35,000

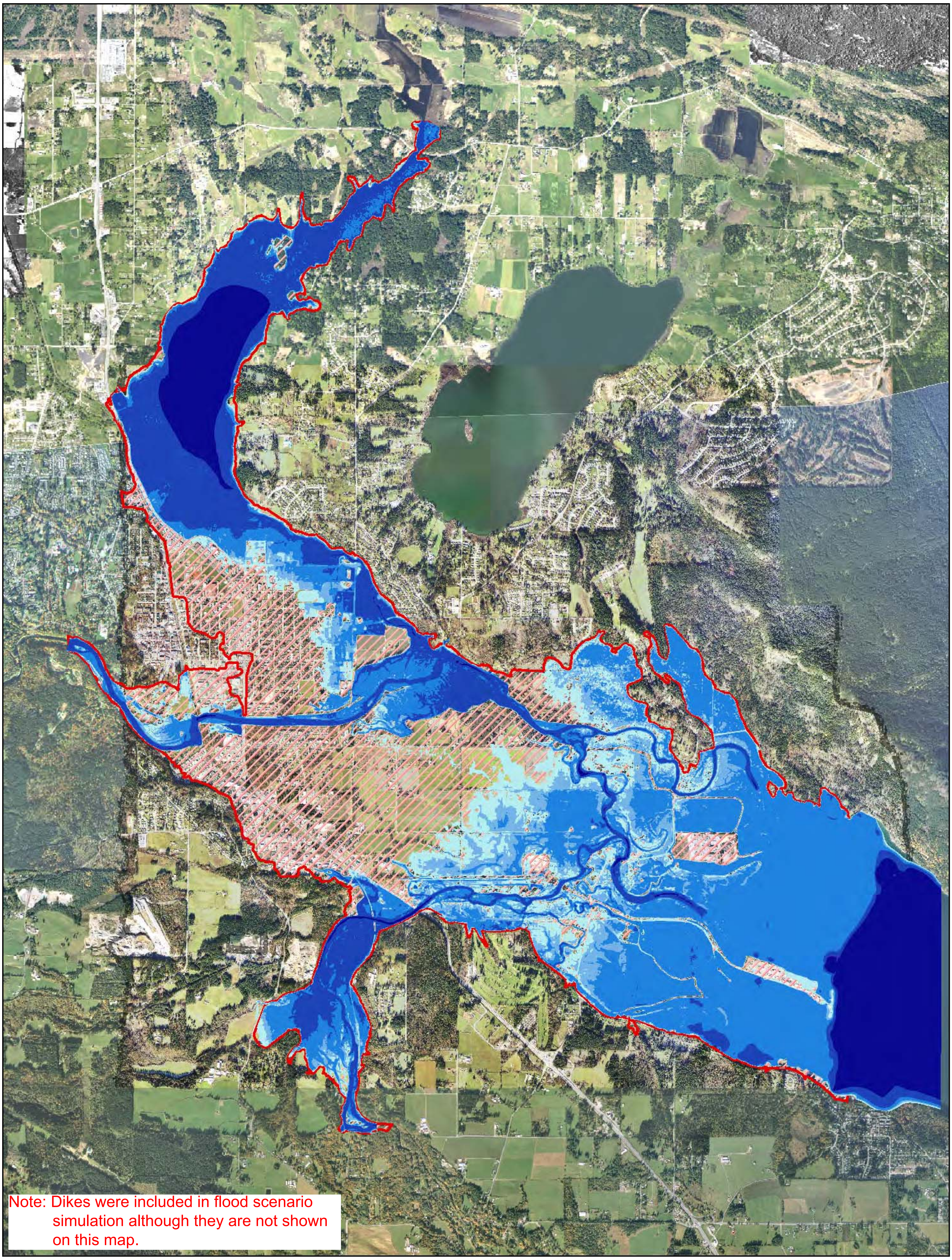
1 0.5 0 1 Kilometers

N W E S

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_50_101.mxd

Figure 4.3



Legend

Channelized Flows and Overbank Spilling

Flood Depth (m) - Freeboard not included

- 0.15 - 0.6: most houses are dry; walking in moving water is potentially dangerous
- 0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
- 1.0 - 2.0: ground floor flooded; residents move to upper floors or evacuate
- 2.0 - 5.0: first floor and often roof covered by water; evacuate
- > 5.0
- Flood Management Planning Area - Potential Inundation and Ponding

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation folder name: C_nhc_D_100_101_1.couple

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Flood Scenario Map
100 Year Flood - Water Depth

Scale - 1:35,000

1 0.5 0 1 Kilometers

N E S W

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

Figure 4.4

JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_100_101.mxd

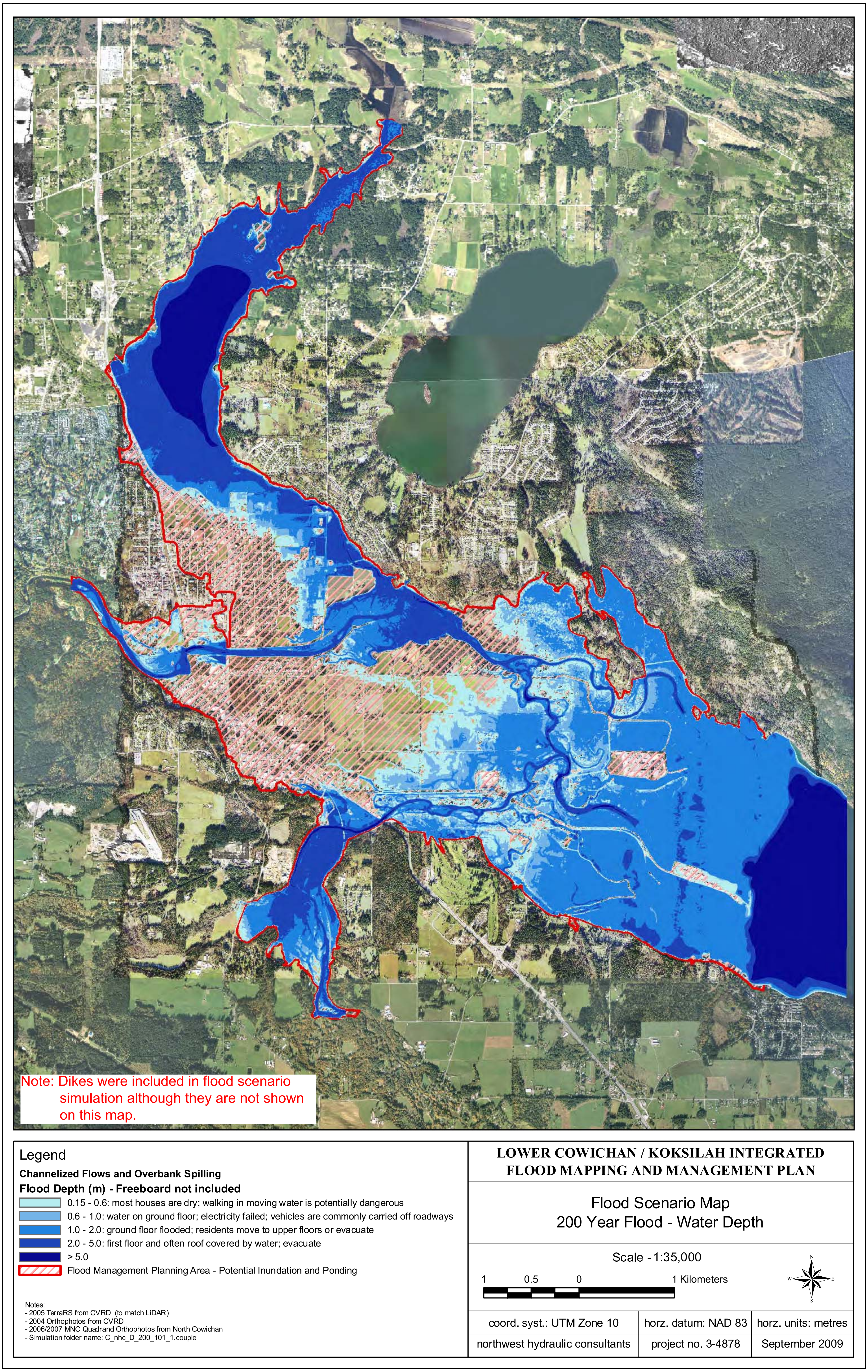

Note: Dikes were included in flood scenario simulation although they are not shown on this map.
Legend
Channelized Flows and Overbank Spilling
Flood Depth (m) - Freeboard not included
0.15 - 0.6: most houses are dry; walking in moving water is potentially dangerous
0.6 - 1.0: water on ground floor; electricity failed; vehicles are commonly carried off roadways
1.0 - 2.0: ground floor flooded; residents move to upper floors or evacuate
2.0 - 5.0: first floor and often roof covered by water; evacuate
> 5.0
Flood Management Planning Area - Potential Inundation and Ponding
Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Simulation folder name: C_nhc_D_200_101_1.couple
LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN
Flood Scenario Map
200 Year Flood - Water Depth
Scale - 1:35,000
1 0.5 0 1 Kilometers
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
JXD, X:\34878 Cowichan FPM\GIS_Phase3\34878_Cowichan_JXD_Depth_200_101.mxd

Figure 4.5

4.2.2 HISTORIC MAPPING

The available historic sequence of geo-referenced aerial photographs provides the basis for constructing the channel migration zone (CMZ) maps. In general, the longer the historic record the more reliable predictions of future channel development will be. However, changes in land management practices and climate change introduce uncertainty into any predictions. As it is known that Cowichan River has been subject to a number of significant forced changes before the 1980s (including channelization, channel alignment, diking and gravel removal) only more recent channel maps (1984, 1998, 2005 and 2008 river surveys) were used in the analysis. The Koksilah River has not been as severely channelized or altered so its mapping record is extended from 1946 to the present. The 1984 and 2005 photography also encompasses the lower Koksilah River, although the 1998 imagery does not.

For each date, the channel banks and islands were digitized on the Cowichan River (north and south branches) and Koksilah River within the study limits. Polygon maps of the channel and floodplain were subsequently created and coded as either active channel (which includes bars and the wetted channel) or floodplain, including islands. Overlays of these morphologic maps for different dates represent the historic migration zone, or area that has been occupied by the active channel at some time over the mapping record (Figure 4.6). The current active channel is located within this zone, which also includes areas of recent floodplain construction. Locations beyond the historic migration zone have been stable over the period of mapping, though areas proximal to the main channel may have been active during earlier periods. An extensive network of side-channels is found on the adjacent floodplain in a few locations provides direct evidence of past channel activity. Such areas are subject to avulsion during flood. Stable floodplain elements may also be at risk from erosion through natural migration processes, or through the effects of anthropogenic impacts.

4.2.3 HAZARD ZONE CLASSIFICATION

The channel migration hazard maps are assigned to one of five zones based on the relative risk of erosion as shown in Figure 4.7. Stable floodplain polygons were divided into separate zones based on the extent of floodplain channels (side-channels) and their connectivity to the contemporary active channel. There is an extensive network of connected side-channels on Cowichan River, roughly bounded by the JUB dike extending to Somenos Creek confluence on the north floodplain, and bounded by Mission Road dike on the south floodplain. There is another set of side-channels at the confluence of the south arm of Cowichan River where there is a risk of a partial avulsion into the south river channel. High rates of past channel shifting at this location appear to be related to woody debris jams that periodically block channel entrances. There are also a number of prominent side-channels on the south bank of Koksilah River near the intersection of Tzouhalem and Cowichan Bay Roads.

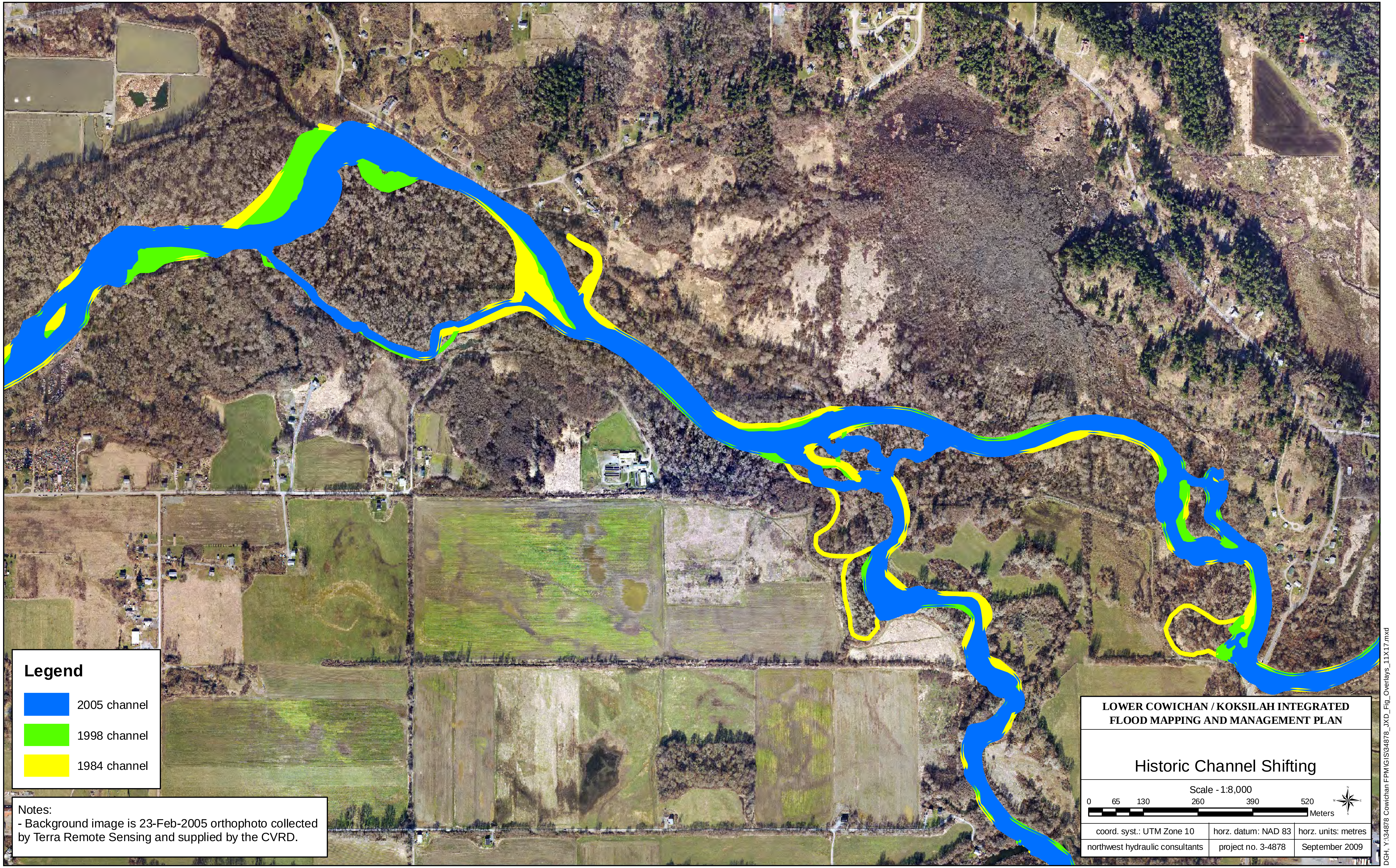
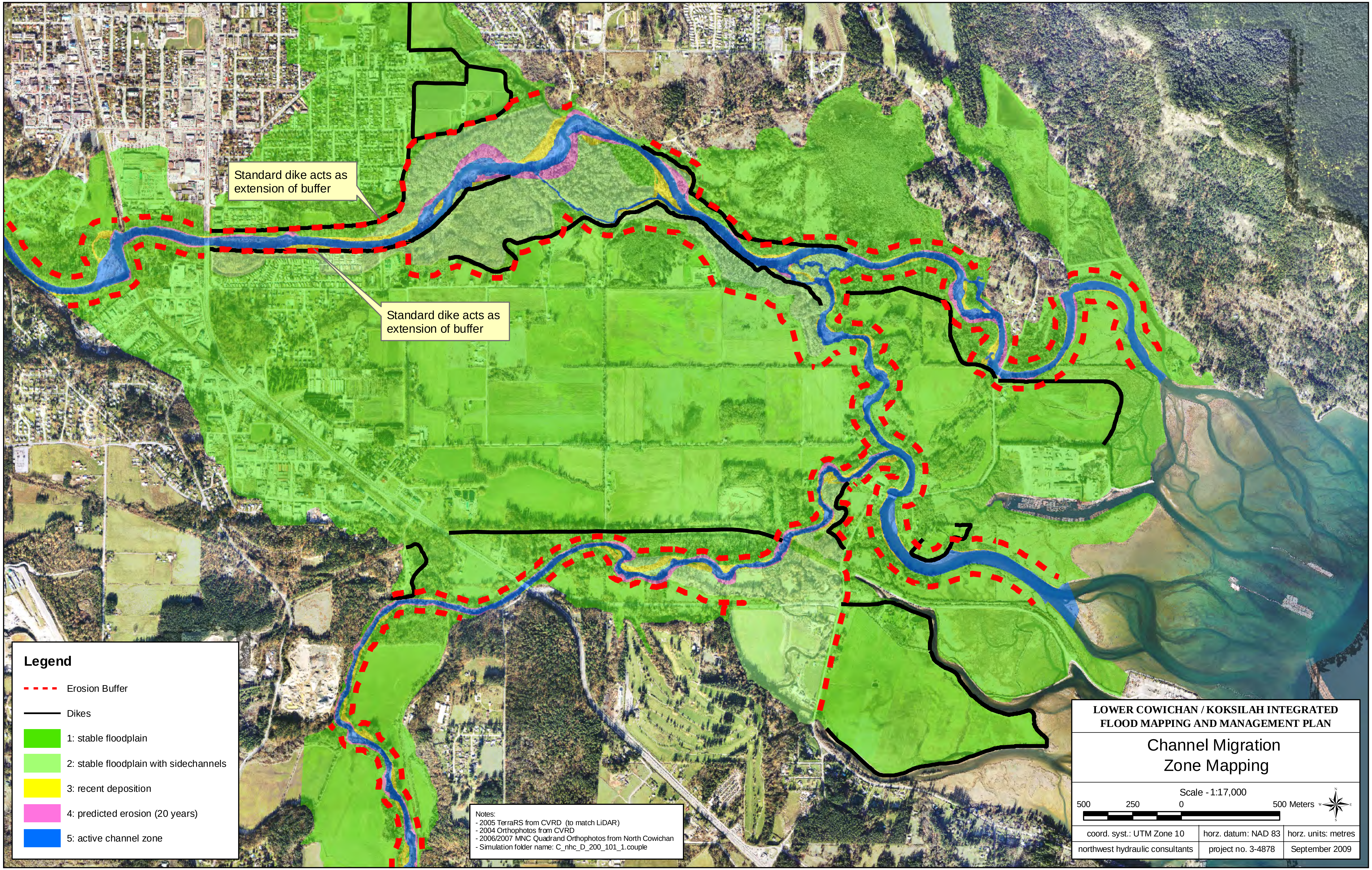

Legend
2005 channel
1998 channel
1984 channel
Notes:
- Background image is 23-Feb-2005 orthophoto collected by Terra Remote Sensing and supplied by the CVRD.
LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN
Historic Channel Shifting
Scale - 1:8,000
0 65 130 260 390 520
Meters
N
S
W
E
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
DGH, Y:\34878 Cowichan FPM\GIS\34878_JXD_Fig_Overlays_11X17.mxd

Figure 4.6



JXD, X:\34878 Cowichan FPM\GIS\34878_JXD_ChannelMigration.mxd

Figure 4.7

Zone 1: Stable lands lying outside of the historic migration zone and not containing active side-channels;

Zone 2: Floodplain areas lying outside of the historic channel migration zone but containing active side-channels. Side-channels may become reactivated during large flood events, especially if there is no woody debris blocking the entrance;

Zone 3: Floodplain within the historic channel migration zone including areas of recent deposition (new islands or floodplain).

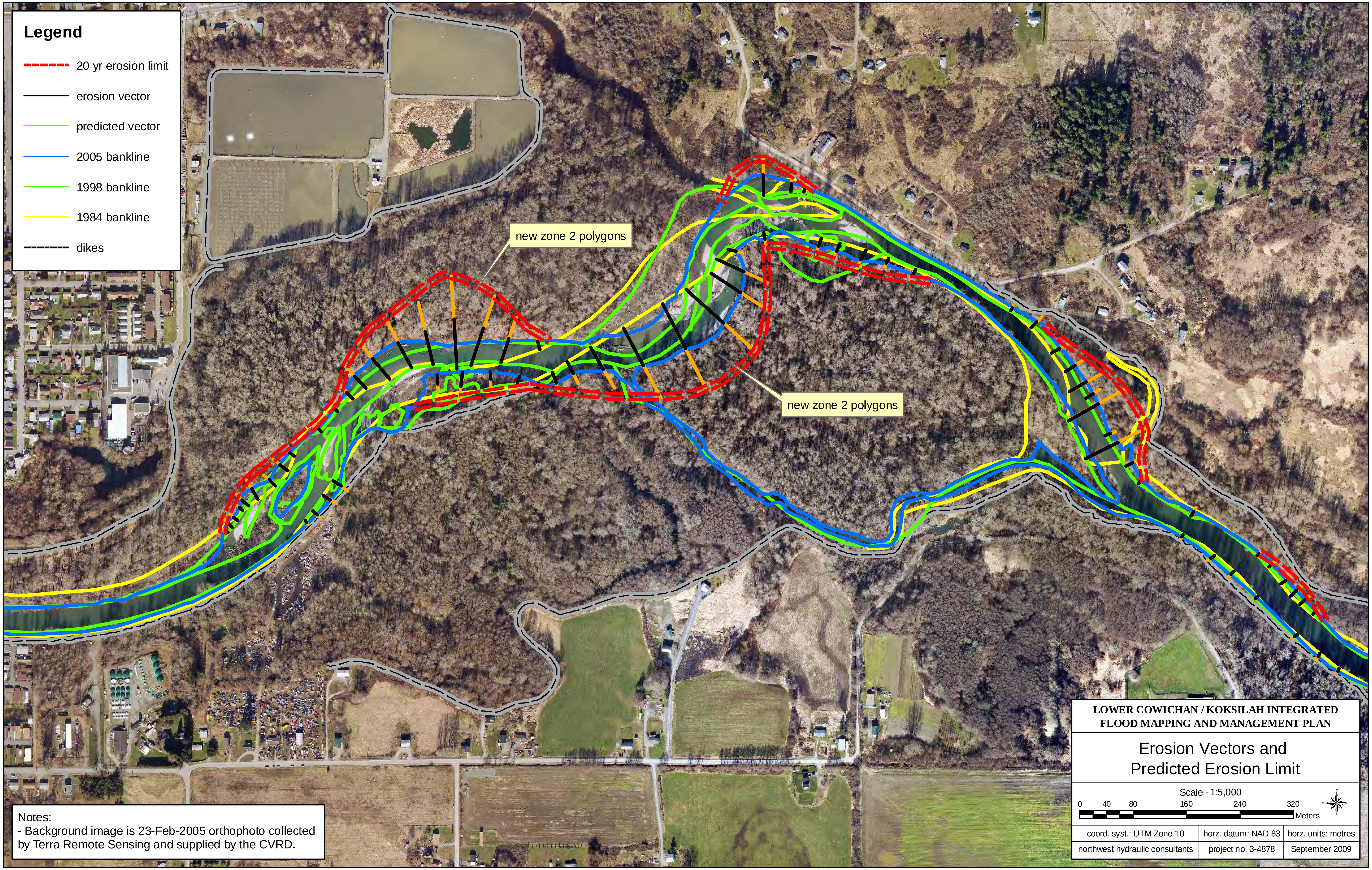
Zone 4: Predicted bank position after 20 years, based on average long-term rate of recession (described further below).

Zone 5: All persistent or recently active channels are assigned the highest risk category. These areas are apt to remain unstable in the future, and areas adjacent to zone 5 are potentially at risk from erosion in the future. These areas are also at high risk of overbank flooding.

4.2.4 CHANNEL MIGRATION ZONE

Not all areas adjacent to the current active channel are at immediate risk from future erosion. The erosion risk changes over time in response to overall evolution of channel morphology. The direction of prevailing erosion was defined by digitizing vectors perpendicular to the direction of bankline shifting over time (Figure 4.8). The length of each vector, divided by the measurement period (23 years for Cowichan River, 61 years for Koksilah River) gives the average erosion rate. Multiplying this rate by the prediction period (20 years) gives the estimated extent of future erosion based on historic average rates. A period of 20 years was adopted for this study since erosion is unlikely to occur for longer periods in a single direction. A smoothed bounding line was then drawn on the outer margins of the extent of the longest vectors, where some interpretation is required to produce a realistic eroded bankline (Figure 4.8). This interpretation is necessary because the extended vectors are sometimes of variable length, and connecting them directly produces an unrealistic jagged bankline. All polygons falling within the limit of the predicted erosion (Zones 1, 2 or 3) were re-classified as Zone 4. The extent of this zone only provides an indication of potential changes based on average historic erosion rates. It is not appropriate for establishing set-backs or for long-term landuse planning, because local erosion can be substantially higher than average rates due to extreme floods, changing positions of gravel bars, islands and debris jams.

An estimate of an appropriate planning setback distance for the Cowichan and Koksilah Rivers was made by conducting a statistical analysis of historic erosion vector lengths. The adopted planning setback distance was estimated as the maximum length within a 95 % confidence interval. Therefore, the adopted set-back has a 5 % exceedance probability. The values were normalized to represent a 25 year planning period. The corresponding set-backs were 50 m for the Cowichan River and 40 m for the Koksilah River.



DGH, Y:\34878 Cowichan FPM\GIS\34878_JXD_Fig_Vectors_11X17.mxd

Figure 4.8

4.3 HABITAT MAPPING

The habitat mapping component was intended to identify and highlight important fisheries and wildlife habitat features and then develop a three-tiered ranking system for freshwater and riparian ecosystems. This data was integrated into GIS to illustrate potential interactions between sensitive habitat features and the existing flood protection infrastructure as well as existing/proposed urban, industrial, agricultural and commercial development. This is an important tool in the development of a fully integrated flood management plan.

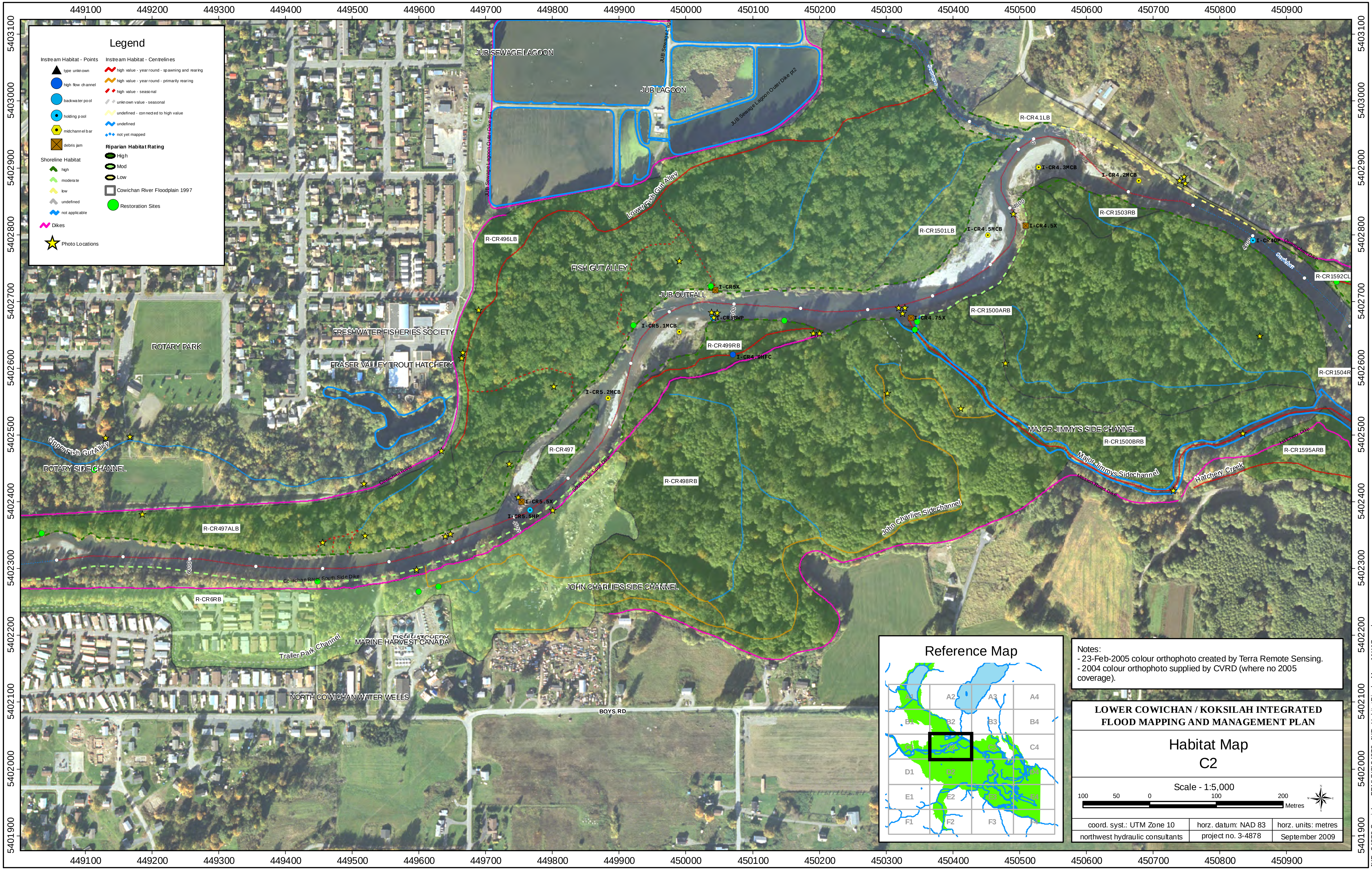
For each habitat category (riparian, instream and shoreline), a three-tiered habitat value or sensitivity rating (Very High/High, Moderate and Low) system has been developed. A description of each habitat value is provided in Appendix B and is based on known ecological features as outlined in Section 2.5 and Appendix A.

A habitat sensitivity pilot project was completed as part of this study and is intended to be an iterative product that will be reviewed and updated with collection of new data or integration with other mapping products. The intent of the pilot mapping tool is to provide a starting point as a tool for land and resource management that illustrates known fisheries and wildlife habitat values and conceptual habitat restoration opportunities. Two panels (Figure 4.9 and Figure 4.10) of the Habitat Mapping Area were completed as part of the pilot study and are described in detail in Appendix B.

4.3.1 RECOMMENDATIONS FOR FUTURE HABITAT SENSITIVITY AND RESTORATION MAPPING

The proposed habitat sensitivity ratings and management recommendations require review and discussion amongst key local practitioners and interested user groups involved with resource planning and resource management activities within the lower Cowichan River. The review process should include:

- Demonstration and/or review of the user friendly pilot GIS mapping and database files
- Ensure known sensitive habitat features have been included and identify additional information needed
- Review, discuss, modify and agree upon sensitivity ratings
- Review and discuss acceptable management of the 3 sensitivity types within the shoreline, riparian, and instream categories
- Discuss integration of habitat restoration data
- Expand the Habitat Pilot Study Area mapping to cover the entire Flood Management Planning Area
- Develop an iterative process to revise and update the sensitivity ratings and mapping tool



Legend
Instream Habitat - Points
type unknown
high flow channel
backwater pool
holding pool
midchannel bar
debris jam
Shoreline Habitat
high
moderate
low
undefined
not applicable
Dikes
Photo Locations
Instream Habitat - Centrelines
high value - year round - spawning and rearing
high value - year round - primarily rearing
high value - seasonal
unknown value - seasonal
undefined - connected to high value
undefined
not yet mapped
Riparian Habitat Rating
High
Mod
Low
Cowichan River Floodplain 1997
Restoration Sites
JUB SEWAGE LAGOON
JUB LAGOON
FISH GUT ALLEY
JUB OUTFALL
FRESHWATER FISHERIES SOCIETY
ROTARY PARK
FRASER VALLEY TROUT HATCHERY
ROTARY SIDE CHANNEL
MAJOR JIMMY'S SIDE CHANNEL
JOHN CHARLIE'S SIDE CHANNEL
MARINE HARVEST CANADA
NORTH COWICHAN WATER WELLS
BOYS RD
Upper Fish Gut Alley
Lower Fish Gut Alley
Cowichan River
Cowichan River South Side Dike
Trailer Park Channel
John Charlies Sidechannel
Major Jimmys Sidechannel
Hatchery Creek
Reference Map
Notes:
- 23-Feb-2005 colour orthophoto created by Terra Remote Sensing.
- 2004 colour orthophoto supplied by CVRD (where no 2005 coverage).
LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN
Habitat Map
C2
Scale - 1:5,000
Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
JXD, 34878 Cowichan FPM\GIS\34878_JXD_HabitatDisplayMap_11X17.mxd

Figure 4.9

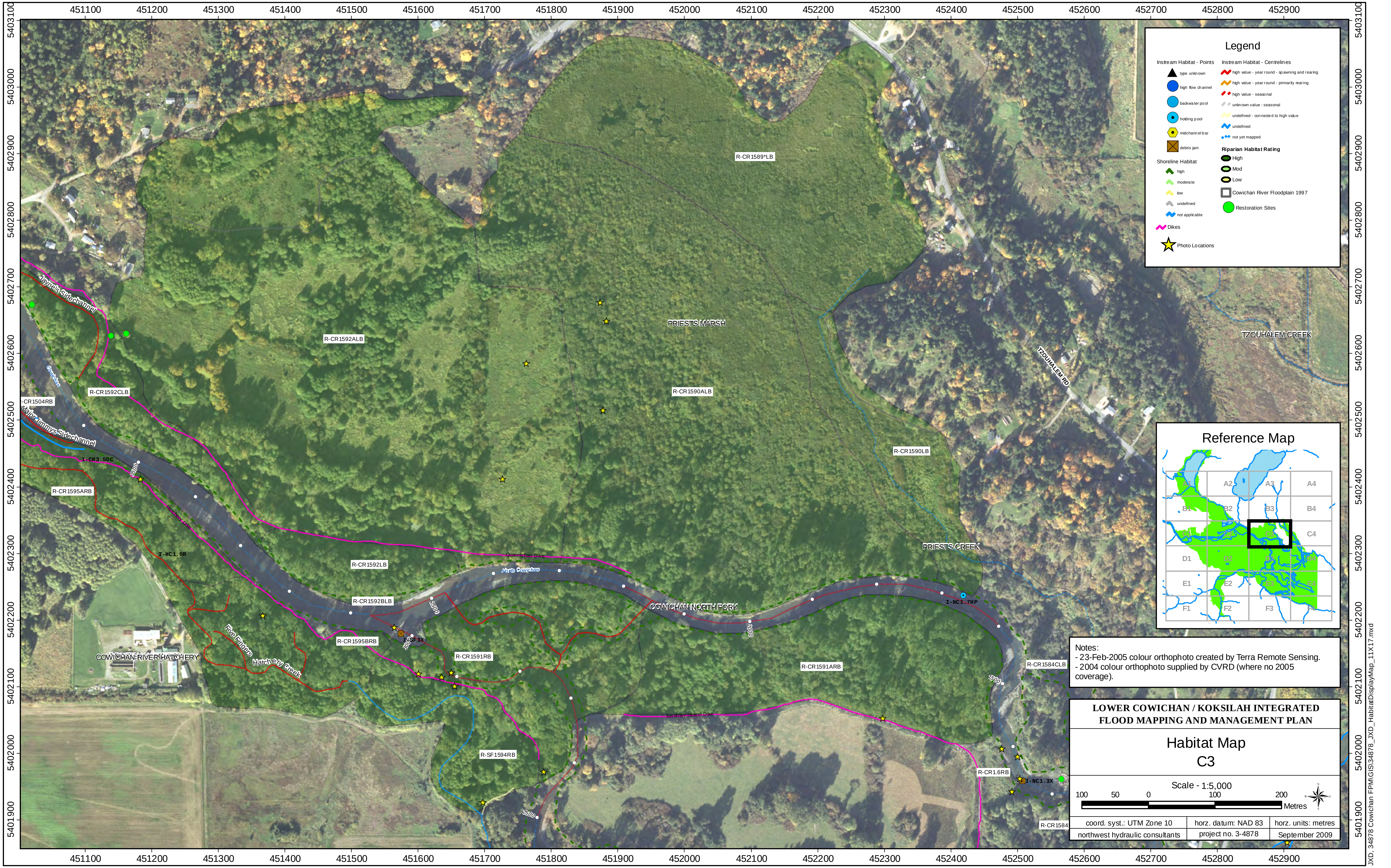

Legend
Instream Habitat - Points
type unknown
high flow channel
backwater pool
holding pool
midchannel bar
debris jam
Shoreline Habitat
high
moderate
low
undefined
not applicable
Dikes
Photo Locations
Instream Habitat - Centrelines
high value - year round - spawning and rearing
high value - year round - primarily rearing
high value - seasonal
unknown value - seasonal
undefined - connected to high value
undefined
not yet mapped
Riparian Habitat Rating
High
Mod
Low
Cowichan River Floodplain 1997
Restoration Sites
Reference Map
PRIESTS MARSH
PRIESTS CREEK
TZOUHALEM CREEK
TZOUHALEM RD
COWICHAN NORTH FORK
COWICHAN RIVER HATCHERY
Jaynes Sidechannel
Major Jimmys Sidechannel
Hatchery Dike
Quamichan Dike
Five Fingers
Hatchery Creek
R-CR1589*LB
R-CR1592ALB
R-CR1590ALB
R-CR1590LB
R-CR1592CLB
R-CR1595ARB
R-CR1592LB
R-CR1592BLB
R-CR1595BRB
R-CR1591RB
R-CR1591ARB
R-SF1594RB
R-CR1584CLB
R-CR1.6RB
I-CR3.5DC
I-NC1.0R
I-NC1.7HP
I-NC1.3X
Notes:
- 23-Feb-2005 colour orthophoto created by Terra Remote Sensing.
- 2004 colour orthophoto supplied by CVRD (where no 2005 coverage).
LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN
Habitat Map
C3
Scale - 1:5,000
Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009

Figure 4.10

The methodology for determining habitat sensitivity ratings as well as management recommendations requires review and feedback from local practitioners. The review process will provide the opportunity to ensure the ratings have been derived appropriately and the management recommendations are embraced and adopted by the managing agencies including Fisheries and Oceans Canada, BC MOE, Cowichan Tribes, CVRD, City of Duncan and Municipality of North Cowichan. From the habitat sensitivity mapping, Proposed Conservation Zones as well as proposed Development Zones could be delineated within the lower Cowichan and Koksilah basins.

Recommendation #1: Complete the habitat mapping on high priority areas within the Cowichan/Koksilah Flood Management Planning Area

Highest priority areas include portions of the floodplain with a high flood risk where flood management or maintenance activities may be required that geographically overlaps with areas having high ecological values. Priority areas based on high ecological values and high flood risk that require further investigation and integration into the Habitat Mapping includes:

- the Cowichan River and Koksilah River between the Trans-Canada Highway downstream to Tzouhalem Road.
- Somenos mainstem from the Somenos Lake outlet downstream to the confluence with the Cowichan River.

It is important to note that ecologically important upland habitat values adjacent to the floodplain were not included in this study.

Recommendation #2: Prioritize Habitat Mapping where flooding issues are ongoing and flood maintenance or management activities will likely be required.

Recommendation #3: Integrate the Habitat Restoration Opportunities developed as part of the Integrated Flood Management Plan into a GIS overlay

Integrate a Habitat Restoration layer that illustrates past habitat restoration projects as well as future habitat restoration options (see section 8.2.6) into the Habitat Sensitivity Mapping project. The Habitat Restoration Mapping can be used to illustrate options for habitat compensation on a site specific basis as may be required as part of instream or riparian flood management and maintenance works. This information can assist with the preservation, rehabilitation and future restoration/enhancement of fisheries and wildlife resources within the Flood Management Planning Area.

5 BRITISH COLUMBIA'S FLOOD MANAGEMENT CLIMATE

This chapter reviews processes for flood hazard management in terms of the policy and legislative environment, the institutional framework, and available management tools currently in use in British Columbia.

5.1 POLICY AND LEGISLATIVE ENVIRONMENT

Table 5.1and Table 5.2 illustrate the broad range of legislation associated with water management in BC, particularly related to flood management. The more relevant Federal and Provincial legislation for the Cowichan flood plan is detailed below.

5.1.1 FEDERAL LEGISLATION

Canadian flood control policy since 1975 has fallen under the *Federal Flood Damage Reduction (FDR) Program* (Canada 1996) which was created under the *Canada Water Act* following extensive flood damage throughout the country in the early seventies. In 1987, a mapping program in BC was accelerated through the additional signing of the *Canada-BC Agreement Respecting Floodplain Mapping* (British Columbia 1998). The aim of the program was to discourage future flood vulnerable development through floodplain mapping programs which were carried out by individual provinces with funding assistance and monitoring by the Federal government. Although the agreement was strongly worded, there is little legislation to back it up (Lyle 2001, Lyle and McLean 2008).

A further Federal policy that affects flood management is the *Federal-Provincial Disaster Financial Assistance* (DFA) arrangement. The DFA provides guidelines for the cost sharing of disaster payments between Federal and Provincial governments. Both governments contribute to the rebuilding of public and private properties after major floods, with the Federal government paying an increasingly larger share of the costs with escalating damage costs (Canada 1988). Private citizens, local level and Provincial governments rely upon post-disaster payments as an adjustment to flood risk.

In addition to the legislation designed specifically for flood management, there are numerous other federal legislations that can affect flood management; in particular, legislation relating to fisheries and habitat protection. This legislation can limit certain structural flood protection alternatives in terms of timing, location and extent.

The *Fisheries Act* was established to manage and protect Canada's fisheries resources and is binding to federal, provincial and territorial governments. As federal legislation, it overrides provincial legislation when any conflicts arise. Subsection 35 of the Act is a general prohibition of harmful alteration, disruption or destruction (HADD) of fish habitat. The only relief from this general prohibition is when an Authorization is issued for the HADD. Subsection 37 allows fisheries personnel to request plans, specifications, studies or any other information that will allow them to determine if a HADD is likely to occur. Requirements for modifying the plans to avoid or mitigate impacts may be specified. In 1986, a Policy for the

Management of Fish Habitat was implemented to support the habitat provisions of the Fisheries Act. This requires that the current productive capacity of existing habitats is maintained by applying the *no net loss* guiding principle.

Table 5.1: Federal Legislation Related to Integrated Flood Management

Jurisdiction	Legislation	Scope Related to Integrated Flood Management
Fisheries & Oceans Canada	Fisheries Act	Has ultimate authority over fish and fish habitat
Transport Canada	Navigable Waters Protection Act	Protects public right to marine navigation including fresh water
Environment Canada	Canadian Environmental Assessment Act	Provides for environmental assessment of triggered projects including those on Indian Reserves
	Canadian Environmental Protection Act	Aimed at protecting the environment and human health by managing toxic substances, marine pollution and other sources
	Canadian Water Act	Provides for cooperative management of water resources and water quality-applies to federal waters and inter-jurisdictional waters of significant national interest.
Various	Species at Risk Act	Aims to prevents endangered or threatened wildlife from becoming extinct or lost from the wild, and to help in the recovery of these species.
Public Safety Canada	Federal-Provincial Disaster Financial Assistance Program	Provides guidelines for the cost sharing of disaster payments between Federal and Provincial governments. Both governments contribute to the rebuilding of public and private properties after major floods, with the Federal government paying an increasingly larger share of the costs with escalating damage costs.

5.1.2 PROVINCIAL LEGISLATION AND POLICY

The BC government is in the process of reviewing and updating water policy and has described the new direction in the policy paper *Living Water Smart BC 2008* (BC 2008). The focus of the legislative review will be to:

- Recognize the needs of aquatic ecosystems and protect their health;
- Encourage water efficiency;
- Build in more flexibility to be able to better adapt to climate change;
- Consider options that will enable broader participation in decision making.

It is expected that the policy plans will be implemented by 2012. The new policy direction in flood management is described as follows:

Living Water Smart concentrates on reducing human and property damage during floods. Concentrating on floodplain management and structural flood protection will decrease spending on emergency response and reduce damage in the long term. New design standards for buildings in flood-prone areas and flood protection infrastructure will be developed that reflect increasing flood risk. Effective ways of helping communities better manage the risk of more frequent floods include:

- *avoiding building in flood prone areas*
- *allowing room for rivers to meander*
- *improving flood protection infrastructure*
- *adopting flood proofing measures*

In the meantime, flood policy is legislated using various instruments as outlined in Table 5.2.

Table 5.2: Provincial Legislation Related to Integrated Flood Management

Jurisdiction	Legislation	Scope Related to Integrated Flood Management
Ministry of Environment Water Stewardship Division	Water Act	Allocation and management of water, development of water management plans
	Water Protection Act	Prohibits bulk export of water and large scale transfers between watersheds
	Water Utility Act	Regulates privately owned water systems for corporations
	Dike Maintenance Act	Establishes the Inspector of Dikes to supervise construction and maintenance of dikes and diking authorities
	Drainage Ditch and Dike Act	Regulation and authorization of ditches, water courses, dikes and drainages
Ministry of Environment Environmental Stewardship Division	Fish Protection Act	Protects fish and fish habitat by prohibiting bank-to-bank dams of 17 protected rivers (the Cowichan is not currently a designated river), authorizes designation of sensitive streams, provincial directives for streamside protection, calls on local governments to protect riparian areas during residential, commercial, industrial development.
Ministry of Environment	Environmental Management Act	Regulates industrial & municipal waste discharge, pollution and hazardous site remediation, water source & system assessment
Ministry of Forests	Forest and Range Practices Act	Sets out the requirements for planning, road building, logging, reforestation and grazing on provincial lands. Provides authority to take actions to ensure maintenance of environmental values including designating fisheries sensitive watersheds (FSW) and designating community watersheds. No streams within the Cowichan watershed are currently designated as FSW.
Ministry of Environment	Environmental Assessment Act	Establishes an environmental assessment procedure and requires an environmental assessment certificate

Jurisdiction	Legislation	Scope Related to Integrated Flood Management
		before major projects can be constructed-includes dams, dikes, water diversions, shoreline modifications
Ministry of Community Services	Community Charter	Provides a legal framework for municipalities to identify and meet community needs. Provides authority to establish bylaws in spheres of concurrent authority
Ministry of Community Services	Local Government Act	Sets out the corporate authority of various types of local governments; sets out powers and responsibilities relating to landuse, growth, infrastructure and other works.
Ministry of Public Safety and Solicitor General	Emergency Program Act	Sets out Provincial Emergency Program
Provincial Agricultural Land Commission	Agricultural Land Commission Act	Preserves agricultural land through the designation of the Agricultural Land Reserve. Much of the farmed areas of the Cowichan floodplain are protected by this designation. This policy limits development and encroachment on the floodplain.

Present policies related to flood protection are summarized by the BC Ministry of Environment as follows:

> *The goals of the provincial Integrated Flood Hazard Management program are to reduce or prevent injury, human trauma and loss of life, and to minimize property damage during flooding events. The program consists of three components:*
>
> *Landuse management,*
>
> *Emergency management and*
>
> *Dike safety.*

Landuse Management

In 1986, the *Municipal Act* was passed in BC, providing municipal governments the authority to adopt local floodplain bylaws. The provincial government continued to conduct and administer floodplain mapping programs and to assess and approve sub-division applications in floodplains.

In 2003 the provincial government devolved some of its powers related to the development of provincially designated floodplains through the promulgation of the *Flood Hazard Statutes Amendment Act* and other related legislation. A key provision of these changes was the removal of the requirement for BC Ministry of Environment approval for subdivisions and floodplain bylaws (FBC 2008). Local government bylaws in flood hazard areas were allowed to proceed, provided Provincial guidelines are taken into consideration. Authority was also given for local governments to establish minimum setbacks from watercourses and dikes, to specify minimum flood levels for habitable dwellings, and to specify the structural support necessary to protect buildings. Approval of exemptions to a local bylaw to manage floodplain hazards was authorized, provided the exception is consistent with Provincial guidelines or the local government receives a report certified by a professional engineer that "*the land may be used safely for the use intended*".

In 2008, Fraser Basin Council assessed how well the legislative changes were working, what challenges exist and what improvements are needed (FBC 2008). This involved undertaking a survey of local governments, approving officers and other water management professionals. Fewer than one third of the respondents indicated that the legislation and related management tools were sufficient to adequately manage flood hazards (FBC 2008).

Emergency Management

Emergency response legislation (*Emergency Program Act*-1995) is the responsibility of the Ministry of Public Safety and the Solicitor General. The provincial emergency management structure is activated when a BC community or any significant infrastructure is threatened by an emergency or a disaster. Local authorities are responsible for management of recovery and reconstruction within their municipal boundaries. Local authorities may request assistance from the provincial government or other jurisdictions. The provincial government is responsible for recovery of its services and reconstruction of its services. It is also responsible for reconstruction in unorganized areas where there is no local government structure. The provincial government will only assume leadership of recovery and reconstruction operations in an organized area if a catastrophic event occurs which has rendered the local government incapable of fully managing the operations or if the local government has requested support and the province agrees that the request is reasonable.

Dike Safety

The principle legislation pertinent to flood protection works is the provincial *Dike Maintenance Act* (DMA). Private dikes or dikes on First Nations lands are not regulated under the act. The Ministry of Environment maintains a database that indicates whether a particular structure is a dike regulated under the act. Only the Cowichan (City of Duncan) Dike and Cowichan River South Side Dikes are identified as being regulated under DMA. In order to obtain DMA approval any proposed work on dikes must conform to the ministry's "Dike Design and Construction Guide: Best Management Practices for BC" (MWALP 2003) as well as other specified requirements.

Dikes constructed on First Nations land are not subject to provincial regulations. Since most of the existing dikes (Quamichan, South Spur Dike, Mission Road Dike, Tooshley Island Dike, Koksilah Dike) are situated on lands of the Cowichan Tribes these structures are not subject to provincial regulation.

5.1.3 LOCAL GOVERNMENT LEGISLATION

Municipal and regional governments can promote and establish bylaws and zoning regulations for flood management. In British Columbia each municipality has the authority to create its own floodplain management by-laws. In 1986, the *Municipal Act* called for municipalities to create Official Community Plans (OCPs). The OCP allows a community to "designate areas for protection of development from hazardous conditions". Peters (2000) noted that “in general, OCPs do not appear to have been effective in directing development away from the floodplain”. The *Local Government Act* gives authority to local government to make zoning decisions; however, the *Act* does not obligate local government to designate floodplains or to zone the land appropriately. Thus, local governments have few incentives to make restrictive landuse decisions that could reduce the long-term costs and damages associated with flooding.

The OCPs prepared by the District of North Cowichan and the City of Duncan include a number of specific references to floodplain management:

- New residential development will be discouraged within designated floodplains. Where no alternative exists and/or where residential development is currently allowed within the floodplain, structures should be floodproofed to standards specified by MOE.
- Lands subject to flooding should, where possible, be left in a natural state, or used for parks and open space recreation.
- The majority of floodplain areas are zoned for agricultural use and are in the Agricultural Land Reserve. Future water management and flood control policies will consider the potential impact on agricultural land. Floodproofing is not typically required for farm buildings other than for dwelling units and enclosed livestock structures.
- The District/City will discourage filling and development within designated floodplains due to the cumulative impact that such works may have. Where filling cannot be avoided, it will only be permitted when it is shown that the drainage of other lands is not affected.
- On site stormwater management systems will be encouraged throughout the District to reduce potential flood impacts.
- Where a floodplain setback from a designated watercourse renders a property totally undevelopable, setback may be reduced provided that: A geotechnical report from a professional engineer certifies that the land may be safely used for the intended use.

The OCP prepared for Districts D and E of the CVRD contains policies relating to flood management that are generally in line with the guiding principles of IFM.

- Lands subject to a general liability to flood should, where possible, be used for parks, open space recreation or agricultural uses. Where there is no other alternative land available, and where mobile homes or buildings to be used for habitation, business or the storage of goods damageable by floodwaters are to be located or constructed in any area liable to flooding, development shall be prohibited except where:
    1. The proposed development is adequately flood proofed.
    2. The proposed use of the property would involve minimal risk to life and property.

5.2 FLOOD MANAGEMENT POLICY INSTRUMENTS

The following management policy instruments are commonly used in BC to regulate developments on floodplains:

- Permits and regulations
- Official Community Plan goals, policies and related by-laws
- Registration of Covenants
- Engineer's or Geoscientists Reports

Table 5.3 summarizes the permits that are most commonly required for construction of any works in and around floodplains on provincial or federal lands. The focus of this table is on works or developments that affect flood management and does not include permits related to water supply and licensing, pollution or major works such as dams.

The two Federal permits that regulate developments in and around rivers are the Fisheries Act Authorization issued by FOC and Navigable Waters Protection Authorization issued by Transport Canada.

The BC Ministry of Environment, Water Stewardship Division issues a permit for any works that may change conditions in and about a stream.

The Ministry also requires a permit under the Dike Maintenance Act (DMA) for any alterations of an existing dike or for construction of any new dike on Provincial lands. One specific requirement for DMA approval states: "The raising of dikes or the construction of new dikes or other works shall not impact the safety of other dikes or increase the flood risk to others".

Table 5.3: Permits and Regulations Related to Development on Floodplains

Permit	Agency	Activity
Section 9- Application for Changes In and About a Stream	BC Ministry of Environment, Water Stewardship Division	Bank erosion protection, bridge maintenance /removal, stream diversion, debris & gravel removal, culvert installation; Restoration/maintenance of fish habitat.
Section 2(4)-Dike Maintenance Act Approval	BC Ministry of Environment, Deputy Inspector of Dikes	Changes or alterations to cross section or crest elevation; Installation of culverts, pipes. flood-boxes, pump stations; Construction of any works on or over a dike right of way; Alteration of channel if works could increase flood levels or impact integrity of dike; Construction of a new dike.
Federal Fisheries Act Authorization	Fisheries & Oceans Canada, Habitat and Enhancement Branch	Any works in and around fish bearing streams. FOC authorization will stipulate conditions and restrictions in terms of timing and extent of works
Navigable Waters	Transport Canada	Regulation of structures which may obstruct

Permit	Agency	Activity
Protection Act		navigation by the public or other water users.
CEAA Application	Canadian Environmental Assessment Agency	Guides environmental assessments on federal lands including Reserves
Riparian Areas Regulation	BC Ministry of Environment, Environmental Stewardship Division	Residential, commercial and industrial developers must hire qualified environmental professionals to assess habitat and potential impacts, develop mitigation measures and avoid impacts to fish and habitat (particularly riparian). Set-backs established to protect sensitive riparian areas.
Building and subdivision approvals	Agricultural Land Commission	Approval of development on designated farm lands within the ALR
Building Permits	Local Government OCPs and by-laws	Approval of sub-division of lands in floodplain areas; Establish building set-backs to channels; Establish minimum building elevations on floodplains.

Projects such as new dikes or flood protection works on Federal lands (including Reserves) may be subject to a CEAA Review under the Canadian Environmental Assessment Agency.

The Riparian Area Regulations (RAR) are applied to all new residential, commercial and industrial developments in the riparian zone and require the establishment of mitigation plans and building set-backs to avoid impacts to fish habitat. The regulations are applied by a qualified environmental professional (R.P.Bio.) who is hired by the developer. Although the regulations apply specifically only to preserving habitat, they overlap to some extent with flood hazard issues since the set-backs may also preserve floodplain conveyance.

The Agricultural Land Commission acts as a *de facto* government over much of the floodplain management area, as most of the agricultural lands in this region are within the Agricultural Land Reserve. The Commission aims to mitigate loss to agricultural land in the province, and as such tends to limit development on ALR lands.

Flood management bylaws and guidelines for regulating development in areas subject to flood hazards are incorporated into the region's municipal bylaws and the Official Community Plans for the CVRD, DNC and Duncan. Major policies relating to flood management from these documents are detailed in section 5.1.3.

5.3 INSTITUTIONAL FRAMEWORKS

5.3.1 WATER STEWARDSHIP AND FLOODPLAIN MAPPING

The BC Ministry of Environment, Water Stewardship Division (MOE) administers a wide range of programs related to dam safety, flood hazard management, flood mapping, flood forecasting, water use planning, licensing and allocation and wetlands. Since the legislative changes in 2003-2004, the provincial government has removed provincial approvals for subdivisions and floodplain bylaws. Authority was also given for local governments to establish minimum setbacks from watercourses and dikes, specify minimum flood levels for habitable dwellings and to specify structural support necessary to protect buildings (FBC 2008). Previously, these activities were conducted by MOE. General guidelines for preparing floodplain maps were prepared to assist local governments implement any new flood mapping projects (FBC 2004a). However, it is our understanding that MOE will not advise directly on new floodplain mapping projects at the present time.

5.3.2 OPERATION AND MAINTENANCE OF EXISTING DIKES

Local authorities, diking districts, municipalities, crown corporations and senior government departments may own and operate public diking systems in British Columbia. Responsibility for operation and maintenance (including inspection and emergency response) is vested with these organizations. In the Cowichan study area, only the Cowichan South Side Dike (under authority of the District of North Cowichan) and Cowichan Dike (under authority of the City of Duncan) fall under this category. The District of North Cowichan has a municipal engineering department with a staff of civil engineers and technologists responsible for a broad range of services, including water supply, storm water management and drainage. The City of Duncan has a Public Works Department and together with the District operates the JUB waste treatment facility.

There are over 20 flood protection systems on Provincial lands in BC which do not have a responsible local authority. Inspection of these dikes is presently the responsibility of the Deputy Inspector of Dikes.

Most of the dikes on the Cowichan-Koksilah floodplain are constructed on lands of the Cowichan Tribes and are not subject to provincial regulations. These dikes were originally funded mainly by Indian and Northern Affairs Canada (INAC) and relatively little systematic maintenance work is being carried out to our knowledge. It is our understanding that individual band members may be considered responsible for dike maintenance if they hold a Certificate of Possession for lands with dikes constructed on them. Few individuals have the resources for this type of work.

5.3.3 EMERGENCY MANAGEMENT BRITISH COLUMBIA

Emergency Management British Columbia (EMBC), a provincial agency created in 2006 , in partnership with the Federal Building Canada Plan initiated the Flood Protection Program in 2008 to provide funds for various structural flood control projects in BC. Eligible projects include structural protection measures (dikes, pump stations, etc), gravel mining and erosion protection. Projects that are not considered eligible include new flood works to protect new developments and new infrastructure, or projects that involve routine maintenance of existing works.

Projects are cost-shared equally between the Federal, Provincial and Local governments; however, gravel removals are not funded by the Federal government. The total budget for 2008/09 was $19.25 million. Applications for funding are accepted from local governments (municipalities and regional districts) and diking authorities. Although multi-year projects can be submitted, funding is considered only on a year-by-year basis.

5.3.4 COWICHAN TRIBES

Cowichan Tribes is a community-driven organization providing access to services and programs, and to promote the respect of First Nations culture and traditions and the individuality and success of native people. The Chief and Council administer a range of programs related to education, environment, land and governance, sustainable housing, health, and child and family services. The Tribes has staff resources in environment and GIS and retains engineering consultants to provide technical advice for issues related to flood protection. The environment and lands management departments can advise local band members on issues related to flood protection or new construction on floodplain lands.

Land tenure on reserve land differs from standard practice. For tribal lands, individual owners may hold a Certificate of Possession (CP), which is documentary evidence of a First Nation member's lawful possession of Reserve lands; the Government of Canada retains legal title to the land. A CP holder is entitled to use the lands, and the rights are transferable by sale or bequeath. This different approach to land tenure means that many traditional policy instruments used for flood management are not applicable on Tribal lands.

In the past, INAC has provided funds for constructing dikes on Tribes land. However, there is little information available on these works and it appears there is minimal maintenance being carried out on them.

The Tribes is in the process of providing water and sewer infrastructure to its members through its own utility company. They have proposed that the company would run in parallel to a working agreement with the City of Duncan and District of North Cowichan to replace the valley's current lagoon system. Areas running along Indian Road, Wilson Road and Quamich Village are presently lacking basic infrastructure such as water and sewer services.

5.3.5 LIVING RIVERS TRUST FUND

The Provincial government established the Living Rivers Trust Fund to *"create a legacy for the province based on healthy watersheds, sustainable ecosystems and thriving communities"* (LRTF 2009). Living Rivers-Georgia Basin/Vancouver Island (LR-GB) was initiated by the BC Conservation Foundation in collaboration with the Ministry of Environment and Fisheries and Oceans Canada. They have developed a collaborative management model and secured many contributing partners. The group focuses on improving water flows for fish, restoring river and estuarine habitat, enriching stream productivity, encouraging community participation and facilitating adaptive water management plans and pilot governance projects designed to lessen impacts of climate change on high priority watersheds. LR-GB led or supported 20 projects in 2006 worth approximately $2.25 million, including $0.8 million for Phase 1 stabilization of Stolz Slide on Cowichan River and participation in the Cowichan Basin Water Management Plan process.

5.3.6 COWICHAN STEWARDSHIP ROUND TABLE

The Cowichan Stewardship Round Table is a community partnership including representation from key sectors from senior government agencies, First Nations, local government, non-government organizations and private citizens. The committee was formed in 2004 in response to low water levels in the Cowichan River. Since its inception it has continued to expand its mandate with additional collaborative arrangements and stewardship partners. Notable projects completed by the group include the development of the Cowichan Basin Water Management Plan, the stabilization of the Stolz slide and major channel restoration projects. This group was recently awarded the National Heritage Rivers Award for its substantive work on the river system and for the innovative approach to relationship building.

The Cowichan River Ad Hoc Water Advisory Group (a subset of the round table), provides comment and community input to Catalyst Paper who control the summer water flows from the weir at the Cowichan Lake outlet under the direction of the BC Ministry of Environment. This group has developed a refined set of ramping protocols to protect valuable water resources and ecosystem attributes.

5.3.7 COWICHAN BASIN WATER MANAGEMENT PLAN

The Cowichan Basin Water Management Plan was produced in 2007 by a partnership of organizations including the CVRD, BC Ministry of Environment, Fisheries and Oceans Canada, Catalyst Paper Corporation, Cowichan Tribes and Pacific Salmon Commission (Westland 2007). The purpose of the plan was to provide actions to manage water and its use that:

- have broad public support
- protect the ecological function of the system

- balance water supply and use today and in the future
- increase the understanding of the Cowichan Basin and its water issues.

One of the key proposed next steps for the Plan is to develop a Watershed Advisory Council. Such an organization could guide the implementation of this Flood Management Plan. In fact, the implementation of this Flood Management Plan needs broad stakeholder support and strong leadership that could only be provided by such a group.

There is a long established history of collaborative planning in the basin through the efforts of the Cowichan Stewardship Round Table as well as successful projects led by the Living Rivers-Georgia Basin/Vancouver Island initiatives. A vision of water management in the basin, relevant to this project, was stated in the CBWMP as follows:

"Cowichan Basin communities conserve and manage water to ensure reliable supplies for human use, thriving ecosystems and a healthy economy".

Although the focus was primarily on water supply, some of the goals and objectives in the water management plan are relevant to integrated flood management:

Goal 4: Reduce the impacts of high water levels, respecting the importance of winter floods to natural systems;

Objective 4a: Establish adequate setbacks from Cowichan Lake and River to reduce potential flooding risks. Specific actions included:

- Reviewing current 200-year floodplain mapping and update as required using state-of-the art hydrotechnical data and hydraulic analysis techniques.
- Continue to enforce by-laws that prohibit new development or deposit fill below the 200-year flood level;
- Flood proof at-risk structures where practical.

Objective 4b: Increase the flood buffering capacity of floodplain and constricted channel areas. This included:

- Preparing and implementing a flood and drainage manual plan to provide a coordinated approach to storm water and flood management.
- Maintain the capacity of the Cowichan River channel to accommodate flood flows where it is obstructed by gravel, debris or structures.
- Goal 6: Establish clear, accountable and responsive water management decision processes and governance structures.

Objective 6a: Establish and fund a Cowichan Basin Water Management Advisory Council (CBWMAC) that represents basin-wide interests, maintains on-going dialogue among stakeholders and builds trust and ownership among the participants and the public. This included:

- Creating secure and stable funding sources to support water management activities;
- Designating a regional coordinator to oversee the development of the water management strategy;

- Involve landowners, business developers and other members of the public in water management decisions.

Objective 6b: Ensure decisions on restoration and research projects and funding continue to be guided by the Cowichan Stewardship Round Table.

5.3.8 COWICHAN ESTUARY ENVIRONMENTAL MANAGEMENT PLAN

The Cowichan Estuary Environmental Management Plan (CEEMP) was the first estuary management plan in BC and was based on 13 years of analysis and discussion with various stakeholders lead by the Provincial Ministry of Parks and Environment.

As a result of the high environmental concerns, the Cowichan River estuary has been managed since 1996 through an Order in Council under the Environmental Management Act and according to the Cowichan Bay Environmental Estuary Management Plan (MELP 1994). *"The OIC requires compliance with the Plan and establishes its precedence over actions under other government statutes"*. The Plan has been designed to balance the complex needs of land and resource use as well as to sustain and protect high value ecological features within the Cowichan/Koksilah estuary. The purpose of the CEEMP is to provide a framework for land and resource management planning that addresses ecological and other interests. Objectives of the Plan include the establishment of guidelines for land and resource management as well as a review process for proposed development within the estuary study area (MELP 1994). The Plan is proactive and iterative, recognizing the need for review and updates according to changes in land ownership as well as collection of new information.

By 1987, the ecological interests of the estuary were managed under the auspices of the Pacific Estuary Conservation Program developed through a partnership of several agencies and organizations including BC Environment, Ducks Unlimited, DFO, Nature Trust, the Land Conservancy, Nature Conservancy of Canada, Habitat Conservation Trust Fund and the Canadian Wildlife Service. Within 5 years, the group secured nine parcels of key habitat within the estuary totalling 308 hectares (Law 2008). Endeavours of these groups also includes developing management strategies, land acquisitions, monitoring, assessments, mapping as well as restoration and rehabilitation of native and/or culturally significant estuarine species and their habitats.

A major review of the plan was completed in 2005. It concluded the plan was "under-developed and under-implemented". It also stated "the CEEMP cannot fully expect to be successful in conserving and enhancing the ecological values and economic potential of the estuary as long as it is not integrated with other planning/management initiatives" (Vis-à-vis Management Resources Inc. 2005).

6 Flood Management – Best Management Practices

Flood management has evolved over the last decade. A holistic integrated approach is now common practice around the world, while a more engineered structural approach was customary in the past. This chapter outlines best management practices gleaned from other jurisdictions and academic literature. It includes a discussion of the evolution in flood management practices as well as background information on practical flood management tools, policy instruments and policy actions.

6.1 Evolution in Flood Management

Most other countries or jurisdictions describe three distinct stages in dealing with flood hazards (Vinet 2008). The "traditional approach", which lasted until the 1980s, involved relying solely on structural defences such as dikes or dams. The continued experience of rising flood damages in spite of significant investments in structural flood control measures led authorities to recognize that "something was wrong" with the traditional approach (de Wrachien et al. 2008).

Starting in the 1980s, it was gradually realized that society generates risk through vulnerability and exposure by developing in hazardous locations on the floodplain. To reduce risk one can reduce vulnerability by identifying flood hazards, implementing restrictive zoning or changing landuse practices.

The third phase, starting in the 1990s, involved developing an integrated vision of natural risks and their management. The approach has led to the adoption of a wide range of structural and non-structural measures as well as a more integrated approach in terms of strategies, types of measures and institutions. The "Living Water Smart" initiative launched by the BC government and due for implementation in 2012 appears to be consistent with this third approach (BC 2008). The Flood Management Plan outlined in this report aims to integrate engineering, environment and economic issues, resulting in a product that is more in line with modern thinking for risk management (third stage).

6.2 Reliance on Dikes and Levees

It is widely acknowledged that absolute protection from flooding is neither technically feasible nor economically or environmentally viable (WMO 2007). In Alberta, the floodable area behind a dike is considered to be part of the floodway or flood fringe, which means that in terms of flood hazard management the dikes are assumed to be ineffective. Consequently, any new developments behind a dike must be flood proofed.

In the US, flood embankments or levees may significantly affect the extent of the flood inundation. On FEMA flood hazard maps, if levees receive certification from the US Army Corps of Engineers, indicating there is reasonable certainty that the levee will contain the base flood event, then the land behind the levee may be considered flood-free. A stringent risk-based assessment is required for certification and in recent years it has proven increasingly difficult to achieve certification.

Serious flood damages in recent years in the US and Europe have highlighted the failure of conventional structural flood control measures. Vinet (2008) described four main factors that contributed to flood damages in Europe:

- The dikes suffered from a lack of maintenance;
- Landuse planning failed to control the establishment of houses and activities in flood-prone zones;
- The dikes were built to withstand a certain level of risk. Recent floods equalled or exceeded the design standards, possibly due to climate change;
- Dike failures were seldom included in warning plans, primarily because river-side residents believed they were safe.

It can be very difficult to determine the "safe capacity" of a dike since failure will often occur well below the crest elevation. For example, only 60% of dike failures in Europe occurred as a result of overtopping. The remaining 40% occurred as a result of embankment saturation, slope stability failure, excessive leakage and erosion (Nagy 2008).

In general, it is agreed that dikes and other structural measures cannot be relied on to protect from flood damage by themselves. Also, a reliance on structural measures can result in an increase in flood damage risk, an increase in long-term cost, as well as environmental and social network degradation (Lyle 2001).

Alternative methods of mitigating flood damage either through impeding development in hazard zones or by changing development (floodproofing, dike setbacks, floodway naturalization for example) are presented below.

6.3 FLOOD PROTECTION STANDARDS

Design standards for flood protection works and flood hazard maps vary appreciably, depending on the landuse, exposure to risk and other factors. In North America, design floods typically range from 100-years to 500-years. It is now becoming common to adopt more severe standards in highly developed areas or to protect critical infrastructure. For example, Alberta sets a 500-year flood protection standard for critical "lifeline" facilities that are important to the health and safety of a community such as administration buildings, schools, seniors residences, key roads, sewage treatment plants and water supply plants. A 1,000 year flood protection standard is set for hospitals, extended care facilities power plants and critical related maintenance facilities (Alberta Infrastructure 2001). It is also generally recognized that consideration should be given to events that exceed the design flood.

6.4 FLOODWAY PRESERVATION

Flood hazard areas are now commonly delineated in most jurisdictions by defining a separate "*floodway*" zone and "*flood fringe"* zone. The floodway represents the portion of the channel and floodplain that is critical for conveying the flood flows. The flood fringe is subject to potential inundation but has a minor contribution to the total conveyance. Development in the floodway is restricted, while development may be allowed in flood fringe areas subject to flood proofing. The boundary between the floodway and flood fringe zones is generally determined using a hydraulic analysis, although several different approaches have been used (Volume 1 – Scoping Report (NHC 2008) and Appendix C of this volume). One approach is to map out zones of "fast and deep flow" (USBR 1988).

Another approach is to set encroachments on each bank of the floodplain and determine the effect on the flood levels. The encroachments are increased gradually until the flood level is increased by some limiting value (typically 0.3 m in the US and Alberta). These encroachment boundaries are then adopted as the floodway.

A recent approach advocated by the US Association of State Floodplain Managers involves adopting a "no net adverse impact" floodplain policy. A no net impact floodplain is one in which

> *the actions of one property owner or community does not adversely affect the flood risks for other properties or communities as measured by increased flood stages, increased flood velocity, increased flows or the increased potential for erosion and sedimentation, unless the impact is mitigated as provided for in a community or watershed-based plan. (Larson and Plasencia, 2001)*

The "zero rise" floodway definition adopted by King County in Washington is an example of this approach.

6.5 INTEGRATED FLOOD MANAGEMENT

Integrated flood management (IFM) has emerged as the best approach for reducing flood damages and loss of life (WMO 2004; Vinet 2008; State of California 2005; GOC 2001). WMO (2004) states:

> *The defining characteristic of IFM is integration, expressed simultaneously in different forms: an appropriate mix of strategies, points of intervention, types of interventions (structural or non-structural), short or long-term and a participatory and transparent approach to decision making-particularly in terms of institutional integration.*

The World Meteorological Organization describes three main options for flood mitigation:

- Reducing the flood hazard
- Reducing the communities exposure to the hazard
- Reducing communities vulnerability

Table 6.1 provides a list of typical measures that could be considered under each option. A mixture of structural and non-structural measures is generally required for effective flood management (WMO 2004).

Table 6.1: Options for Reducing Flood Risk - World Meteorological Organization

Reduce Hazard	Reduce Exposure	Reduce Vulnerability
• Dams and reservoirs • Diversion channels • Landuse management (building codes) • Infrastructure building practices	• Dikes, flood walls, elevated roads & rail lines • Flood proofing • Flood warning and evacuation • Land regulation (zoning)	• Physical: Improving infrastructure & living environment • Constitutional: providing social support system, education and skills • Motivational: building awareness and facilitating self-organization

There is a trend towards multi-objective floodplain management that enables managers to access a broader range of funding than would be available for conventional flood control works. This can result in habitat enhancement work being carried out in partnership with flood protection works, rather than simply trying to mitigate environmental impacts associated with flood control projects (State of California 2005). There are a number of programs underway that share these common features.

Levee Set-Back: Several counties in Washington State (Whatcom County, Yakima County and King County) are implementing programs to set-back or breach existing levees in order to reduce flood levels and to open up portions of the floodplain for fisheries habitat development. These programs were developed over a period of 10 to 15 years and involved consultation and cooperation amongst federal, state, county and local community stakeholders. One of the driving forces for these initiatives is the Endangered Species legislation, and recent concerns about the state of *salmonid* populations in Pacific Northwest rivers.

"Room for River and People" concept: A holistic risk management process involving mainly non-structural measures such as flood forecasting, planning and landuse controls. River cross sections are widened to increase conveyance by situating the dikes further away from the river or by lowering the river forelands (de Wrachien 2008).

State of California: Responding to California's Flood Crisis: The State has adopted multi-objective management approaches for floodplains where feasible. This approach enables flood managers to leverage other sources of funding for flood system maintenance. These projects result in habitat enhancement rather than simply mitigating for environmental impacts.

6.6 COLLABORATIVE WATERSHED GOVERNANCE

Collaborative governance recognizes that decisions are made based on complex relationships between many actors with different priorities. It is the reconciliation of these competing priorities that is at the heart of the concept of governance (United Nations Human Settlements Programme 2009).

Technical solutions – structural and non-structural measures for flood hazard management – are available. However, sustainability of these measures is to a large part determined by the institutional framework that is in place (i) to ensure these measures are understood by and accurately reflect the interests of the majority of stakeholders, (ii) to engage stakeholders such that on-going support, both monitoring and maintenance is provided, and (iii) to make certain that adequate funds are provided on an on-going basis to undertake requisite maintenance and improvements.

A number of successful water basin governance models have been implemented in Canada. Three types are discussed briefly in this section (further information is contained in Appendix A).

Alberta Watershed Planning and Advisory Councils

The Watershed Planning and Advisory Councils (WPACs) are regional organizations with the mandate to engage governments, stakeholders, other partnerships and the public in watershed assessment and planning. These WPACs are formed on the basis of Alberta's major river basins, as defined under the *Water Act*.[2] WPACs work with government in an adaptive management cycle of basin planning and evaluation; they undertake a variety of actions to benefit watersheds including collaborating with land managers, providing advice and support to Watershed Stewardship Groups, presenting issues to the Alberta Water Council, raising awareness about the state of the watershed, building long-term partnerships that examine watershed issues, and making recommendations to water/landuse decision-making authorities.

Fraser Basin Council

The Fraser Basin Council is a unique partnership of public and private interests, assuring broad representation from all sectors of society and emphasizing an integrated approach to realizing social, economic and environmental goals (FBC 2008b). It provides a non-confrontational, consensus-based forum in which no participant is first among equals, and in which the interests of all stakeholders can be presented. The Fraser Basin Council is a means of doing business together across insurmountable boundaries and it allows for inclusive, shared decision making. Governments were made part of Fraser Basin Council's management structure in an effort to allow for greater influence on government policy and programs than is normally generated through traditional non-governmental organizations. No similar organization exists in Canada today.

[2] Several major basins were split into more manageable planning units with a WPAC assigned to each planning unit.

The Fraser Basin Council is designed to achieve its goals by facilitating cooperative and collective action throughout the basin. It does not duplicate existing governmental and non-governmental mandates and activities. It does, however, act as a catalyst to minimize duplication and facilitate harmonization and collaboration among diverse basin interests. The approach has allowed basin-wide planning and has involved First Nations communities and private stakeholders in ways that traditional government organizations sometimes find difficult. However, the Council can not implement its plans and must constantly work to maintain its funding and resources (Blomquist et al. 2005).

Okanagan Basin Water Board

The Okanagan Basin Water Board (OBWB) was established as a partnership of the three regional districts and its jurisdiction covers the geographical bounds of the Okanagan watershed, rather than being restricted to political boundaries. The OBWB's programs are supported through property tax assessments on all parcels within the watershed and initiatives are focused on activities that have valley-wide benefits. These activities would be difficult or impossible for individual governments to lead because of their limited jurisdiction, funding or mandate. The Board does not have regulatory authority but supports water management by providing a basin-wide perspective. Activities include:

- Implementing basin-wide programs for maintenance, sewage infrastructure funding, water science and management;
- Acting as a hub for water information-increasing communication, building partnerships;
- Advocating and representing local needs to senior levels of government;
- Providing science-based information to decision makers;
- Expanding local capacity by providing a stable source of funding and in-kind partnerships and as a single organization for coordinating projects;
- Providing a forum of debate about watershed priorities.

One lesson-learned from these initiatives is that a significant amount of time and resources is required for implementation. They also require the cooperation and active commitment from a broad range of groups, agencies and layers of government.

6.7 TECHNICAL TOOL - FLOOD HAZARD MAPPING

Flood hazard maps are a critical component of flood management plans, and as such are a key tool that has been developed for this plan. Considerable effort is being made to update floodplain maps using recent technological advances in hydraulic modelling, remote sensing, GIS mapping and internet-based information technology (FEMA 2003, GOC 2001, van Alphen et al. 2008). The main advances that allow more realistic representations of flooding in complex river/floodplain systems are:

- LiDAR, which provides high resolution and relatively accurate topographic mapping of the floodplain and important features such as roads and dikes;

- GIS-mapping products such as ArcGIS, which can process large amounts of spatial data and can integrate flooding information with other types of landuse and habitat mapping information;
- Development of commercial two dimensional hydrodynamic models that reproduce the interaction of floodplains and complex channel networks and can simulate a wide range of scenarios and future development alternatives.

Significant advances have also been made in using internet-based resources (such as Google Earth) for displaying flooding extent in near real-time conditions (Kim and Pavlow 2008).

6.8 POLICY INSTRUMENTS

In addition to the legislative tools and policy instruments already in use in British Columbia (Section 5.2), there are further policy instruments that are not presently used in the province, that may be applicable to the Cowichan area including:

- Economic incentives (taxation)
- Action through education

6.8.1 ECONOMIC INCENTIVES

One of the most powerful incentives for change amongst private citizens is economic reform. Economic incentives can be used as a mechanism to encourage natural approaches to flood management. Senior and local level governments can implement economic incentives to create change. Senior level governments can provide incentive for homeowners to become more responsible for flood damage by discontinuing post-disaster payments; thus placing the onus of risk on individual property owners.

Subsidies and grants can also be effective economic instruments. For example, grants or subsidies can be given to homeowners to flood proof their property. This up front economic incentive can reduce the long-term costs of flood damage.

Property tax assessments can incorporate the economic cost of flood risk for properties on the floodplain. This can be an effective tool for change, as in addition to providing revenue for flood management projects it can be a powerful instrument to increase awareness of flood risk amongst floodplain homeowners.

6.8.2 ACTION THROUGH EDUCATION

Flood damage can be greatly reduced simply by the education of those at risk in how to minimize their losses. It has been shown that the greater the advice in advance of a flood the lower the vulnerability of the possible victims (Handmer and Tunstall 1991, as cited in Green et al. 1994). Two main areas of information will help the public in advance of a flood. First, sufficient warning is essential so that the public realizes that the flood risk is high. This role is assumed in part by the BC River Forecast Centre and the Provincial Emergency

Management Program for the Cowichan River. And second, adequate information is required about what measures can be taken by floodplain residents to minimize the damage.

In general, education is rarely a part of flood control projects; a 1997 survey of floodplain officials in Canada suggested that "for the most part, municipalities do not take part in public education or the provision of information to the public regarding floodplain areas" (de Loe and Shrubsole 1999). The development of this Flood Management Plan is the first step in a long process that will require a commitment to public education and engagement.

The education of floodplain property owners greatly increases the likelihood that they will make decisions regarding the use of their private property based on factual knowledge. In addition, educated citizens are more likely to lend support to large non-traditional flood control projects if they fully understand the benefits and disadvantages of such action. In particular, the education of homeowners will likely mean an increase in floodproofed buildings.

Public education programs are a simple, cost-effective measure, which can have great impacts on flood management.

6.9 Actions for Best Practice

6.9.1 *Floodproof Development*

When construction within a floodplain is unavoidable specific flood proofing measures should be taken to minimize damage and to prevent loss of life. Flood proofing can be applied both to existing structures by retro-fitting and to new developments by incorporating flood proofing concepts into the design. Flood proofing commonly includes placing fill to raise the elevation of a building above the flood level, constructing the building on columns or a foundation wall or some combination. The Design Centre for Sustainability at the University of British Columbia has produced an overview of basic floodproofing concepts and methods, which has been summarized as follows (Design Centre for Sustainability 2009).

Dry Flood Proofing: The entire building is made water tight by either elevating the building or sealing it. If continuous walls are used then they must have openings that allow the flood water to flow unobstructed through them to avoid developing excessive hydrostatic pressure forces. Scour protection measures around the foundation will also be required.

Wet Flood Proofing: Allows the basement to flood while keeping the habitable portions of the structure above the flood line. This approach deliberately allows water to enter the building in order to balance the water pressure on the inside and outside of the structure.

Green Infrastructure: Landscaping can be carried out to assist in flood proofing by using parks and wetlands as areas for conveying and storing flood water.

It is possible to retrofit existing buildings against floodwaters. Three primary methods are used (1) elevation, (2) re-location and (3) floodwalls. Elevation involves raising the lowest floor of the building above the Flood Construction Level. Foundations may need to be strengthened to accommodate the additional loads. This approach may not be appropriate if the building is located within the floodway where the velocities and depths are excessive. A floodwall can be constructed around a house to prevent flooding. The wall will have to be reinforced and anchored to withstand the hydrostatic pressure and may require scour protection to avoid undermining.

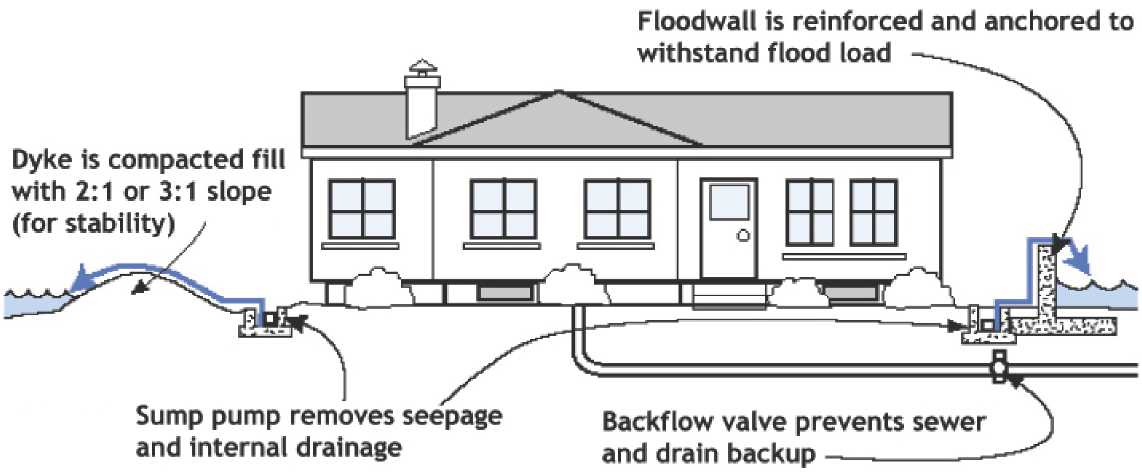


Figure 6.1: Example of floodproofed home

The recent catastrophic flood damage in New Orleans and across Europe has triggered a new emphasis amongst architects and builders to develop more flood-resistant structures. A recent architectural design competition in the United Kingdom concluded (Bustler 2008):

> *Reducing the risk of flooding does not begin and end with concrete walls and buildings on stilts. Good design lies at the heart of creating communities that are more resilient against flooding, of lessening the cost caused by flooding when it does occur and of minimizing the impact it has on local livelihoods and safety.*

Photo 6.1: Flood damage to mobile home

7 INTEGRATED FLOOD MANAGEMENT FOR THE COWICHAN RIVER - GUIDING PRINCIPLES

Integrated flood management (IFM) has emerged as the best approach for reducing flood damages and loss of life. The defining characteristic of IFM is integration, expressed in different forms: an appropriate mix of strategies, points of intervention, types of interventions (structural or non-structural), short or long-term and a participatory and transparent approach to decision making-particularly in terms of institutional integration.

Given the general philosophy expressed in the CBWMP and discussions with stakeholders at the Cowichan Stewardship Round Table, this study has focused on establishing more flood-resistant communities by reducing vulnerability and reducing exposure. Essentially, the plan promotes a comprehensive approach to flood management in line with the generalized characteristics of IFM. In particular, the plan promotes a more naturalized approach to flood management, lessening the reliance of the community on structural measures to reduce their flood hazard.

7.1 STUDY GOALS

The overall goals of the study, as stated in the Call for Proposals, are as follows:

Goal 1

The plan should aim to reduce flood risk to all communities on the floodplain, while protecting aquatic and riparian habitat and addressing the cultural values of the rivers.

Goal 2

The plan should promote innovative methods of flood hazard management to minimize short and long-term economic, environmental and social costs and where possible, provide an increase in the environmental and social capital of the region.

In addition to these two explicit goals, the scope has also been broadened to incorporate new information and lessons-learned from other integrated flood management planning organizations. In particular we have aimed to adhere to the goals set out by the community in the Cowichan Basin Water Management Plan (5.3.6). A third goal relating to the implementation of the plan is shown below. However ultimately, the stakeholders, local governments and Cowichan Tribes will need to frame their own goals and objectives in order to implement the final plan.

Goal 3

The plan should be achievable and should be supported by project stakeholders and the community at large. And, tools and recommended actions should be sustainable in the long-term.

7.2 GUIDING PRINCIPLES AND STRATEGIES

The following ten strategies have been followed in preparing preliminary concepts and initiatives in support of the plan and the goals outlined above.

- **Strategy 1: Return the rivers to a more naturalized state.** The Cowichan River has been artificially straightened and confined by riprap and dikes. This type of channelized river generally requires a high degree of maintenance and repair. It also adversely impacts fisheries habitat by reducing habitat complexity. Therefore, restoring the river to a more "naturalized" channel configuration that has room to convey water within a broad floodway should be a part of a long-term strategy
- **Strategy 2: Sustain the natural state of existing floodplain**. Remaining undeveloped floodplain areas should be sustained in a natural state. And, initiatives should be compatible or be integrated with programs that protect and enhance aquatic and riparian habitat
- **Strategy 3: Site future development in areas with low flood hazard and low habitat sensitivity**. Future development should be sited in areas with low flood risk and low habitat sensitivity
- **Strategy 4: Ensure new or upgraded flood protection structures do not adversely increase the overall flood hazard.** Based on past experience along the river, a "no-net adverse impact" flood level policy for future developments on the floodplain, including future diking and flood protection works, is needed. Constructing new dikes or extending existing ones should not increase the risk of flood damage in other vulnerable areas
- **Strategy 5:** Decrease vulnerability of existing development areas: Where key infrastructure and residential areas currently lie on the floodway and cannot easily be moved, decrease the vulnerability of these people and structures. This can be achieved through floodproofing of existing structures, and through improvements to public education, flood warning and flood response systems.
- **Strategy 6: Mitigate impacts of high flows on mainstem.** Impacts of high flows on mainstem should be mitigated by facilitating flow through suitable off-channel habitat
- **Strategy 7: Maintain channel conveyance**. Consider and maintain sites of debris jams and debris/gravel accumulation. An "adaptive" maintenance approach that incorporates habitat enhancement as part of channel maintenance is needed
- **Strategy 8: Create accessible and sustainable tools for flood management**. New tools developed for the project need to be designed so they can be used interactively and dynamically for emergency management, improved landuse planning, public awareness and education

- **Strategy 9: Promote basin-wide planning initiatives.** Basin-wide planning is important, particularly since most of the flood water, sediment and debris originates upstream of jurisdictional boundaries in the basin headwaters.
- **Strategy 10: Monitor and maintain flood management program.** Monitoring and maintenance are essential components of a flood management program. This should not just apply to dikes or bank protection works, but the channel as a whole.

7.3 KEY CHALLENGES

Many aspects of IFM are already in-place in the Cowichan Region. For example, floodplain mapping has been prepared as part of this project, landuse controls are being administered by local governments, flood dikes and other infrastructure have been constructed and there is a strong base of community stakeholder involvement through the Cowichan Round Table and preparation of a Water Management Plan. However, there are many challenges to overcome before an effective integrated flood management program can be implemented, given the number of jurisdictions involved and the limited capacities of local governments.

7.3.1 DISCONNECT BETWEEN BASIN AND ADMINISTRATIVE BOUNDARIES

Flood planning and management is most effective when it is done at the basin scale. However, the jurisdictions of the local governments do not extend into the headwaters where much of the runoff, sediment and debris is generated. Portions of the headwaters are privately-held land (Timber West, Island Timber) and local governments on the floodplain have little influence on landuse decisions made on these lands.

7.3.2 FRAGMENTATION OF ADMINISTRATIVE BOUNDARIES

There are four separate jurisdictions in the floodplain, each with different resources for planning, operations and maintenance. Furthermore, differences exist between administration of lands subject to federal and provincial legislation. For example:

- Technical and financial resources vary considerably across the jurisdictions. In some cases local individuals are responsible for maintenance of dikes.
- Dikes constructed on Tribes land are not subject to provincial legislation (dike maintenance act). Some dikes have been constructed without assessing their overall effect on other structures;
- There is no single organization to regulate developments on the floodplain, plan and implement maintenance programs or upgrade flood protection or coordinate flood protection and habitat enhancement works.

7.3.3 PLANNING UNDER UNCERTAINTY

A very important obstacle to flood management is the difficulty involved in creating policy under uncertainty. The risks associated with floods are difficult to quantify and are uncertain at the best of times. There is uncertainty in both the intensity and timing of flood events. Expenditures are difficult to justify when benefits may not be realized in the foreseeable future, and will most probably not be realized during short governmental term horizons. The problem is exacerbated by the relatively short flood memory half-life. Even in regions that are highly vulnerable, such as the Cowichan Valley, flooding is not are the forefront of public concern except during periods of flood threat. Increased levels of awareness amongst the public and policy makers can improve this situation.

In addition, there is a general recognition that climate change over the next century will lead to more severe flood discharges and higher extreme ocean levels than in the past. Climate change could also affect forest cover and slope stability in the headwaters; again leading to higher sediment and debris inputs to the floodplain. However, at this time, these changes in hazard level are not quantifiable, making justification for additional flood works difficult.

7.3.4 SUPPORT TO LOCAL GOVERNMENTS

Recent changes to provincial legislation related to flood hazard management have devolved authority from the Ministry of Environment to local governments. Specific powers granted to local governments include: (1) approval for subdivisions and floodplain bylaws, (2) establishment of minimum setbacks from watercourses and dikes, (3) specifying minimum flood levels for habitable dwellings, (4) specifying the structural support necessary to protect buildings, and (5) approval of exemptions to a local bylaw to manage floodplain hazards.

The tools made available to local governments for administering these activities are generally not adequate. Furthermore, the local government organizations generally do not have the staff resources and expertise to carry out these extra duties. The considerable expertise within the Ministry of Environment can not provide technical advice to local governments on some aspects such as floodplain hazards mapping and flood management plans.

Funds for upgrading and maintaining dikes and erosion protection works are limited, particularly for works on Cowichan Tribes lands. For example, provincial funding of flood works through EMBC exclude First Nations involvement.

7.3.5 FUTURE OF COWICHAN BASIN WATER ADVISORY COUNCIL

The Cowichan Basin Water Management Plan recommended formation of a Basin Water Advisory Council as a step towards local water governance. The Council needs political and funding support to achieve the goals of the Plan. It is our understanding a director is being hired to lead this organization. The Council will also need to facilitate and bring together a broad range of local interests and stakeholders to build a consensus on preferred actions and alternatives. It is not clear how technical input and specialist studies will be funded.

8 INTEGRATED FLOOD MANAGEMENT FOR THE COWICHAN RIVER – PROPOSED ACTIONS

A full spectrum of engineering, habitat and policy actions are proposed as part of the Integrated Flood Management Plan. These projects and actions have been selected to meet the goals and strategies of this plan. They include priority projects as well as longer-term engineering/habitat works and policy and planning initiatives. The plan components are detailed in this chapter and are summarized in Table 8.1.

Table 8.1: Summary of Integrated Flood Management Components

Strategy	Project /Action	Jurisdiction
Priority Projects		
Ensure new or upgraded flood protection structures do not adversely increase the overall flood hazard	Dike Upgrades and New Dike Construction • JUB Sewage Lagoon • Cowichan Dike • Lakes Road Dike • Koksilah Village Dike	Province City of Duncan MNC CVRD Cowichan Tribes
Mitigate impacts of high flows on mainstem	Channel Maintenance and Improvement Programs • Rotary Park Channel • Jayne's side-channel • Koksilah side-channels • Koksilah bank revetment	FOC Province MNC CVRD Cowichan Tribes
Maintain channel conveyance	Gravel Removal and Maintenance	FOC, Cowichan Tribes, CVRD, MNC
	Log Jam Modification and Removal	Province, FOC, Cowichan Tribes, CVRD, MNC
	Selective Vegetation Removal from Dikes	Province, Cowichan Tribes, CVRD, MNC
Long-Term Projects		
Return the rivers to a more naturalized state	Set-back Dikes and Channel Naturalization • Hatchery Dike • South Side Set-Back Dike • Trailer Park Channel • Mainstem Channel between White Bridge and E&N Railway • Koksilah Golf Course Creek • Shu-hwuykwselu Creek Diversion	FOC Province MNC CVRD Cowichan Tribes
	Dike Modification • Priest's Marsh (Quamichan Dike) • Cowichan South Side Dike	FOC Province MNC CVRD Cowichan Tribes
Maintain channel conveyance	Upstream Sediment and Debris Control	FOC, Province – coordination through CSRT
Ensure new or upgraded flood protection structures do not	Road Modifications	
	Bridge Replacements	MNC

Strategy	Project /Action	Jurisdiction
adversely increase the overall flood hazard		
Policy and Planning		
Sustain the natural state of the remaining undeveloped floodplain areas		Province City of Duncan MNC CVRD Cowichan Tribes
Promote future urban development in areas with low flood risk and lower habitat sensitivity		Province City of Duncan DNC CVRD Cowichan Tribes
Decrease vulnerability of existing development areas	Flood proofing	City of Duncan MNC CVRD Cowichan Tribes
	Public Education	Province City of Duncan MNC CVRD Cowichan Tribes
	Flood Warning	
	Emergency Response Planning	
Create accessible and sustainable tools for flood management.	• GIS Database • Modelling Tools • Mapping (Digital and Paper)	CVRD
Promote basin-wide planning initiatives		Province City of Duncan MNC CVRD Cowichan Tribes Other Stakeholderse
Monitor and maintain flood management program		

Structural options involving major engineering works (such as dams and diversion channels) are unlikely to be economically or environmentally feasible in the Cowichan Basin and are outside of the scope of this present investigation. However, there may be some possibility of modifying the Cowichan Lake weir to reduce the frequency and duration of some floods in the lower watershed (NHC 2005). However, this was outside the scope of the present study.

8.1 LANDUSE PLANNING

8.1.1 SUSTAIN THE NATURAL STATE OF THE REMAINING UNDEVELOPED FLOODPLAIN AREAS

An important part of the long-term flood management strategy is to restore and maintain a natural channel configuration that provides capacity within a broad floodway. Remaining undeveloped floodplain areas within the study area are valuable biophysical features, which provide both flood buffering and critical habitat. The following rational should be considered during the early planning stages for projects concerning undeveloped floodplain areas.

- Ensure the preservation of fish and wildlife resources through retention of the remaining undeveloped floodplain areas, including the estuary, and limit further resource and urban development.
- Limit industrial and agricultural activity in the floodplain and estuary to the existing development sites and ensure additional development guidelines are consistent with flood management activities (Lill et al. 1975).
- Where possible, continue to rehabilitate habitat that has been adversely affected by resource development and/or flood management activities, including encroachment by commercial development, diking, channelization, dredging and infilling of floodplain and estuarine habitat.
- Ensure future works are compatible with natural floodplain ecology as well as flood management objectives.

Examples of undeveloped floodplain areas with high habitat sensitivity ratings are described below and in Figure 2.10 and Figure 2.11.

Tooshley Island – North of the 1 km long Tooshley Island Dike lies an estimated 14.4 ha of forested floodplain contributing to mainstem floodway between kms 2+200 – 0+900 (Figure 2.10). Habitat sensitivity in this area is considered high.

Fish Gut Alley – An estimated 23.7 ha forested floodplain bounded to the north by Cowichan River Dike and JUB Sewage Lagoon Outer Dike between mainstem kms 5+800 – 4+400 (Figure 2.10). Ingress of mainstem flow is known to occur during moderate to high water and also increases proportionally as bedload accumulates in the adjacent mainstem. Fish Gut Alley supports valuable year round habitat for both aquatic and terrestrial wildlife. A proposed setback dike to increase freeboard around JUB Outfall Sewage Lagoons is not expected to have significant impact to existing habitat provided mitigative measures are in place.

John Charlie/Major Jimmy's/5 Fingers – The combined area of these significant neighbouring floodplain areas give rise to an estimated 41.5 ha between mainstem kms 5+300 – 3+600 (Figure 2.10). This largely unfragmented forested floodplain is bounded to the south by Mission Road Dike and Hatchery Dike as well as partially to the north by South Side Spur Dike. Flow occurs year round by way of a natural intake near km 4+750 RB and the area accommodates a broad floodway. Potential exists to increase side-channel habitat in this area.

Priest's Marsh/Priest's Backchannel (Creek) –Priest's Marsh is characterized by an estimated 62 ha wetland ecosystem, which is known to provide year-round off-channel rearing for salmonids. While floodplain connectivity is partially impaired on the western portion by Quamichan Dike opportunity exists to restore floodplain capacity with anticipated benefits of reducing flood level in Somenos Creek. Confinement of mainstem flood flows along this reach is exacerbated by the opposing Hatchery Dike on the immediate south side of the river (Figure 2.10).

8.1.2 PROMOTE FUTURE URBAN DEVELOPMENT IN AREAS WITH LOW FLOOD RISK AND LOWER HABITAT SENSITIVITY

Habitat sensitivity mapping can be used to identify potential sites for future urban development where lower riparian habitat values geographically overlap with low flood risk areas or areas outside the floodway (Map 1). Completion of the habitat mapping would identify the best candidate areas for future residential and commercial development.

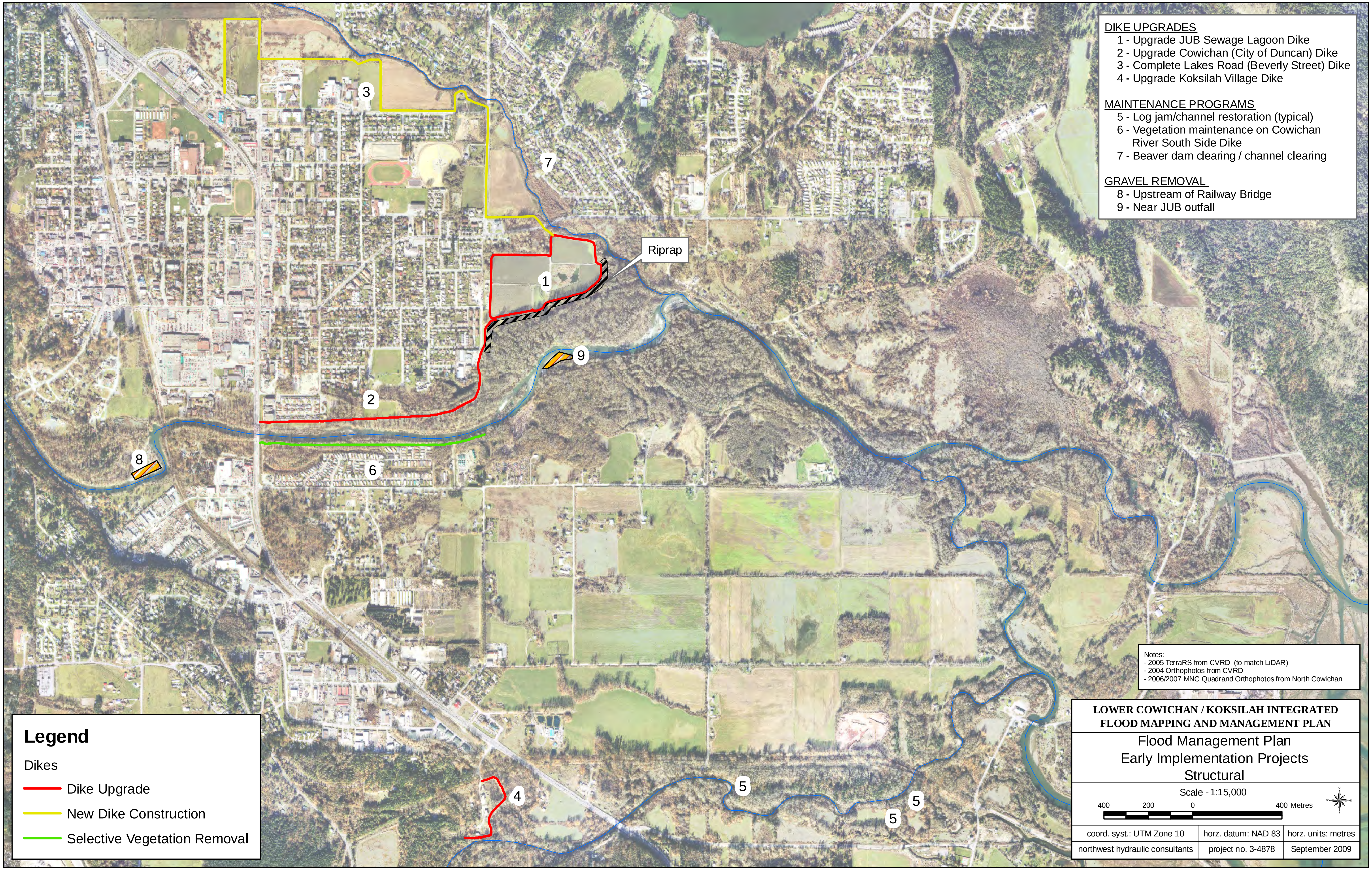
8.1.3 FLOOD PROOFING

Flood proofing should be promoted on all portions of the floodplain. However, the relatively sparsely populated areas on the Koksilah floodplain should be a particular focus for future efforts, since these sites are difficult to protect by structural measures and are subject to significant overbank spilling at high flows. Another high priority area is on the south bank of the Cowichan River along Boys Road, particularly the high density mobile home development. The existing dike does not eliminate the threat of flooding in this area. Furthermore, mobile homes may be more vulnerable to flood damage if they are not permanently anchored to the ground as illustrated in Photo 6.1.

8.2 PRIORITY STRUCTURAL PROJECTS

The following measures should be considered for early implementation due to the urgent nature of the problem and perceived benefits of the works. In most cases, additional site-specific surveys, detailed designs, environmental investigations and costing will need to be carried out as part of the implementation. Figure 8.1shows the location of these initiatives.

Strategies described in this section adopt a pro-active and integrated approach to flood management and flood maintenance that takes into consideration the ecological impacts of flood control measures. The measures are believed to be consistent with the Plan's objectives of preserving, rehabilitating and enhancing existing fisheries and wildlife resources. Site specific recommendations for habitat restoration and compensation measures are provided where anticipated short term impacts to ecological values are anticipated. Any flood management or maintenance works should consider natural floodplain hydraulics and seasonal contribution of flows necessary to sustain existing high value side-channel habitat. In particular, side-channel habitat along the mainstem Cowichan River between kms 3.8 to 6 is sensitive to manipulations to mainstem overbank flows.



VFOC, X:\34878 Cowichan FPM\GIS_Phase3\34878_VFOC_EarlyImplementation.mxd

Figure 8.1

8.2.1 DIKE UPGRADE OR NEW DIKE CONSTRUCTION

Four main criteria were used for identifying projects for dike upgrading or new dike construction:

1. The level of protection for residential, industrial and commercial landuse should be at least 200-years - new diking projects should not encourage development in areas where the level of protection is at a lower standard;
2. Dike upgrading should not increase flood levels at other sites - there should be no adverse impact on flood levels;
3. High priority should be given to improving security of critical infrastructure and densely populated areas or sites with high exposure to flood hazards;
4. Works should not result in loss of riparian areas or aquatic habitat.

Table 8.2 is a preliminary "screening level" assessment of alternative dike upgrades in terms of perceived flood protection benefits and impacts on upstream flood levels. The hydraulic model simulations were used as a basis for assessing the effects of raising the dikes. The anticipated ecological effects and recommended mitigative measures for the four priority dike upgrades are summarized in Table 8.3.

Table 8.2: Assessment of Dike Upgrade Priorities

Dike	Effect if dike is raised		Comment
	Flood protection benefit	Raises flood levels at other locations	
Cowichan (City of Duncan)	high	no	Critical infrastructure; protects Duncan and Somenos area
JUB lagoons	high	no	Critical infrastructure
Lakes Road	high	no	Protects Duncan from backwater induced flooding
Cowichan South Side	low	no	Existing dike not overtopped; raising dike improves freeboard
Quamichan	low	yes	Raising dike would increase flooding in Somenos/JUB area
South Side Spur	minor	yes	Raising dike increases flood levels at Highway 1 & Duncan
Hatchery	low	yes	Raising dike could increase flooding in Somenos/JUB;
Mission Road	moderate	no	
Tooshley Island	none	no	existing dike is above 200-year flood, water can flow on both sides
Koksilah Village	high	no	Potentially high hazard to local residents if dike overtops

Dike	Effect if dike is raised		Comment
	Flood protection benefit	Raises flood levels at other locations	
Clem Clem	moderate	no	

Table 8.3. Summary of Critical Dike Projects, Anticipated Ecological Effects and Recommended Measures

Project Name	Description	Length (km)	Anticipated ecological effects	Recommended measures
JUB Sewage Lagoon	Upgrade (including riprap armouring)	1.6 (incl 0.7 riprap)	Moderate effects. Armouring will encroach an estimated 7,000 m^2 into sensitive instream habitat.	Soften structure with bioengineering methods Replace trees elsewhere Enhance instream habitat
Cowichan Dike	Upgrade	1.1	Minor effects. Minor encroachment into existing riparian habitat on Cowichan.	Soften structure with bioengineering methods Replace trees elsewhere Enhance instream habitat
Lakes Road Dike	New construction	2.8	Minor effects. Suitably set-back with approximately 415 m overall encroachment into riparian habitat on Somenos.	Soften structure with bioengineering methods Enhance instream habitat
Koksilah Village Dike	Upgrade	0.5	Minor effects. Minor encroachment into existing riparian habitat on Koksilah.	Soften structure with bioengineering methods Enhance instream habitat

JUB Sewage Lagoons and Cowichan (City of Duncan) Dikes

The updated hydraulic investigations indicate that a high priority should be given to upgrading the dikes at the JUB sewage lagoons and the adjoining Cowichan (City of Duncan) Dike. The need for upgrading protection at the JUB dike was identified previously (Willis Cunliffe and Tait 1992). However, due to a lack of funds no action was taken. It is our understanding that consideration is being given to modifying the JUB sewage treatment facility, possibly even re-locating it. If the facility was moved, the existing JUB dikes would still need to be raised since they are lower than the Cowichan Dike. If the JUB treatment facility remains operational for several years or more, then the flood protection issue is more serious, since a failure of the lagoons during a flood would be very undesirable. In this case, we recommend upgrading the dike to a higher standard than a 200-year flood (similar to practice in Alberta). The upgrading should include riprap erosion protection since there is a significant risk of the river avulsing into the side-channel (Fish Gut Alley) that runs along the toe of the dike. Furthermore, a design review of the plant operations during extreme flood conditions is needed to establish adequate freeboard for effluent storage in the lagoons.

Proposed upgrades to the JUB Sewage Lagoon dike will increase freeboard around the overall 1.1 km perimeter giving rise to an estimated 5 m horizontal displacement beyond the existing structure. As an added measure of flood protection 670 m x 5 m of rock armouring is proposed along the toe of the upgraded dike as shown in Figure 8.1. An estimated 6,700 m^2 of sensitive aquatic and riparian habitat associated with lower Fish Gut Alley channel will be altered (Photo 8.1).

Photo 8.1: Downstream view of lower Fish Gut Alley side-channel

Angular riprap is commonly used to armour banks to increase stability and reduce erosion, which potentially limits habitat complexity by reducing the frequency of undercut banks, low overhead cover and natural recruitment of LWD (Schmetterling et al. 2001). Studies by Schmetterling et. al (2001) however shows that interstices purposefully created between large angular riprap provide habitat for juvenile salmonids where streams have been degraded. Placement of riprap dike protection along the toe should aim to ensure roughness over the surface to achieve a net positive effect on fish habitat. Riparian habitat within the project site consists of a riparian community with understory natives and mature cottonwood dominating the canopy. Accordingly, reasonable reclamation measures would include minimizing disturbance to existing riparian trees and replacement of riparian understory natives by way of bioengineering methods. In combination with other bioengineering methods including rock complexing, placement of ballasted LWD features and planting riparian natives the amount of compensation is expected to suitably offset the 6,700 m^2 disturbance anticipated from upgrading the JUB Sewage Lagoon dike.

Lakes Road Dike

The Lakes Road Dike was proposed in 1992 to protect residents in Duncan from backwater flooding in Somenos Creek (Figure 8.1). Although pump stations and control structures were constructed to treat interior drainage, the dikes were not constructed and the land is still subject to potential backwater inundation. The total length of diking required is approximately 2,900 m, with the alignment following portions of Lakes Road and Beverly Street. Willis Cunliffe and Tait (1992) estimated the cost of the Somenos diking program was $712,000. The Willis Cunliffe and Tait study included constructing a large spur to deflect the Cowichan River southward in an attempt to restore its previous channel alignment. This re-location was intended to reduce flood levels at the mouth of Somenos Creek. At the time, this project was not supported by the Cowichan Tribes as there was some concern about the downstream impacts from the channel shift. Based on the results of the current investigation, this project would have created a wide range of impacts to habitat, river stability and river hydraulics. Therefore, the spur dike is not recommended in this Plan.

The proposed location of Lakes Road dike is suitably set back from the active Somenos flood channel bisecting agricultural fields and more critical community infrastructure. In three locations the proposed dike alignment approaches moderately sensitive riparian habitat potentially encroaching an overall 415 m along its 2.8 km length. Cumulative ecological effects of the new dike are expected to be minor with mitigative measures in place.

Recommended measures to offset potentially adverse ecological effects include the utilization of bioengineering methods along low elevation portions of the dike encroaching into riparian habitat. While the control of tree species is required on dikes, proposed installations of live brush layering and live stakes using willow species is intended to provide additional slope stability and reasonably restore adjacent riparian habitat. Bioengineering installations increase long-term stability by reinforcing fill material and armouring as roots develop, adding significant resistance to sliding or shear displacement. Additional instream restoration measures are described further in section 8.2.6.

Koksilah Village Dike

The Koksilah Village Dike upstream of Highway 1 is another existing structure that should have a high priority for upgrading because the existing houses behind it are exposed to a high hazard if overtopping or breaching occurs. It would be impractical to flood proof the existing houses in this area because of the fast and deep flow conditions that would occur. Other options such as re-location might be considered. Upgrading the dike will require raising the embankment, re-grading the side slopes and placing additional riprap on the river-side.

Proposed upgrades to an estimated 1.1 km of the Cowichan dike and the 0.5 km long Koksilah Village dike are expected to have minor effect on adjacent riparian habitat with mitigative measures in place. Mitigative measures described previously include bioengineering installations along the dike toe where encroachment into riparian habitat occurs. Where appropriate, instream fish habitat restoration work should also be considered.

Cowichan South Dike

Dike raising is warranted along portions of the Cowichan South Dike to improve its freeboard, without adversely affecting adjacent flood levels in the river. Additional general maintenance is required in terms of selective clearing and removal of vegetation (further details described below).

Proposed upgrades to an estimated 1.1 km of the Cowichan dike and the 0.5 km long Koksilah Village dike are expected to have minor effect on adjacent riparian habitat with mitigative measures in place. Mitigative measures include bioengineering installations along the dike toe where encroachment into riparian habitat occurs. Where appropriate, instream fish habitat restoration work should also be considered.

Hatchery Dike, Quamichan Dike and South Side Spur Dike

The results of the hydraulic model simulations indicated that further raising of the Hatchery Dike, Quamichan Dike and South Side Spur dike would raise flood levels and potentially increase flood damages at other nearby locations. Therefore, we suggest deferring any improvements to these particular structures at this time.

8.2.2 CHANNEL MAINTENANCE AND IMPROVEMENT PROGRAMS

An adaptive maintenance program or series of programs needs to be implemented to address the state of the existing dikes as well as the mainstem, side-channels and riparian zone of the Cowichan and Koksilah Rivers. This program should aim to (1) provide long-term benefits to aquatic habitat and (2) gradually result in reduced flood damages to property and important infrastructure. The scope of these measures will need to be defined through consultation with agencies and local governments. The following examples highlight some maintenance activities that could be carried out.

Rotary Park Channel

Rotary Park channel was improved in 1977, 1983 and 1987 (Burns 2002). Rotary Park Creek and ponds historically provided good spawning habitat for chum and good overwintering habitat for coho. Gradually however productivity of Rotary Park channel diminished due to poor base flows and limited fish access (Brown 1977; Bonnell 1988). A cost effective maintenance solution exists for Rotary Park channel using groundwater from #2 well that can be readily supplied by an existing discharge pipe (Figure 8.1 and Figure 8.3). Based on preliminary discussions with operations personnel at City of Duncan the concept of utilizing a relatively small proportion of flow to improve fish productivity (min 5 litres per second) for 5-6 months of the year is acceptable as these volumes have insignificant effect on their broader water requirements. The project is summarized in Table 8.4.

Table 8.4: Rotary Park Channel Improvement Project Summary

Objective	Improve base flows to Rotary Park Channel, deepen channel where required and further improve rearing habitat by installing cover features and deepening the channel in shallow segments.
Benefits	Anticipated 2,400 increase in annual smolt production based on existing biostandards. Increase in utilization by rearing juveniles and spawning adults.
Risk	Low
Estimated Cost	While cost to seasonally open City of Duncan existing #2 well valve is minimal, the approximate cost to deepen the channel where required and to install 24 LWD cover features is approximately $48,500.

Side-channel Improvements

Some existing side-channels with unprotected intakes could be improved by installing ballasted LWD to increase long-term stability and ensure minimum base flows. Examples shown in Figure 8.1 and Figure 8.2 include Jaynes', Major Jimmy's and lower Fish Gut side-channels at kms 3+875 LB, 4+750 RB and 5+025 LB respectively. Details on habitat improvements for Jayne's side-channel are detailed below.

Jayne's side-channel provides an estimated 2,030 m^2 of spawning and rearing habitat for chum, coho, steelhead and trout. The channel is bounded to the northeast by Quamichan dike, providing ready access to the entire alignment. Fish habitat restoration opportunities include installation of 11 ballasted LWD cover features along the 290 m long channel and installation of a ballasted LWD intake feature at km 3+875 LB to ensure long term stability and minimum base flows (Figure 8.5). The project benefits and costs are summarized in Table 8.5.

Table 8.5: Jayne's Side-channel Improvement Project Summary

Objective	Increase long-term stability of the side-channel by installed ballasted LWD intake and cover features throughout.
Benefits	Improved intake stability and maintenance capability Increased annual fish production by an estimated 1,360 smolts Increased channel stability
Risk	Low
Estimated Cost	Cost to install a ballasted LWD intake is approximately $20,000. Estimated cost to install 11 ballasted LWD features within the 290 m long channel is $28,000.

Other existing side-channels with unprotected intakes could be similarly improved by installing ballasted LWD to increase long-term stability, improve maintenance capability and ensure minimum base flows. Examples shown in Figure 8.4 include lower Fish Gut Alley and Major Jimmy's side-channels at kms 5+025 LB and 4+750 RB respectively. Estimated cost to improve the existing intakes at Fish Gut Alley and Major Jimmy's is $25,000 and $30,000 respectively.

Similarly, some distributary channels on the Koksilah River have been artificially blocked by land-owners to reduce potential erosion further downstream. Re-opening the side-channels would reduce flooding on the mainstem and be beneficial in terms of habitat utilization. Bio-engineered erosion protection measures (ballasted root wads or engineered log cribs) could be installed on the banks of the side-channel to prevent erosion.

Koksilah Side-channels

Large woody debris jams on the Koksilah River have partially blocked the entrance to some side-channels potentially limiting fish production due to impaired flow and fish access as well as reduced water quality (Photo 8.2). Impaired flow to side-channels identified in this section also reduces the overall capacity of the channel, potentially increasing flood levels in the mainstem. Opportunity exists to modify existing jams by partial removal and construction of ballasted intake features.

Photo 8.2: Downstream view of LWD jam obstructing side-channel intake at km 2+080 LB

Table 8.6: Koksilah Side-channels Project Summary

Objective	Restore and improve connectivity to 3 side-channels identified on Koksilah River at kms 2+080 LB, 1+380 RB and 1+180 RB (Figure 8.7).
Benefits	• Increase stability of side-channel intakes and ensure minimum base flows. • Improve flood conveyance. • Increase available rearing and spawning habitat.
Risk	Low
Estimated Cost	Cost to modify each side-channel intake at kms 1+380 RB and 1+180 RB is approximately $35,000. The estimated cost to restore the side-channel intake at km 2+080 LB is $80,000

Maintenance to Old Koksilah Bank Revetment Site

An existing 25 m long bank revetment site at km 1+360 on the right bank of the Koksilah River is showing evidence of deterioration including failed alder tree bank anchors, broken clips, large voids between logs and overall loosening (Figure 8.9 and Photo 8.3). Alder tree bank anchors appear to have failed due to the combined effect of decay and over loading from LWD recruitment. As the feature was not designed for excess load and not ballasted for buoyancy vertical migration during large water level fluctuations appears to have destabilized the bank and limited recovery of vegetation. Cost to reconstruct the bank revetment to current WRP design standards is estimated at $40,000.

Photo 8.3 : Upstream view of log jam on Koksilah River at km 3+290

8.2.3 GRAVEL REMOVAL AND MAINTENANCE

The channel of the lower Cowichan River has aggraded in recent years and this trend is expected to continue in the future. This sedimentation has contributed to bank erosion and channel instability problems. It is presently threatening to cause the river to avulse into a back channel, towards the JUB sewage lagoon dikes. The gravel accumulation has also contributed to increased water levels. Two tentative sites for gravel removal have been identified on the Cowichan River:

- The aggrading gravel bar opposite the JUB outfall and accessible from the south side dike, where mainstem flow is avulsing into the lower Fish Gut Alley side-channel (Photo 8.4 and Figure 8.4)
- The large aggrading point bar upstream of the railway bridge and accessible from the north bank (Figure 8.3).

Approximately 4,000 m^3/year of gravel would be removed from each site for three consecutive years. The gravel removal would be carried out by bar scalping in the dry on the exposed higher elevation areas of the bars. The sites would be carefully monitored and decisions on whether to continue the program would be made annually after a review of the observations. It is anticipated that gravel removal would be discontinued after three years in order to allow the bars to recover. The need for continuing gravel removal at other locations would be made on the basis of monitoring bed level changes in the reach. Other long-term programs directed at controlling sediment sources (Section 8.3.4) might eventually reduce the need for ongoing gravel removal.

Photo 8.4: Downstream view of lower Fish Gut Alley side-channel intake showing avulsing mainstem flow and proposed installation of ballasted LWD intake feature.

Significant impacts to sensitive habitat are not anticipated for gravel and LWD removal strategies with the following guidelines in place.

- Develop suitable habitat restoration opportunities to offset potentially harmful alteration (see section 8.2.6)
- Confine gravel removal to within the bankfull channel width, with all material removed from site rather than sidecasted or temporarily stockpiled within the floodplain.

- Dredging should be limited to sustain present seasonal water levels and existing inflows to off-channel areas (side-channels, sloughs, ponds, wetlands, etc.)
- If gravel removal works occur where excess debris accumulations are located, opportunities for debris removal should be considered while equipment is onsite. For example, excessive LWD and SWD accumulations exist along length of right bank (outer) meander bend km 4.5 to 4.75 that has impaired natural shoreline features.
- Gravel removal should be carried out in the dry and limited to scalping the exposed higher elevation areas of the bars.
- Bioengineering techniques are preferred to stabilize exposed banks vulnerable to erosion.
- One of the final phases of gravel removal activity should be grading to ensure juvenile fish are not stranded in excavated depressions as water levels decrease over the gravel bar during inundation cycles.

8.2.4 Log Jam Modification and Removal

Log jams on the Koksilah River have blocked the entrance to some side-channels potentially limiting fish production due to impaired flow and fish access as well as reduced water quality. Fish utilization is observed to be low due to perched intakes and limited flows. At the same time the blockages reduce the capacity of the mainstem channel, contributing to higher flood levels. Selective modification of the jams (partial removal, with compensating stabilization of large woody debris) could be carried out under the direction of an engineer and biologist.

Log-jams can span the entire width of the Cowichan and Koksilah River, leading to avulsions, erosion to adjacent dikes, blockage of bridges and increased flood levels. For example, log jams in 2005 and 2007 on the Koksilah River contributed to flooding problems. A log jam in 2006 on the Cowichan River caused serious damage to the JUB sewer outfall, requiring repairs totalling $400,000. It is better to carry out regular maintenance to remove or stabilize a portion of the debris rather than wait until a major problem develops and be forced to carry out extensive repairs.

The goal of this strategy is to proactively remove or stabilize debris jams of concern before threats to infrastructure occur. A channel spanning debris jam located on Koksilah River at km 3+290 should be further assessed to determine flood risk to the Koksilah Dike, residential property and the E&N Railway crossing located downstream (Figure 8.8 and Photo 8.5).

Photo 8.5: Upstream view of log jam on Koksilah River at km 3+290

8.2.5 SELECTIVE VEGETATION REMOVAL FROM DIKES

Selective vegetation removal is required along portions of the Cowichan South Dike and Cowichan (City of Duncan) Dike in order to meet minimum guidelines by MELP and FOC (1999). A compensation plan will be required to ensure there are no net impacts from the clearing. Given the generally poor state of most other dikes, it is better to leave the existing vegetation in-place on these other structures.

Channel maintenance and clearing could be carried out along Somenos Creek to ensure adequate drainage during recession of floods and to improve water quality and fish habitat. Beaver dams need to be removed on a regular basis and a regular cleaning program should be initiated.

8.2.6 RECOMMENDED COMPENSATION PROJECTS

Previous notable studies undertaken in the Cowichan-Koksilah Flood Management Planning Area describe fish habitat restoration opportunities, including Lill et al. (1975) and Burns (2002). Restoration concepts identified by these studies have been instrumental in the implementation and adaptation of projects carried out by ad hoc partnerships often including Cowichan Tribes. In 2004 Cowichan Tribes initiated the Cowichan Recovery Plan, which was completed by LGL in 2005. While the Cowichan Recovery Plan was intended to support ongoing treaty negotiations it has also served as an important planning tool as well as a starting point for a community partnership group known as the Cowichan Stewardship Round Table (CSRT). Current habitat restoration strategies are typically coordinated by the CSRT, including Cowichan Tribes, government, industry and NGOs.

The following projects should be considered when designing a compensation plan to offset any impact from the construction of flood protection works. Further investigation is needed to determine the feasibility of these projects.

Chesterfield Creek Summer Refuge Improvement – Somenos Basin

Chesterfield Creek flows into Somenos Creek at km 1+050 m and despite the channelization and marginal marginal temperature and oxygen levels it provides valuable summer refuge habitat for coho and cutthroat juveniles. The channel length extends for 125 m from Lakes Road to the Chesterfield Creek confluence. Restoration options include enlarging and deepening the pool immediately downstream of Lakes Road as well as flow augmentation to the wetland complex upstream through upstream excavation to increase groundwater inflows to the wetland and Chesterfield Creek. Summer flows at Lakes Road were minimal during observations in 1998 by Burns (2002). During May 2009, water quality in the Lakes Road pond was good (Dissolved Oxygen=7.8 mg/litre, Temperature = 15.8C) with an estimated < 1 litre/second of inflows observed through the gate valve at the Lakes Road culvert. Riparian vegetation is dominated by reed canary grass and hardhack with Scouler's willow. Riparian structure, function and diversity could be improved through riparian planting that includes species that provide shade and channel stability (e.g. red osier dogwood, ninebark, willow, Cottonwood, alder).

Mainstem Somenos Riparian Restoration – Somenos Basin

Riparian habitat along the mainstem Somenos is dominated by mature shrubs and thereby lacks a mature overstory canopy that could provide shade and structural complexity to the riparian stand. The Somenos mainstem is a very low gradient channel that is typically backwatered by Cowichan River flows. Slightly elevated flood benches along the lower reaches are regularly inundated and support largely wetland plant communities. Sections of the stream channel have extensive growth of reed canary grass (*Phalaris arundinacea*) throughout the channel cross section. Opportunities to restore a more diverse and natural stand structure include planting suitable native tree species tolerant of regular inundation with the intent to improve the quality of aquatic features by increasing overhead cover and shade to the channel.

Groundwater fed Rearing Habitat at Fun Pacific Mini Golf – Somenos Basin

A 160 m long groundwater fed (4.1 litres/second) excavated ditch is known to support fish habitat. Further study is required to explore suitability for utilization by fish and potential for restoration work.

8.3 LONG-TERM STRUCTURAL PROJECTS

8.3.1 OVERVIEW

This section describes a number of potential flood mitigation measures that may be feasible over a longer planning horizon (several years to decades). The overall objective of these is to increase security against flooding by restoring channel conveyance through a program of naturalizing the existing diked and confined channel of the Cowichan River. This would focus on dike set-backs and potentially restoring flow through side-channels that were blocked or filled in several decades ago. The schemes are all integrated with projects that mitigate damage or improve overall habitat quality. These concepts are comparable to a number of recent levee set-back projects that have been carried out in Washington State as well as the “Room for River and People” initiative that are being implemented in Europe (Appendix C). These projects could not be implemented without substantial public consultation and inter-governmental cooperation and would require a paradigm shift in the current approach to managing flood hazards. Several alternative concepts are shown in Figure 8.2. Associated restoration and compensation projects are summarized in Figure 8.3 through Figure 8.9.

8.3.2 SET-BACK DIKES AND CHANNEL NATURALIZATION

Artificially channelized rivers are vulnerable to erosion and require ongoing repair and maintenance to prevent damage by undermining from scour or bank erosion. The Hatchery Dike, Quamichan Dike, Cowichan South Dike and South Side Spur Dike confine the Cowichan River in a narrow floodway. Consideration should be given to restoring the floodplain capacity in this reach, possibly by constructing a new set-back dike or by opening portions of existing dikes. The benefits of these modifications would involve primarily (1) reduced flood levels at upstream locations, (2) improved riparian habitat. Some adverse effects could occur to residences that are currently protected by the dikes. In this case flood-proofing mitigation or some form of compensation would have to be agreed upon as part of the program. Some change to habitat would also occur if inactive side-channels were re-activated. Therefore, a detailed assessment would be required before going forward. Mitigation and compensation measures would need to be provided. It is expected that this type of measure would be developed over a relatively long-term planning time frame (10 to 20 years).

Three different alternatives have been identified for preliminary discussion and assessment. Brief highlights of the options are summarized in Table 8.7. The layout of each option is shown on Figure 8.2.

Hatchery Dike

Set-back Hatchery Dike to the existing road that parallels the dike, tie-in to the Mission Road Dike, upgrade that structure and extend it to join the Cowichan South Dike. The eastern end of the South Side Spur Dike would be re-opened. This could reduce flood levels at the Somenos Creek junction and the JUB lagoons by approximately 0.6 m. It would also eliminate the spill that presently can occur when water backs up between the South Side Dike and the Mission Road Dike. However, it could adversely affect the Five Fingers back channel habitat restoration work that has been carried out by the Ministry of Transportation (Wong 2008).

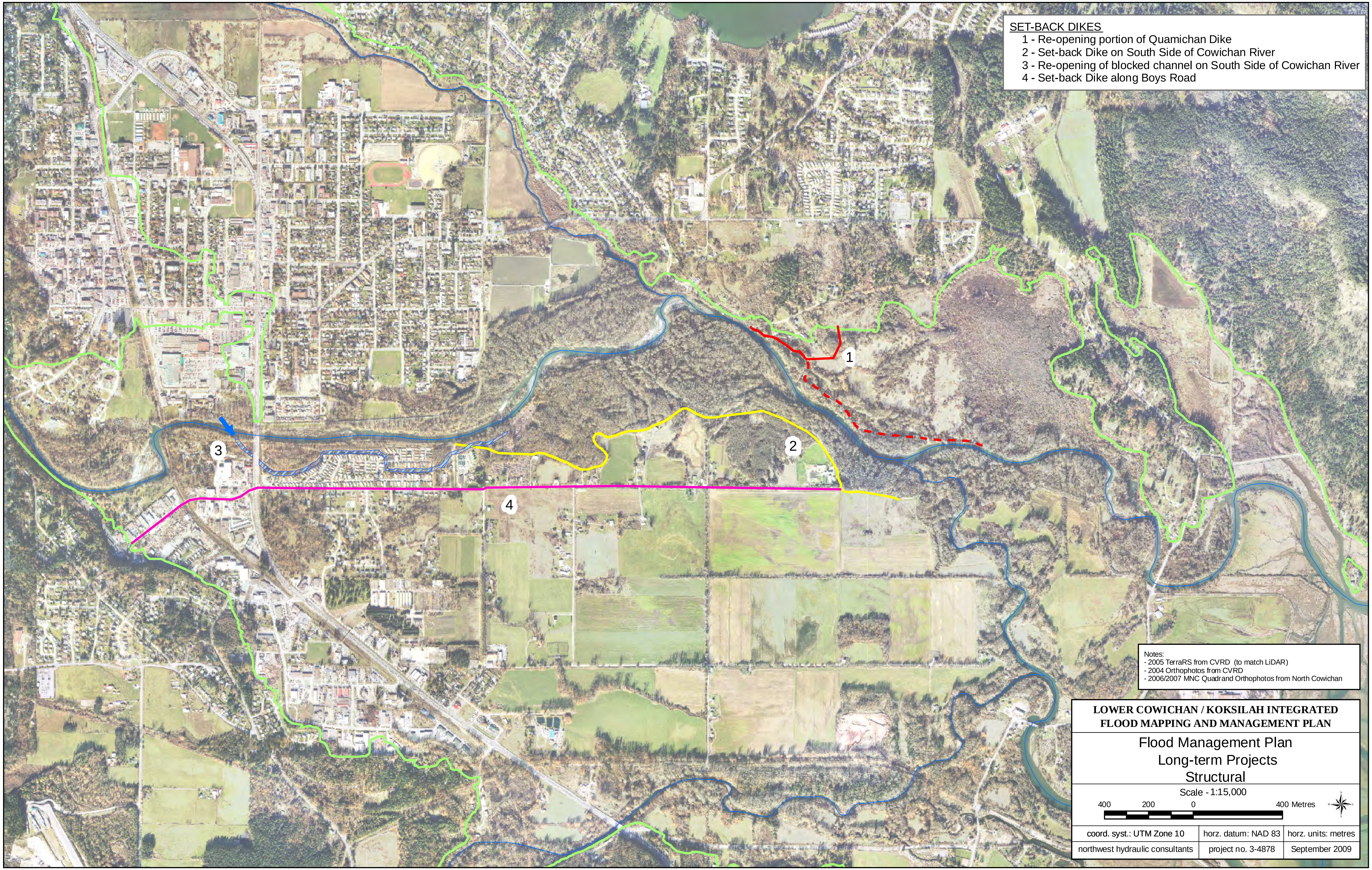


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Figure 8.2

South Side Set-Back Dike

A continuous set-back dike on the south side of the river could be built by raising Boys Road from upstream of the Railroad to the Hatchery Dike. This continuous dike would provide flood protection against spills over the right bank upstream of Highway 1 and significantly increase the flood storage area within the dikes. No simulations were done to investigate the reduction of flood levels at the Somenos Creek junction and the JUB lagoons, but it is expected to be greater than 0.7 m. Critical infrastructure including the District of North Cowichan wells and the Cowichan River Hatchery, and residential and business developments would be located on the river side of the dike.

Table 8.7: Comparison of Options for Dike Modification

Option	Alternative	Potential Benefits	Potential Adverse Effects
1	Modify Alignment of Quamichan Dike to re-open left bank to allow flood flows into Priest's Marsh	1. Reduce 200-year flood levels upstream. 2. Restore riparian habitat	Increase 200-year flood levels on North Cowichan Branch.
2	Set-back Hatchery Dike to existing road, upgrade Mission Rd Dike and Cowichan South Dike	1. Set-back dike configuration, reduce 200-year flood levels upstream. 2. More naturalized bankline is more sustainable in long-term	Damage to existing habitat restoration at Five Fingers.
3	Re-open blocked south channel upstream of Highway 1, provide flow control and maintain side-channel south of existing dike. Maintain existing Cowichan South Dike for erosion protection to existing infrastructure.	1. Re-opening channel system provides some reduction in flood levels and improves fish access to side-channels.	Requires land acquisition for side-channel extension.
4	Raise Boys Road from upstream end down to Hatchery Road.	Raising Boys Rd prevents potential right bank spills from upstream of Rail Bridge.	Properties and critical infrastructure are on the river side of Boys Road.

Flood pressure in the mainstem could potentially be mitigated by facilitating a larger proportion of the flow volume to existing side-channel and off-channel habitat. In some cases, flow volume has been reduced through these areas as a result of increased accumulation of sediment and/or woody debris, thereby reducing the natural conveyance of flood flows through existing side-channel and natural overbank flooding. Increasing flow to off-channel habitat by softening channel banks has the potential to decrease the effects of channelization and associated bank erosion issues that currently exist in the mainstem

Another critical factor to consider is to ensure that these off-channel areas will not contribute to entrapment of salmonids once the high discharge period is over and water levels decrease.

Suitable opportunities to improve the conveyance of flood flows through off-channel areas are described below.

Trailer Park Channel

The present slough was originally part of the mainstem Cowichan River until it was isolated during the 1950s when a new alignment was dredged following construction of the Trans-Canada Highway crossing (Brown 1977). Utilization of the slough by spawning adult salmon and rearing juveniles is documented by Brown (1977) and Marshall (1973) despite continued alterations during development of the trailer park in 1972. Enhancement potential to improve ingress and egress of fish in Trailer Park Channel was first described by Marshall (1973) and Brown (1977) based on fish presence and incubation survival of chum and coho.

Table 8.8: Trailer Park Channel Project Summary

Objective	Re-open the blocked channel on the south side of the Cowichan South Dike by installing an intake upstream of the Highway 1 Bridge near km 7+209 RB (Figure 8.3). Future consideration should be given to re-opening this channel when the Highway 1 Bridge is upgraded or replaced. Re-establishing flows to the channel would further augment flow to John Charlie's Side-channel between the South Side Spur Dike and Mission Road Dike.
Benefits	• Increased active side-channel habitat by an estimated 8,000 m^2 (1.6 km long x 5 m wide) giving rise to an estimated annual increase of 5,400 smolts. • Increased base flow, water quality and downstream utilization of John Charlie's side-channel for both spawning and rearing. • Improved riparian habitat. • Minor flood relief.
Risk	Further study and design detail required to assure no risk to owners of Silver Campsites Ltd.
Estimated Cost	$200,000 (approximate)

Flow Reinstatement on Mainstem Channel between White Bridge and E&N Railway

An opportunity first described by Lill et al. (1975) involves construction of an estimated 575 m long side-channel through an aggraded segment of the mainstem between kms 7+084 – 8+050. This side-channel is expected to provide flood relief and if designed to maximize potential for fish production could also be used to offset anticipated impacts from gravel removal, which is a proposed flood mitigation measure at a nearby aggrading point bar located on the left bank at km 7+200.

Table 8.9: Mainstem Channel between White Bridge and E&N Railway Project Summary

Objective	Provide flood mitigation measures using a constructed 575 m long side-channel combined with gravel removal (Figure 8.3).
Benefits	Control excess bedload accumulation known to occur at this site. Proposed development of an estimated 5,800 m^2 of side-channel habitat (575 km long

	x 10 m wide) will potentially increase annual smolt production by 3,853.
Risk	Cumulative impacts are considered low with mitigative measures in place.
Estimated Cost	Approximate cost to build a 5,800 m^2 side-channel is $103,500. Removing approximately 4,000 m^3 of gravel annually for 3-years is expected to be cost neutral.

Koksilah Golf Course Creek Flood Channel Diversion

Previous study by Burns (2002) describes backchannel habitat within lower Golf Course Creek that can be potentially brought into higher production for spawning chum and rearing coho with an engineered diversion channel. As described previously, field reconnaissance during this study found a log jam at the confluence of the associated distributary channel on the right bank of the Koksilah River at km 1+380 (Photo 8.6). Riparian and fish habitat downstream of Cowichan Bay road is characteristically altered by vegetation clearing, channel confinement and encroachment. Opportunity exists to divert the distributary channel to an alignment where a net increase in fish production and flood conveyance is expected.

Photo 8.6: Downstream view of LWD jam partially obstructing side-channel intake at km 1+380 LB

Table 8.10: Koksilah Golf Course Creek Flood Channel Diversion Project Summary

Objective	Construct an estimated 500 m long diversion channel to improve flood conveyance, increase fish production and improve riparian habitat (Figure 8.9).
Benefits	• Alleviation of flooding on adjacent agricultural and residential properties and Cowichan Bay Road. • Anticipated 3,350 increase in annual smolt production based on existing biostandards. • Improve hydraulic regime of existing fish habitat within lower Golf Course Creek.
Risk	While the diversion is expected to alleviate flooding further study is required to confirm elevations and landowner cooperation.
Estimated Cost	Cost to construct the 500 m long diversion channel is estimated at $100,000.

Cowichan Mainstem Diversion to Shu-hwuykwselu Creek

Cowichan River historically supplied flow to Shu-hwuykwselu Creek with a distributary confluence north of Allenby Road near km 7+770 RB. Figure 8.6 shows a conceptual mainstem diversion to restore year round water supply to Shu-hwuykwselu Creek. Further study is required to assess feasibility of this project.

Table 8.11: Cowichan Mainstem Diversion to Shu-hwuykwselu Creek Project Summary

Objective	Construct an estimated 1 km diversion from Cowichan River to improve flow to Shu-hwuykwselu Creek (Figure 8.6).
Benefits	• Minor flood relief to Cowichan River in the vicinity of White Bridge. • Improved flow and water quality to an estimated 1.8 km of Shu-hwuykwselu Creek. • Increased fish production in Shu-hwuykwselu Creek.
Risk	Further study is required to confirm elevations, landowner cooperation and channel capacity in Shu-hwuykwselu Creek.
Estimated Cost	To be determined.

8.3.3 DIKE MODIFICATION

Quamichan Dike Modification to Restore flows to Priest's Mash

Construction of Quamichan Dike has impaired overbank flood patterns that historically provided flushing flows into Priest's Backchannel as well as high water refuge habitat for juvenile salmon. Re-opening a portion of the Quamichan Dike at approximately km 3+700 will restore floodplain connectivity to Priest's Marsh. Opportunity also exists to restore connectivity with Priest's Backchannel by way of a constructed 1.5 km long side-channel, which is expected to increase available year round fish habitat (Figure 8.5). Based on hydraulic simulations carried out during this study an estimated 0.5 m reduction in flood levels in Somenos basin is expected to occur from opening portions of the Quamichan Dike. Flood waters would also inundate the western portion of Priest's Marsh, which has been isolated from the river due to the dike and historic agricultural development.

Table 8.12: Priest's Marsh Flow Restoration Project Summary

Objective	Restore floodplain connectivity to Priest's Marsh by re-opening the eastern portion of Quamichan Dike. Construct a 1.5 km long side-channel to restore year round flows to Priest's Creek.
Benefits	Natural flow patterns over the floodplain remove accumulated fine sediments, improve water quality, mobilize coarse loose debris and limit vegetation. Restoration of natural floodplain hydraulics to Priest's Marsh is expected to improve the hydric regime that supports wetland ecology. Proposed development of an estimated 15,000 m^2 of active side-channel habitat (1.5 km long x 10 m wide) will potentially increase annual smolt production by 10,050.
Risk	While Quamichan Dike provides protection to residents living on the floodplain re-opening the eastern portion of the dike is not expected to have negative cumulative effects with mitigative measures in place. Flood protection measures can be maintained by reconfiguring the dike.
Estimated Cost	$300,000.

South Side-channel of Cowichan South Side Dike

Re-open the blocked channel on the south side of the Cowichan South Dike by installing an intake upstream of the Highway 1 Bridge. This channel was the main channel of the Cowichan River prior to construction of the highway in the 1970s. In the future, when upgrading or replacement of the bridge is needed, consideration should be given to re-opening this channel. This would require constructing an intake upstream of the existing bridge and re-opening the lower end so that more flow could be carried by the side-channels between the South Side Spur Dike and Mission Road Dike. This channel would not provide significant flood relief but it would be beneficial for fish habitat. Natural floodplain hydraulics would be restored to a relatively unfragmented forested habitat. Other anticipated benefits of restoring floodplain capacity in this reach include improved water quality and fish productivity within existing and potential side-channel habitat.

Table 8.13: Cowichan South Side-channel Project Summary

Objective	Re-open the blocked channel on the south side of the Cowichan South Dike by installing an intake upstream of the Highway 1 Bridge.
Benefits	Increased area available for utilization by rearing fish. Flow augmentation to existing side-channel habitat. Restore natural flow patterns over the floodplain.
Risk	While the existing South Side Spur dike would continue to provide some protection to existing restoration work completed in Five Finger's side-channel extreme flood conditions could mobilize installed LWD without ballasting improvements.
Estimated Cost	Cost of opening the eastern end of South Side Spur Dike is estimated at $30,000.

8.3.4 UPSTREAM SEDIMENT AND DEBRIS CONTROL

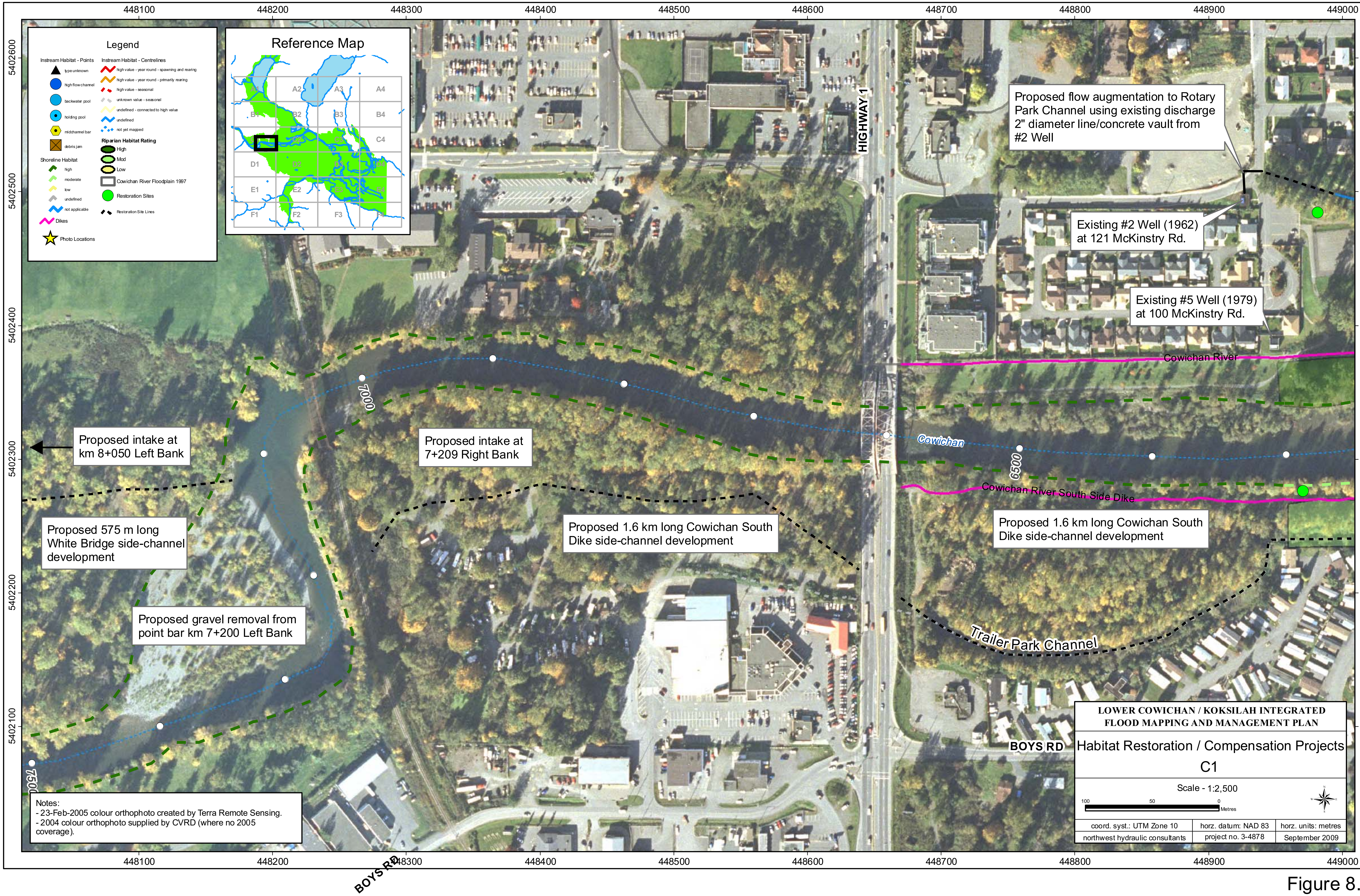
The lower Cowichan River is aggrading and the accumulation of sediments contributes to bank erosion, channel shifting hazards and increased flood levels. Both the Koksilah River and Cowichan River experience major log jams that can trigger bank erosion, obstruct bridges and can cause increased flood levels. These hazards originate primarily upstream of the study area, outside of the jurisdiction boundaries of the local communities. Considerable effort has been made to identify unstable slopes along the Cowichan River that have contributed large quantities of predominantly fine sediment to the river (Kerr Wood Leidal 2005; BC Conservation 2008). Figure 2.7 shows major gravel and sand sources based on air photo assessments and field visits by NHC. In the long-term, it would be beneficial to support basin-wide initiatives that control sediment and debris production. The major stabilization measures constructed near Stolz Slide were justified as a measure for protecting fish habitat from fine sediment. Several other potential bank stabilization projects have been identified but not funded at this point in time. The potential flood control benefit to reducing the need for ongoing gravel removal in the lower reaches should be considered when evaluating these projects. For example, it may be more ecologically sustainable in the long-term to reduce point sources of sediment in the headwaters rather than carry out annual gravel removal in the lower reaches for the foreseeable future.

8.3.5 ROAD MODIFICATIONS

Changing the elevation or alignment of roads on the floodplain may alter flood levels and flow paths. Therefore, any future changes to road alignments should be reviewed carefully in terms of impacts on flood levels. Highway 1 is subject to frequent overtopping from the Koksilah River at a point immediately north of the highway bridge. If the highway was raised in this section without providing relief culverts, then flood levels would be increased on the upstream side of the highway and at the bridge crossing. If a dike were constructed along the left bank of the Koksilah River upstream of the highway to contain the spill, then flood levels would be increased further upstream at the E&N Rail Bridge (which already has inadequate clearance) and at the Koksilah Village dike (which already has inadequate freeboard).

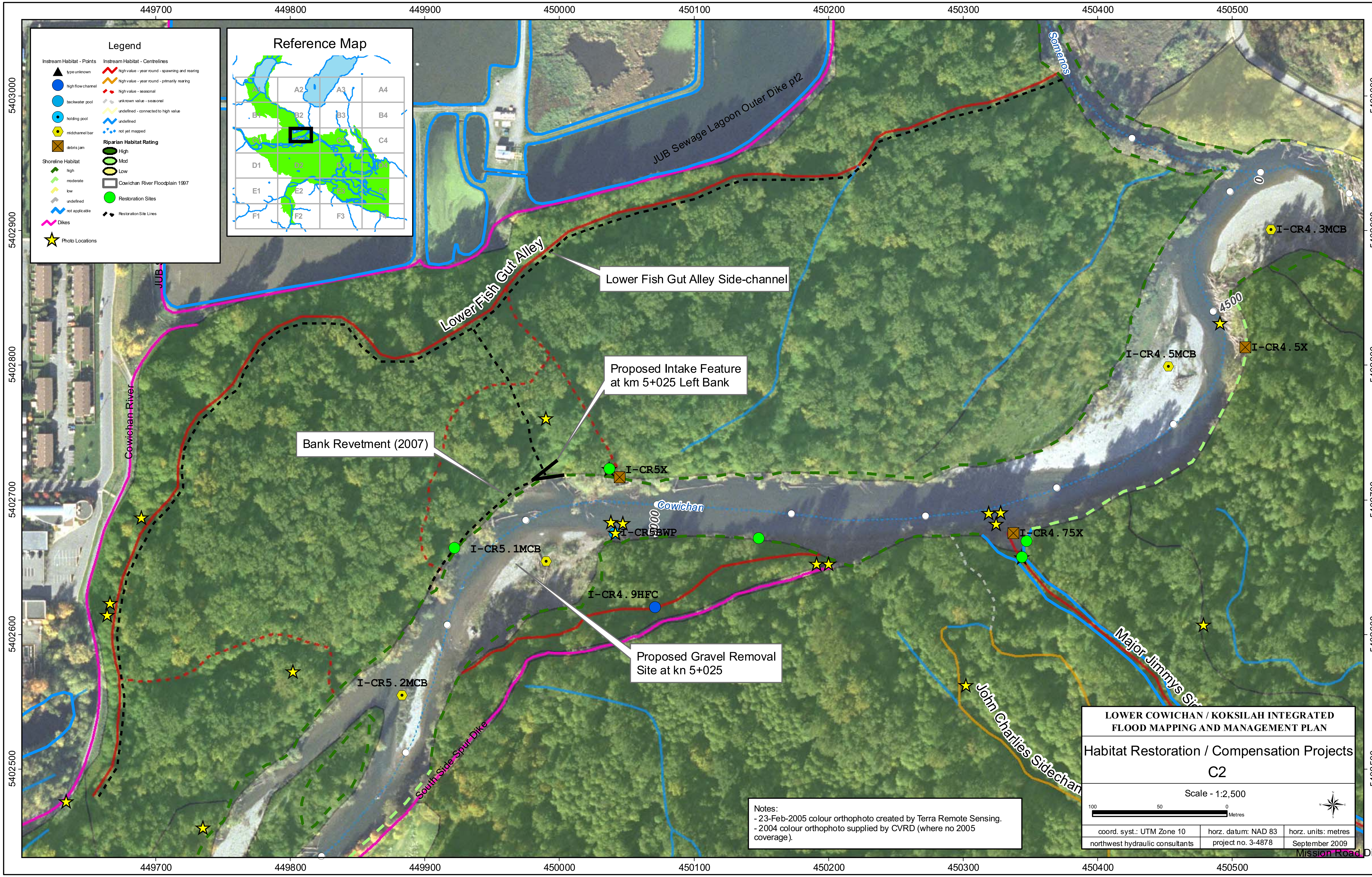
8.3.6 BRIDGE REPLACEMENTS

The vertical clearance for many of the bridges in the region is not adequate under a 200-year flood condition (Table 3.3). It was estimated that the bridges across Somenos Creek (Lakes Road and Trunk Road) will surcharge by over 1 m during a 200-year event. Raising these bridges could be carried out as part of the Lakes Road dike project described above in Section 8.2.1.



Legend
Instream Habitat - Points
type unknown
high flow channel
backwater pool
holding pool
midchannel bar
debris jam
Shoreline Habitat
high
moderate
low
undefined
not applicable
Dikes
Photo Locations
Instream Habitat - Centrelines
high value - year round - spawning and rearing
high value - year round - primarily rearing
high value - seasonal
unknown value - seasonal
undefined - connected to high value
undefined
not yet mapped
Riparian Habitat Rating
High
Mod
Low
Cowichan River Floodplain 1997
Restoration Sites
Restoration Site Lines
Reference Map
HIGHWAY 1
Proposed flow augmentation to Rotary Park Channel using existing discharge 2" diameter line/concrete vault from #2 Well
Existing #2 Well (1962) at 121 McKinstry Rd.
Existing #5 Well (1979) at 100 McKinstry Rd.
Cowichan River
Cowichan
7000
6500
Proposed intake at km 8+050 Left Bank
Proposed intake at 7+209 Right Bank
Cowichan River South Side Dike
Proposed 575 m long White Bridge side-channel development
Proposed 1.6 km long Cowichan South Dike side-channel development
Proposed 1.6 km long Cowichan South Dike side-channel development
Proposed gravel removal from point bar km 7+200 Left Bank
Trailer Park Channel
BOYS RD
BOYS RD
Notes:
- 23-Feb-2005 colour orthophoto created by Terra Remote Sensing.
- 2004 colour orthophoto supplied by CVRD (where no 2005 coverage).
LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN
Habitat Restoration / Compensation Projects
C1
Scale - 1:2,500
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009

Figure 8.3



Legend
Instream Habitat - Points
type unknown
high flow channel
backwater pool
holding pool
midchannel bar
debris jam
Shoreline Habitat
high
moderate
low
undefined
not applicable
Dikes
Photo Locations
Instream Habitat - Centrelines
high value - year round - spawning and rearing
high value - year round - primarily rearing
high value - seasonal
unknown value - seasonal
undefined - connected to high value
undefined
not yet mapped
Riparian Habitat Rating
High
Mod
Low
Cowichan River Floodplain 1997
Restoration Sites
Restoration Site Lines
Reference Map
A2
A3
A4
B1
B2
B3
B4
C4
D1
D2
E1
E2
F1
F2
F3
JUB Sewage Lagoon Outer Dike pt2
Somenos
Lower Fish Gut Alley
Lower Fish Gut Alley Side-channel
Cowichan River
Proposed Intake Feature
at km 5+025 Left Bank
Bank Revetment (2007)
Proposed Gravel Removal
Site at kn 5+025
Cowichan
I-CR5X
I-CR5BWP
I-CR5.1MCB
I-CR4.9HFC
I-CR5.2MCB
I-CR4.75X
I-CR4.5MCB
I-CR4.5X
I-CR4.3MCB
4500
5000
Major Jimmys Si
John Charlies Sidechan
South Side Spur Dike
Mission Road Dike
449700
449800
449900
450000
450100
450200
450300
450400
450500
5403000
5402900
5402800
5402700
5402600
5402500
Notes:
- 23-Feb-2005 colour orthophoto created by Terra Remote Sensing.
- 2004 colour orthophoto supplied by CVRD (where no 2005 coverage).
LOWER COWICHAN / KOKSILAH INTEGRATED
FLOOD MAPPING AND MANAGEMENT PLAN
Habitat Restoration / Compensation Projects
C2
Scale - 1:2,500
100
50
0
Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
JXD, 34878 Cowichan FPM\GIS\34878_Cowichan_JXD_Habitat_C2_Fig8.4_11x17.mxd

Figure 8.4

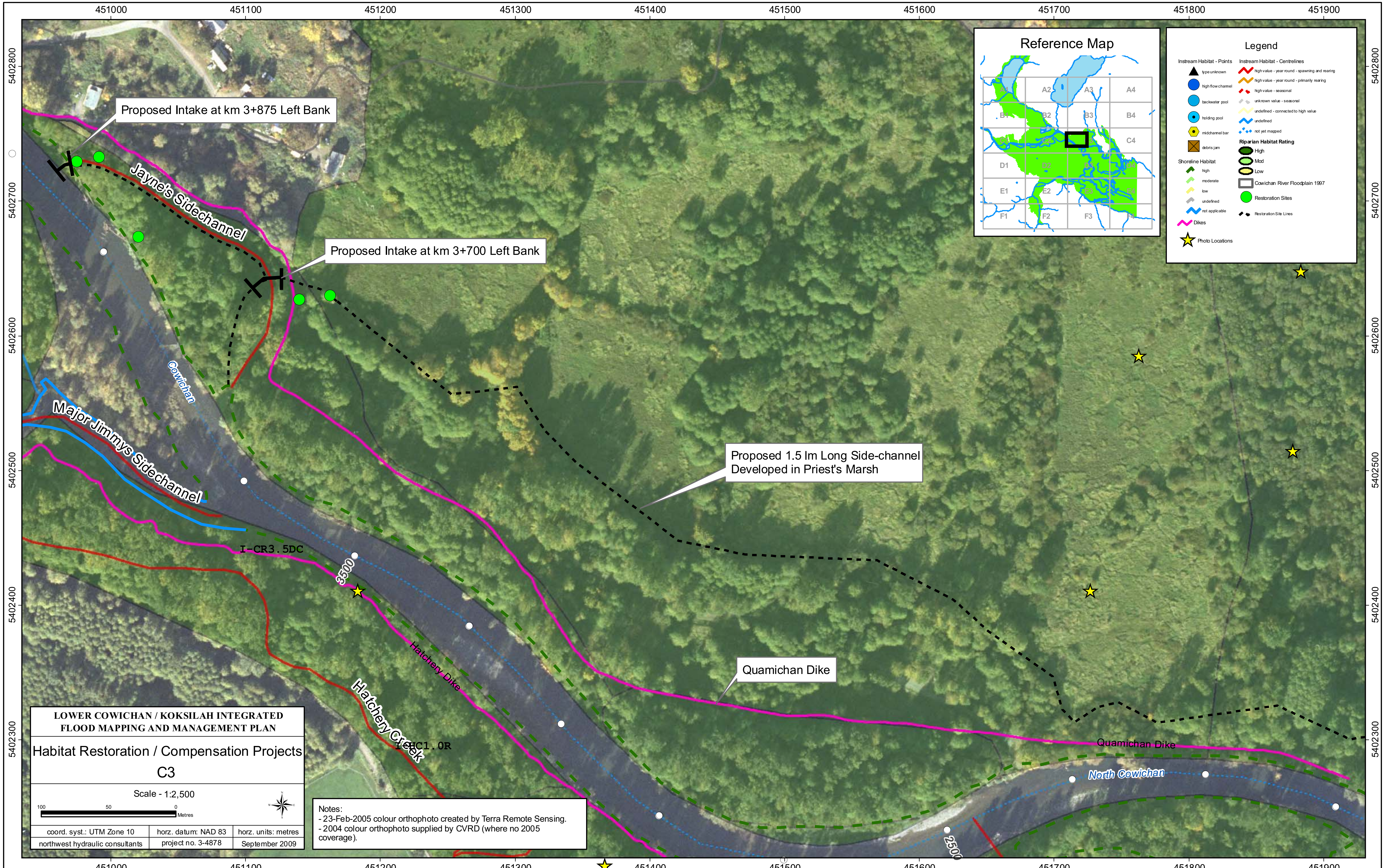

Proposed Intake at km 3+875 Left Bank
Jayne's Sidechannel
Proposed Intake at km 3+700 Left Bank
Cowichan
Major Jimmys Sidechannel
Proposed 1.5 lm Long Side-channel Developed in Priest's Marsh
I-CR3.5DC
3500
Hatchery Dike
Hatchery Creek
I-HC1.0R
Quamichan Dike
Quamichan Dike
North Cowichan
2500
Reference Map
Legend
Instream Habitat - Points
type unknown
high flow channel
backwater pool
holding pool
midchannel bar
debris jam
Instream Habitat - Centrelines
high value - year round - spawning and rearing
high value - year round - primarily rearing
high value - seasonal
unknown value - seasonal
undefined - connected to high value
undefined
not yet mapped
Riparian Habitat Rating
High
Mod
Low
Cowichan River Floodplain 1997
Restoration Sites
Restoration Site Lines
Shoreline Habitat
high
moderate
low
undefined
not applicable
Dikes
Photo Locations
LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN
Habitat Restoration / Compensation Projects
C3
Scale - 1:2,500
100 50 0 Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
Notes:
- 23-Feb-2005 colour orthophoto created by Terra Remote Sensing.
- 2004 colour orthophoto supplied by CVRD (where no 2005 coverage).
JXD, 34878 Cowichan FPM\GIS\34878_Cowichan_JXD_Habitat_C3_Fig8.5_11x17.mxd

Figure 8.5

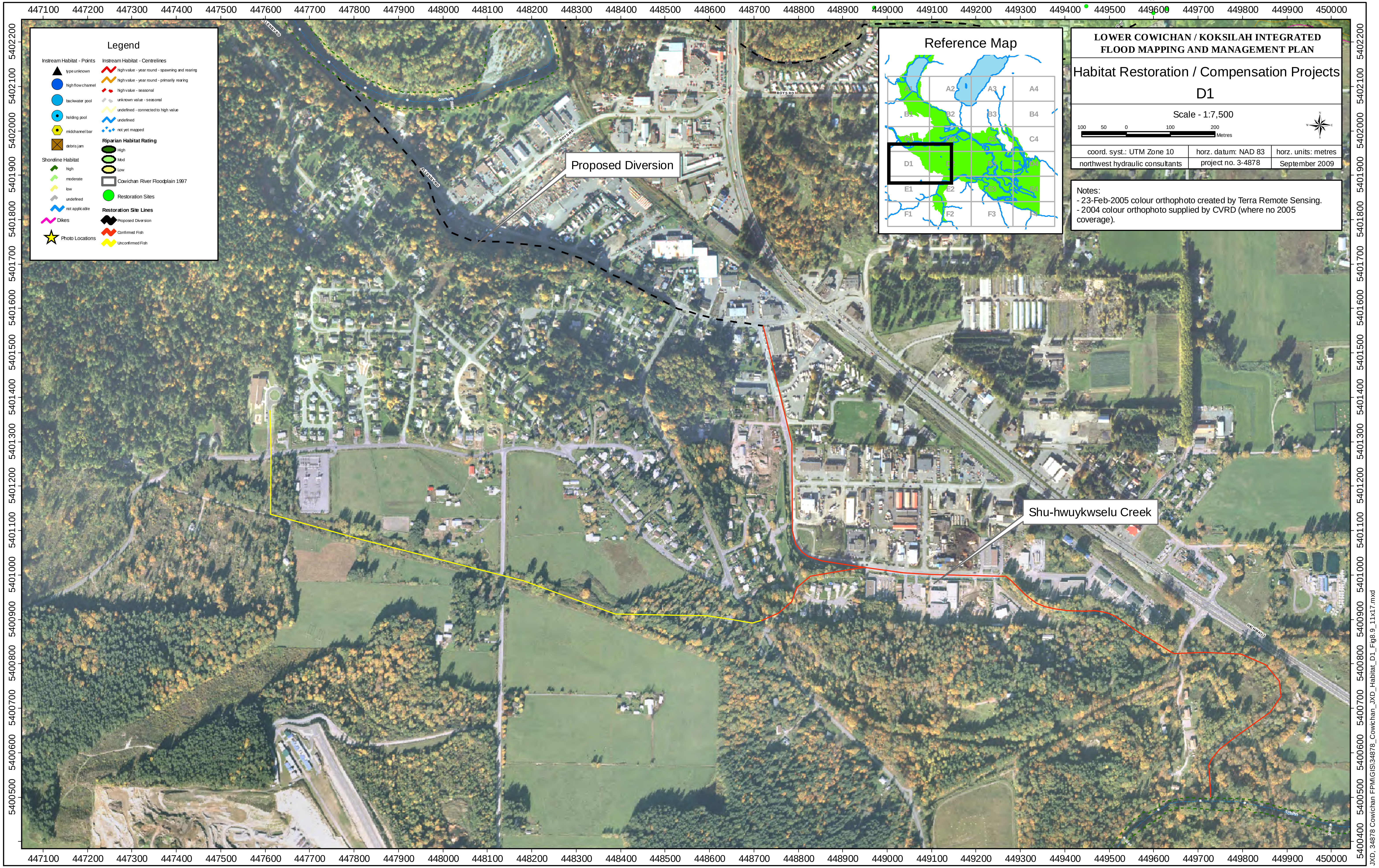

LOWER COWICHAN / KOKSILAH INTEGRATED
FLOOD MAPPING AND MANAGEMENT PLAN
Habitat Restoration / Compensation Projects
D1
Scale - 1:7,500
Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
Notes:
- 23-Feb-2005 colour orthophoto created by Terra Remote Sensing.
- 2004 colour orthophoto supplied by CVRD (where no 2005 coverage).
Reference Map
A2
A3
A4
B1
B2
B3
B4
C4
D1
E1
E2
F1
F2
F3
Legend
Instream Habitat - Points
type unknown
high flow channel
backwater pool
holding pool
midchannel bar
debris jam
Shoreline Habitat
high
moderate
low
undefined
not applicable
Dikes
Photo Locations
Instream Habitat - Centrelines
high value - year round - spawning and rearing
high value - year round - primarily rearing
high value - seasonal
unknown value - seasonal
undefined - connected to high value
undefined
not yet mapped
Riparian Habitat Rating
High
Mod
Low
Cowichan River Floodplain 1997
Restoration Sites
Restoration Site Lines
Proposed Diversion
Confirmed Fish
Unconfirmed Fish
Proposed Diversion
Shu-hwuykwselu Creek
447100 447200 447300 447400 447500 447600 447700 447800 447900 448000 448100 448200 448300 448400 448500 448600 448700 448800 448900 449000 449100 449200 449300 449400 449500 449600 449700 449800 449900 450000
5402200 5402100 5402000 5401900 5401800 5401700 5401600 5401500 5401400 5401300 5401200 5401100 5401000 5400900 5400800 5400700 5400600 5400500 5400400
JXD, 34878 Cowichan FPM\GIS\34878_Cowichan_JXD_Habitat_D1_Fig8.9_11x17.mxd

Figure 8.6

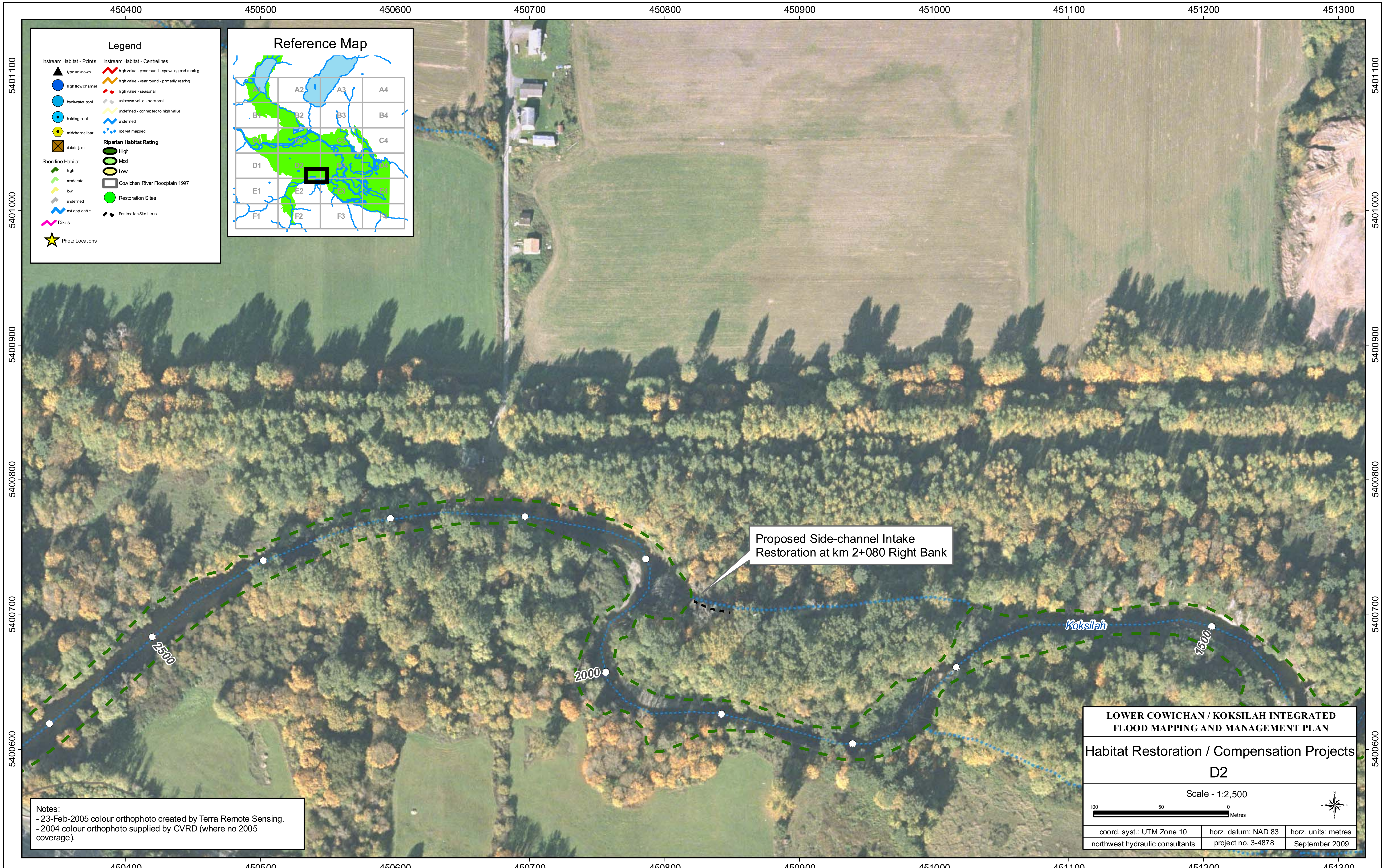
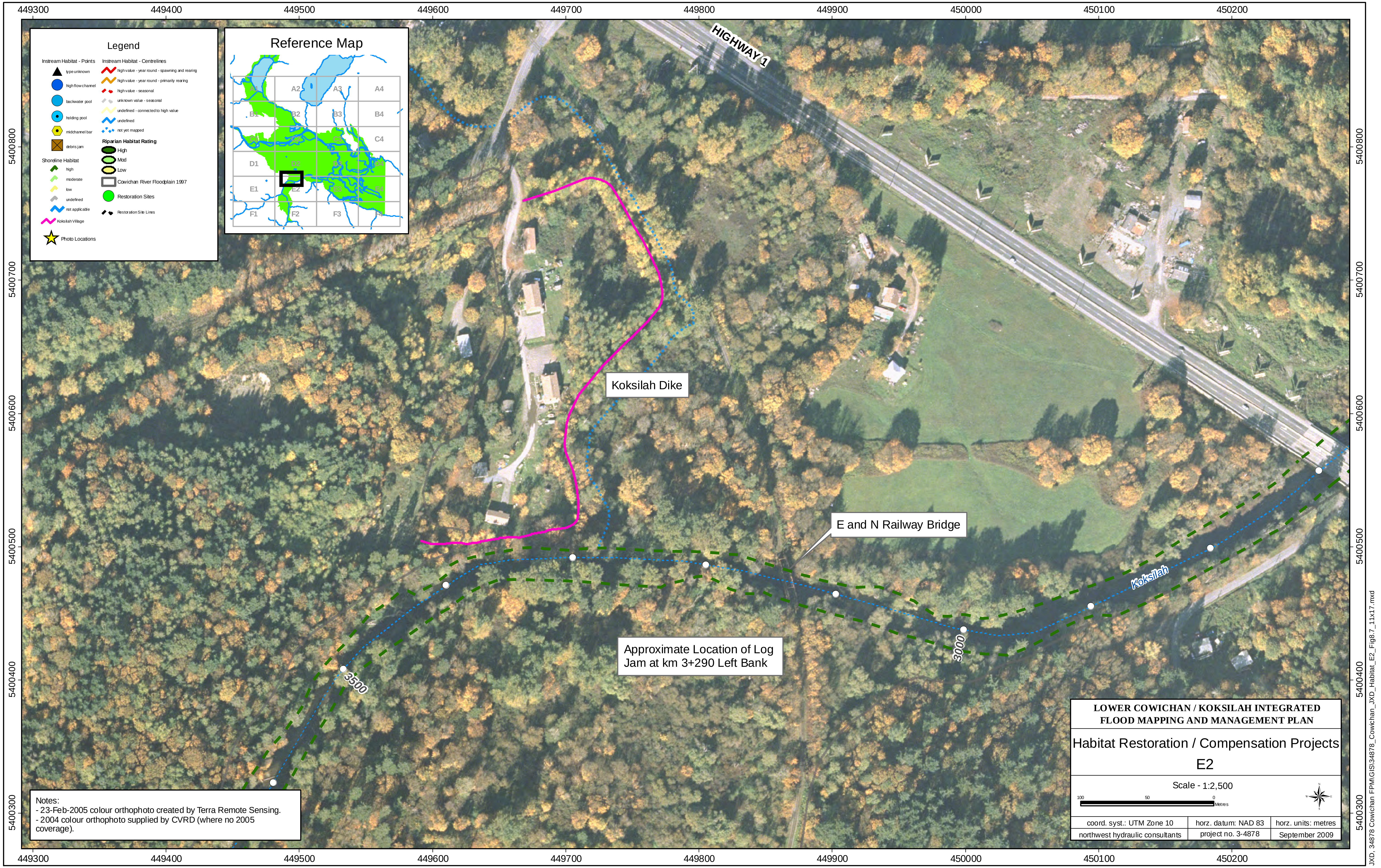
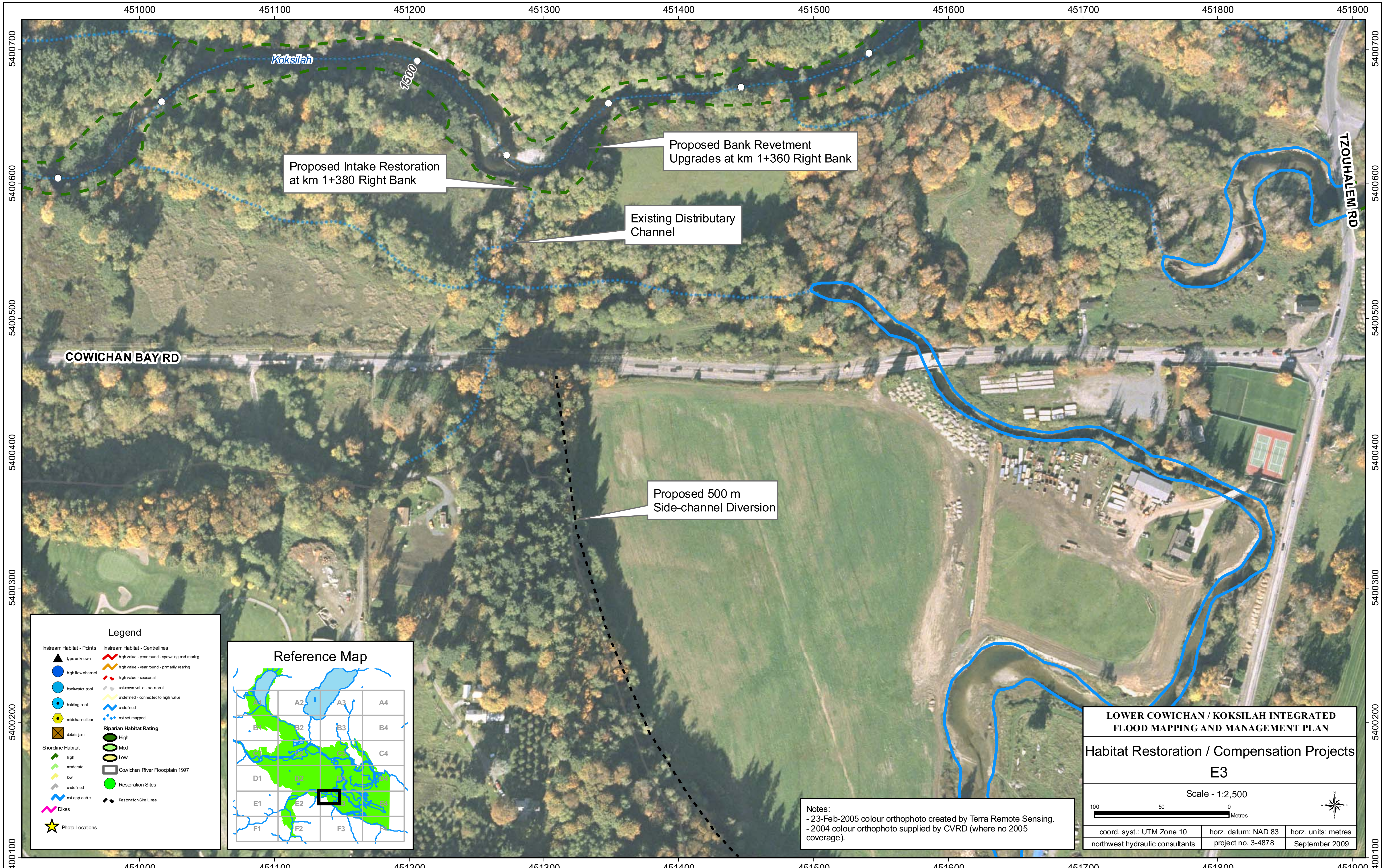

Legend
Instream Habitat - Points
type unknown
high flow channel
backwater pool
holding pool
midchannel bar
debris jam
Shoreline Habitat
high
moderate
low
undefined
not applicable
Dikes
Photo Locations
Instream Habitat - Centrelines
high value - year round - spawning and rearing
high value - year round - primarily rearing
high value - seasonal
unknown value - seasonal
undefined - connected to high value
undefined
not yet mapped
Riparian Habitat Rating
High
Mod
Low
Cowichan River Floodplain 1997
Restoration Sites
Restoration Site Lines
Reference Map
A2
A3
A4
B1
B2
B3
B4
C4
D1
D2
E1
E2
F1
F2
F3
Proposed Side-channel Intake
Restoration at km 2+080 Right Bank
Koksilah
2500
2000
1500
Notes:
- 23-Feb-2005 colour orthophoto created by Terra Remote Sensing.
- 2004 colour orthophoto supplied by CVRD (where no 2005 coverage).
LOWER COWICHAN / KOKSILAH INTEGRATED
FLOOD MAPPING AND MANAGEMENT PLAN
Habitat Restoration / Compensation Projects
D2
Scale - 1:2,500
100
50
0
Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
450400
450500
450600
450700
450800
450900
451000
451100
451200
451300
5401100
5401000
5400900
5400800
5400700
5400600
JXD, 34878 Cowichan FPM\GIS\34878_Cowichan_JXD_Habitat_D2_Fig8.6_11x17.mxd

Figure 8.7



Legend
Instream Habitat - Points
type unknown
high flow channel
backwater pool
holding pool
midchannel bar
debris jam
Shoreline Habitat
high
moderate
low
undefined
not applicable
Koksilah Village
Photo Locations
Instream Habitat - Centrelines
high value - year round - spawning and rearing
high value - year round - primarily rearing
high value - seasonal
unknown value - seasonal
undefined - connected to high value
undefined
not yet mapped
Riparian Habitat Rating
High
Mod
Low
Cowichan River Floodplain 1997
Restoration Sites
Restoration Site Lines
Reference Map
HIGHWAY 1
Koksilah Dike
E and N Railway Bridge
Koksilah
Approximate Location of Log Jam at km 3+290 Left Bank
3500
3000
Notes:
- 23-Feb-2005 colour orthophoto created by Terra Remote Sensing.
- 2004 colour orthophoto supplied by CVRD (where no 2005 coverage).
LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN
Habitat Restoration / Compensation Projects
E2
Scale - 1:2,500
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
JXD, 34878 Cowichan FPM\GIS\34878_Cowichan_JXD_Habitat_E2_Fig8.7_11x17.mxd

Figure 8.8



Koksilah
1500
Proposed Intake Restoration
at km 1+380 Right Bank
Proposed Bank Revetment
Upgrades at km 1+360 Right Bank
Existing Distributary
Channel
COWICHAN BAY RD
TZOUHALEM RD
Proposed 500 m
Side-channel Diversion
Legend
Instream Habitat - Points
type unknown
high flow channel
backwater pool
holding pool
midchannel bar
debris jam
Shoreline Habitat
high
moderate
low
undefined
not applicable
Dikes
Photo Locations
Instream Habitat - Centrelines
high value - year round - spawning and rearing
high value - year round - primarily rearing
high value - seasonal
unknown value - seasonal
undefined - connected to high value
undefined
not yet mapped
Riparian Habitat Rating
High
Mod
Low
Cowichan River Floodplain 1997
Restoration Sites
Restoration Site Lines
Reference Map
A2
A3
A4
B1
B2
B3
B4
C4
D1
D2
E1
E2
F1
F2
F3
Notes:
- 23-Feb-2005 colour orthophoto created by Terra Remote Sensing.
- 2004 colour orthophoto supplied by CVRD (where no 2005 coverage).
LOWER COWICHAN / KOKSILAH INTEGRATED
FLOOD MAPPING AND MANAGEMENT PLAN
Habitat Restoration / Compensation Projects
E3
Scale - 1:2,500
100
50
0
Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
451000
451100
451200
451300
451400
451500
451600
451700
451800
451900
5400700
5400600
5400500
5400400
5400300
5400200
5400100
JXD, 34878 Cowichan FPM\GIS\34878_Cowichan_JXD_Habitat_E3_Fig8.8_11x17.mxd

Figure 8.9

8.4 POLICY INSTRUMENTS

8.4.1 PUBLIC EDUCATION

Improved public awareness of flood issues and the inter-relationship between flood-resistant communities and restoration of riparian habitat is important for implementing a locally-based integrated flood management plan. Previous studies have shown that much of the public does not understand the limitations of structural flood control measures such as dikes. For example, it is not understood why new developments behind dikes need to be flood-proofed. The risk and consequences of experiencing a major event in excess of the design flood is also not understood by many residents or planners. Although there is widespread concern about climate change it is difficult to translate this into a coherent plan.

Communities and counties in the US frequently produce posters and pamphlets which explain these terms and provide supplementary information to help interpret the conditions in their particular region. An emergency preparedness workbook is currently available for the Cowichan Valley. This guide outlines basic safety measures to be observed during flood events. Additional information could be provided on the susceptibility and hazards for area within the floodplain. This type of information is available given the historic data that is available from past floods and the various flood scenario maps that have been produced as part of this study. Since simulated flood extent maps and flood event videos prepared for this report can be displayed interactively on-line using Google Earth there is a great opportunity to use these as an educational resource as well as for planning purposes.

8.4.2 FLOOD WARNING

General region-wide warnings of extreme weather conditions are periodically issued by MOE. It is not practical to forecast peak discharges on small basins such as the Cowichan and Koksilah River given the lack of real-time precipitation data, complex topography, localized orographic effects and unknown antecedent conditions in the watershed. Furthermore, the time of concentration in these basins is quite short; in December 2007 the Koksilah River increased from 10 m^3/s to 350 m^3/s in less than 5 hours. Therefore, there is very little time available to produce forecasts in advance and communicate these to the community at large.

Real-time water level and discharge are published on the internet from Water Survey of Canada's hydrometric stations on the Cowichan River near Duncan and at Cowichan Lake, but not for the Koksilah River gauge at Cowichan Station. It would be useful to upgrade this station to assist with emergency response planning.

However, based on the characteristics of the basins and limited hydro-meteorological information that is available, it is unlikely that there will be significant improvements to flood warning systems for the foreseeable future. Instead, efforts should focus more on public awareness and emergency response.

8.4.3 EMERGENCY RESPONSE PLANNING

The BC Flood Plan summarizes the provincial emergency response structure and response to floods (BC Provincial Emergency Program 2007). During large-scale emergencies, the emergency management structure is activated when a BC community or any significant infrastructure is threatened by an emergency or disaster which may overwhelm a local authority's ability to respond

The province provides general information on flood proofing to minimize damages to homes including sandbagging, disconnecting power and evacuation preparation.

First Nations Emergency Services (FNESS) supports a range of emergency services, including flood-related activities to First Nations members. The Joint Emergency Preparedness Program (JEPP) enables the federal government (INAC) to contribute to or undertake jointly with the province to ensure a relatively uniform level of emergency preparedness and response across the country. JEPP cost-sharing assistance is available to provincial ministry projects, local governments and First Nations, but not to individuals. The following projects are eligible for JEPP funding:

- Emergency plans and exercises
- Training and education
- Telecommunication systems
- Specialized vehicles and equipment
- Emergency operation centres

The updated flood hazard maps and flood scenario maps should assist authorities in planning emergency response. Highway 1 and the Railroad will both be cut-off during a major flood. Contingency plans should be made for the response to a breach of the JUB sewage treatment lagoons. Evacuation plans should be prepared for some of the relatively isolated settlements on the floodplain such as Koksilah Village and portions of the Koksilah floodplain below the highway.

8.5 IMPLEMENTATION OF THE PLAN

8.5.1 INSTITUTIONAL ARRANGEMENTS

The integrated flood plan includes a portfolio of structural and non-structural measures that need to be carried out over a period of several years or more. This section describes various approaches that could be used for implementing the plan. Four different approaches are highlighted in Table 8.14.

Many components could be implemented under the existing structures and organizations that are in-place. The main issues would be overcoming the jurisdictional limitations, coordinating the work and obtaining funding for some programs. If this approach is adopted then the Cowichan Stewardship Round Table could provide a forum for expanding discussions about floodplain management. Individual regional districts could still carry out some of the high priority structural flood control measures and could make progress in the field of public awareness and education about flood issues. It is expected that progress in resolving some of the ongoing flood issues and problems will be slow if this approach is followed.

Table 8.14: Summary of Possible Institutional Arrangements

Organization	Strengths	Weakness
Existing Approach	1. Stewardship Round Table and Living Rivers Advisory Group have successful track record. 2. Flood management by-laws and community plans in-place.	1. Jurisdictional boundaries limit effectiveness. 2. Limited resources and support from senior governments. 3. No overall authority to oversee whether past projects would cause adverse impacts.
Diking Authority	1. Can raise funds for maintenance and upgrading. 2. Can focus on critical infrastructure.	1. Narrow focus. 2. Difficult to integrate with habitat enhancement. 3. Jurisdictional boundaries limit scope.
Cowichan-Koksilah Basin Council	1. Could be a natural extension of the Stewardship Round Table. 2. Relies on existing government organizations for implementation. 3. Can cross jurisdictional boundaries. 4. Can integrate private stakeholders and First Nations.	1. Unable to implement plans and programs it agrees upon - must hand off to others. 2. May be subject to budget uncertainty - not self financing.
Cowichan-Koksilah Basin Board	1. Programs could be supported through property tax assessments as per Okanagan Basin Board. 2. Collaborative governance between stakeholders, local governments. 3. Could incorporate Round Table as advisory group.	1. Requires legislative changes in order to have taxation authority. 2. Requires regional districts to sponsor its formation.

The regional districts and Duncan could also create a region-wide Diking Authority to provide a coordinated program of dike upgrading and maintenance. The authority would be able to raise funds by taxation to carry out maintenance and to construct new works. However, the focus of a Diking Authority is relatively narrow in scope, making it difficult to work in an integrated fashion in terms of habitat enhancement and basin-scale planning. Therefore, we have not considered this type of authority further.

The Water Management Plan recommended establishing a Cowichan Basin Water Advisory Council as a first step to local water governance in the region. This Council could be modelled on the successful Fraser Basin Council and could focus on bringing together multiple sectors and interests in an effort to promote sustainable development in the basin, including integrated flood management. A major focus would involve education and public awareness of water-related issues, coordinating programs and as an advocate for integrated water management in the region.

The Council would be established as a not-for-profit non-governmental organization and would be funded by federal, provincial and local governments and other sources. A Board of Directors would also be established, including representatives from public and private organizations, First Nations, local governments, private sector and other government agencies. Professional staff and resources would be required to carry out its role. The Council would rely on existing organizations for implementing major projects. It would not fund projects or implement policy or programs. The Stewardship Round Table could be incorporated into the organization to provide guidance and direction.

A fourth option would be to establish a Cowichan-Koksilah Basin Board, modelled on the successful Okanagan Basin Water Board. The Board would be established under Provincial legislation with taxation powers to support its actions. The objectives, structure and taxation authority would need to be defined. A group of Directors would be established and agreement would be reached for decision making. For example, in the Okanagan Basin Board, approval by all three regional districts is required for any changes to procedures, for any capital expenditures and for annual budget approval. The programs carried out by the Board would be supported through property tax assessments on all parcels within the watershed, and initiatives would be focused on activities that produce valley-wide benefits.

It would be useful to first gain experience by establishing a Cowichan-Koksilah Basin Council with a relatively limited role of promoting and guiding sustainability and integrated water management (the Fraser Basin Council Model). Eventually, this could evolve into a Cowichan-Koksilah Basin Board with greater powers to raise money and implement projects. The two organizations are certainly compatible. For example, the Okanagan Basin Council provides technical advice and expertise to the Okanagan Water Board.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

Integrated Flood Management (IFM) is a relatively new concept, emerging out of broader water management policies that promote the development and management of water, land and related resources without compromising the sustainability of vital ecosystems. The defining characteristic of IFM is integration, expressed simultaneously in different forms: an appropriate mix of strategies, location of interventions, types of interventions (structural or non-structural), and a participatory and transparent approach to decision making - particularly in terms of institutional integration.

Improving integrated flood management in the region will be a challenge. Fortunately, there is a strong base of community stakeholder involvement through the Cowichan Round Table and a Water Management Plan has already been prepared.

Given the general philosophy expressed in the CBWMP and discussions with stakeholders at the Cowichan Stewardship Round Table, this study has focused on establishing more flood-resistant communities by reducing vulnerability and reducing exposure. Essentially, the plan promotes a comprehensive approach to flood management in line with the generalized characteristics of IFM. In particular, the plan promotes a more naturalized approach to flood management, lessening the reliance of the community on structural measures to reduce their flood hazard.

This present study has provided technical information and a range of new management tools (GIS-based flood, erosion and habitat maps) that can be used as a road map for implementing Integrated Flood Management in the Cowichan-Koksilah basin. However, it will take various stakeholders, local organizations and participating agencies to build and implement a long-term sustainable program.

9.1.1 PROJECT TOOLS

Over the course of the project, two major technical tools were developed to help in the planning process. A two-dimensional hydraulic model was developed to assess the magnitude and extent of flood hazards in the study area. In addition, a comprehensive GIS database that includes habitat sensitivity and flood hazard mapping was developed.

Map 1 shows flood hazard areas established from the hydraulic models and erosion hazard assessments. Two hazard zones have been defined, where areas in the “floodway” are expected to experience deeper and faster flows, and therefore more hazardous conditions, during a flood event. By comparison the “flood fringe” represents the portion of the floodplain that may be subject to inundation and ponding but only contributes marginally to conveying the flood.

The habitat sensitivity pilot project completed as part of this study is intended to be an iterative product that will be reviewed and updated with collection of new data or integration with other mapping products. The intent of the pilot mapping tool is to provide a starting point as a tool for land and resource management that illustrates known fisheries and wildlife habitat values and conceptual habitat restoration opportunities.

9.1.2 PROJECT RESULTS

Extensive background studies were made using the models and mapping to assess the magnitude and extent of the flood hazards in the study area. Results of the analysis showed none of the existing dikes have adequate freeboard for a 200-year flood over their entire length. Key conclusions from the hydraulic analyses are as follows:

- None of the existing dikes have adequate freeboard for a 200-year flood over their entire length. Portions of the City of Duncan are vulnerable to flooding due to overtopping or breaching of the JUB lagoon dike, as well as from backwater flooding from Somenos Creek in the Lakes Road area. Critical infrastructure such as the JUB sewage lagoons and outfall are vulnerable to damage from flooding and bank erosion.
- Under 200-year flood conditions, large spills occur along both banks of the Koksilah River, resulting in overtopping of the Trans-Canada Highway. Deep and fast flow conditions occur on the floodplain, which could pose high erosion hazards to buildings or other structures on the floodplain.
- Flooding and bank erosion can be aggravated by log jams and sediment deposition, so that the most severe potential flood damages may not necessarily arise from the most severe hydro-meteorological events. The log debris and sediment originate in the headwaters of the watersheds, upstream of the Flood Management Planning Area.
- Flood levels and flood spills over the entire floodplain area are vulnerable to alterations in dike crest levels. Furthermore, raising roads on the floodplain can have a similar effect as raising dikes. Raising or extending a dike or road at one location may raise flood levels farther upstream. It appears many local dikes were constructed without assessing their effect on adjacent areas. Further raising or extension of dikes should not be permitted unless it can be demonstrated there will be no net water level rise at other locations.
- The Cowichan River has been artificially straightened, re-located and confined by riprap dikes, producing a canal-like appearance over much of its length. This produces high velocities and scour through narrow sections, together with localized gravel deposition and channel instability in wider sections. This type of channelized river generally requires regular maintenance and repair. Also, it adversely impacts fisheries habitat by reducing complexity.
- Currently simulated 200-year flood levels on portions of the Cowichan River, portions of Koksilah River upstream of the Trans-Canada Highway, and all of Somenos Creek and Somenos Lake are generally higher than those predicted in earlier studies. Most of the bridges in the study area appear to have inadequate

clearance under open water conditions, and are therefore susceptible to trapping logs and floating debris and potential structural failure.

Major conclusions arising from the habitat and fisheries resources studies and mapping project include:

- There are several unique, sensitive and critical habitat types within the Cowichan Flood Management Area including intact riparian ecosystems, off-channel floodplain habitat, marsh land, and estuarine habitat.
- The Cowichan River is recognized as one of the most important and productive fish bearing rivers on Vancouver Island based on the abundance and variety of salmonid species.
- Resource development, flood management activities and landuse within the Cowichan Flood Management Area have altered natural flood characteristics as well as natural ecological features and function of the floodplain.
- Habitat restoration activities have been ongoing in the lower Cowichan floodplain area for several decades.
- There are many opportunities further for restoration/compensation in valley, and many of these projects dovetail well with projects proposed to mitigate flood hazard.

In addition to the more technical conclusions described above, a summary of findings relating to flood management policy in the Cowichan Valley include:

- Existing legislation has not stemmed development on the floodplain to date. New approaches to flood management are required in order to mitigate flood vulnerability in the Cowichan Valley.
- Reliance on structural flood control measures alone will be costly and may not be practical if only limited funding for upgrading and ongoing maintenance is available.
- There are several obstacles to changing the approach to flood management in the area including jurisdictional issues, planning under uncertainty, and short and long-term availability of resources
- The community has a strong history of collaborative decision making, which will undoubtedly help the stakeholders implement this plan.

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9.2 RECOMMENDATIONS

The results of this study are intended to assist the communities with developing strategies and plans to address flood hazards over the next decade. The measures include both structural flood control and non-structural flood mitigation initiatives in addition to providing resources for future planning. The aim is to help provide a "road map" leading to more flood-resistant communities and a more natural, ecologically productive and sustainable river system. This approach requires that floodwaters and floodways be seen as a resource and opportunity rather than simply a management issue, and that habitat enhancement is carried out as part of the flood protection work, rather than simply trying to mitigate environmental impacts from new flood infrastructure. Ultimately, the stakeholders, local governments and Cowichan Tribes will need to frame their own goals and objectives in order to implement the final plan.

Ten strategies were developed to frame the proposed integrated flood management plan:

- **Strategy 1: Return the rivers to a more naturalized state.** The Cowichan River has been artificially straightened and confined by riprap and dikes. This type of channelized river generally requires a high degree of maintenance and repair. It also adversely impacts fisheries habitat by reducing habitat complexity. Therefore, restoring the river to a more "naturalized" channel configuration that has room to convey water within a broad floodway should be a part of a long-term strategy
- **Strategy 2: Sustain the natural state of existing floodplain**. Remaining undeveloped floodplain areas should be sustained in a natural state. And, initiatives should be compatible or be integrated with programs that protect and enhance aquatic and riparian habitat
- **Strategy 3: Site future development in areas with low flood hazard and low habitat sensitivity**. Future development should be sited in areas with low flood risk and low habitat sensitivity
- **Strategy 4: Ensure new or upgraded flood protection structures do not adversely increase the overall flood hazard.** Based on past experience along the river, a "no-net adverse impact" flood level policy for future developments on the floodplain, including future diking and flood protection works, is needed. Constructing new dikes or extending existing ones should not increase the risk of flood damage in other vulnerable areas
- **Strategy 5:** Decrease vulnerability of existing development areas: Where key infrastructure and residential areas currently lie on the floodway and cannot easily be moved, decrease the vulnerability of these people and structures. This can be achieved through floodproofing of existing structures, and through improvements to public education, flood warning and flood response systems.

- **Strategy 6: Mitigate impacts of high flows on mainstem.** Impacts of high flows on mainstem should be mitigated by facilitating flow through suitable off-channel habitat
- **Strategy 7: Maintain channel conveyance**. Consider and maintain sites of debris jams and debris/gravel accumulation. An “adaptive” maintenance approach that incorporates habitat enhancement as part of channel maintenance is needed
- **Strategy 8: Create accessible and sustainable tools for flood management**. New tools developed for the project need to be designed so they can be used interactively and dynamically for emergency management, improved landuse planning, public awareness and education
- **Strategy 9: Promote basin-wide planning initiatives.** Basin-wide planning is important, particularly since most of the flood water, sediment and debris originates upstream of jurisdictional boundaries in the basin headwaters.
- **Strategy 10: Monitor and maintain flood management program.** Monitoring and maintenance are essential components of a flood management program. This should not just apply to dikes or bank protection works, but the channel as a whole.

9.2.1 KEY RECOMMENDATIONS TO REDUCE FLOOD HAZARD

The existing flood protection around critical infrastructure and higher density populated areas in Duncan should be upgraded as soon as possible. In particular, the existing dikes around the JUB sewage lagoon should be raised and provided with erosion protection and tied in to the Cowichan (Duncan) Dike. A design review of the lagoons should be carried out as part of this work.

The Koksilah Village Dike is vulnerable to overtopping and erosion and local residences are exposed to a higher flood risk than most other locations on the floodplain. Given the deep and fast flow conditions after a dike breach, floodproofing the residences are not a practical option. Discussions should be held with residents on options for dike strengthening and raising versus re-settlement.

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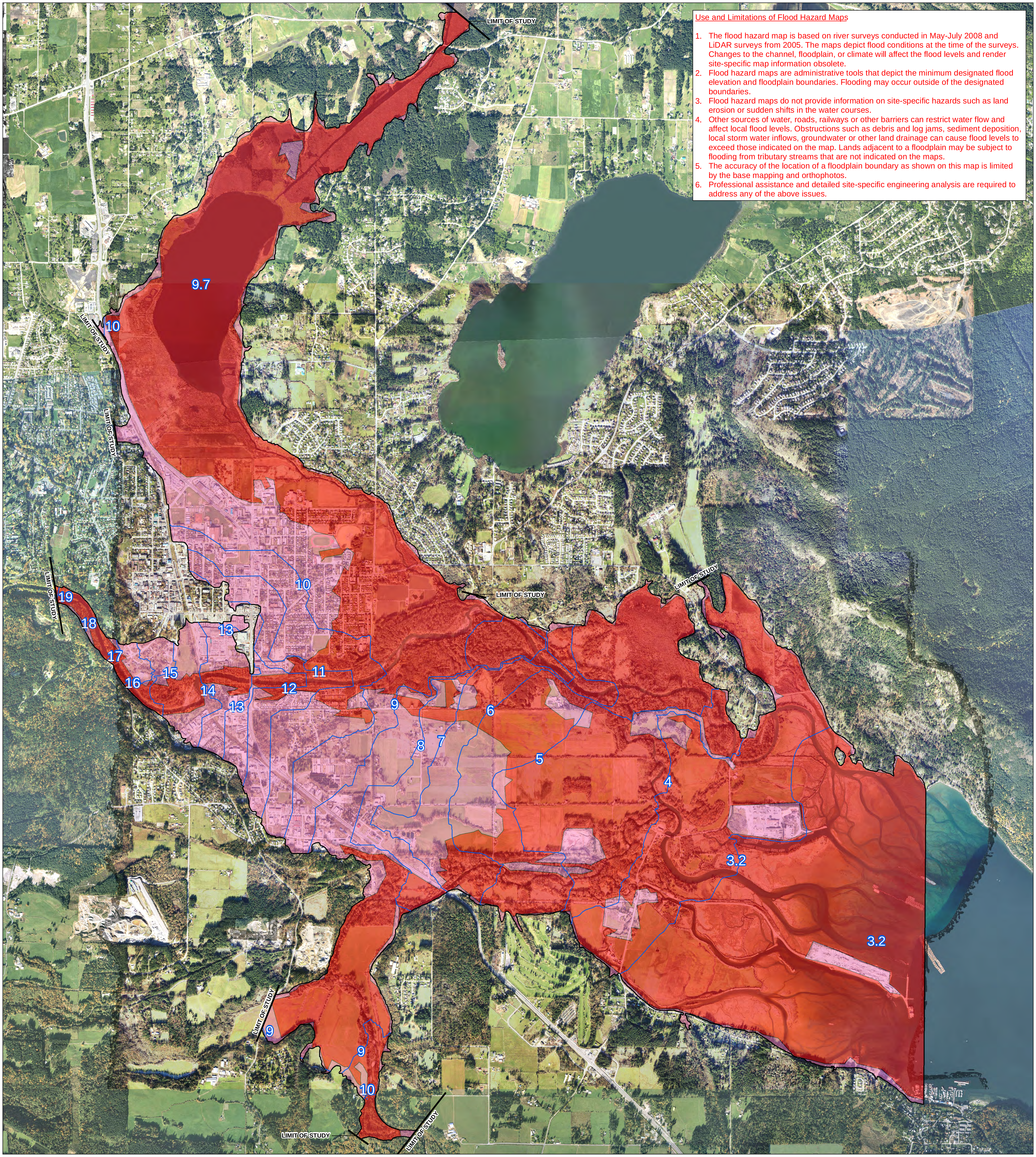
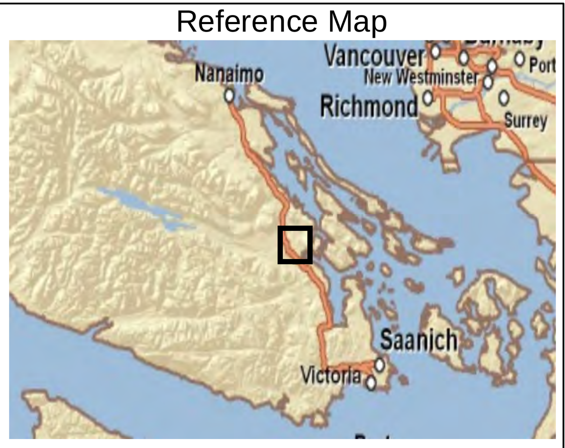


Reference Map



Legend

- Limit of Study
- Flood Construction Levels (elevations in metres GSC)
- Outline
- Floodway Zone (Deep and Fast Flowing Water)
- Flood Fringe Zone

Notes:

- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan
- Ground Survey by: nhc 2008

Notes to Users:

1. The Designated Flood has a statistical return period of 200-years.
2. Flood levels were computed using the hydraulic model MIKE Flood, as described in the report "Lower Cowichan/Koksilah River Integrated Flood Management and Mapping Plan, Volume 2 - Technical Investigations", April 2009 by Northwest Hydraulic Consultants.
3. The flood fringe limits assume the absence of all dikes.
4. The flood construction level (FCL) was computed as the 200-year flood level + 0.6 m freeboard.
5. The floodplain limits are not established on the ground by legal survey.
6. The floodplain limits are not delineated for side streams, local drainage or storm water runoff.
7. The floodway boundary is based on US Department of the Interior, "Downstream Hazard Classification Guidelines", Bureau of Reclamation (1988) and is intended to delineate a zone of "Deep and Fast" flow conditions. Areas outside of this zone may also be subject to high hazards.
8. Flooding may occur outside of the designated floodplain areas. NHC do not assume any liability by reason of the designation or failure to designate areas on the map.
9. Numerical modelling simulations: maximum values from 200-year scenarios 101, 201, 301, 401, 601, and 701 in the report "Lower Cowichan/Koksilah River Integrated Flood Management and Mapping Plan, Volume 2 -Technical Investigations", April 2009 by Northwest Hydraulic Consultants.
10. Recommended setback distance on the Cowichan Mainstem is 50 metres from top of bank and 40 metres for the Koksilah River.
11. The study does not include Quamichan Lake.

Designed by: VFOC and DGM
Reviewed by: MM
Prepared by: JXD

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Flood Hazard Map

Scale - 1:12,000

0 0.25 0.5 1 Kilometers

N E S W

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

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Map 1

HISTORIC PHOTOGRAPHS

1960 FLOOD EVENT IN THE COWICHAN VALLEY

Photos supplied to CVRD by Tom Patterson, BC Historian

Koksilah River flooding near Highway 1. Photograph taken from the old Trestle crossing, looking southeast towards the Koksilah River.

Flooding from Koksilah River on Cowichan Tribes land.

Flooding on Cowichan Tribes land.

Log jam forming at upstream end of bridge.

Flood waters on Cowichan Bay Road near t he Lawn Tennis Club.

Log jam starting to form at upstream side of bridge.

APPENDIX A

ECOLOGY AND HABITAT INVESTIGATIONS

A.1 HABITAT AND FISHERIES RESOURCES

A.1.1 HABITAT TYPES

There are several unique, sensitive and critical habitat types within the Cowichan Flood Management Planning Area including intact riparian ecosystems, off-channel floodplain habitat, marsh land, and estuarine habitat. The following section includes a detailed summary of ecological values within these habitat types based on existing references as well as field observations. This appendix supplements information found in Section 2.5 of the main report.

A.1.1.1 INTACT RIPARIAN ECOSYSTEMS

Riparian areas are distinct and provide critical habitat components for wildlife. Intact riparian habitat provides important features that support biological diversity, structure and function on a floodplain (Photo A.1). They also provide important migration corridors as well as important nesting and foraging habitat for wildlife species (black tailed deer, black bears, furbearers), and numerous species of waterfowl, shorebirds, songbirds and raptors. For example, mature cottonwood trees within riparian habitat along the Cowichan River provide critical roosting habitat for bald eagles during the fall season as well as important nesting habitat during the late winter and spring.

Photo A.1: Aerial view of the Cowichan River mainstem illustrating mid channel bars at km 4.3 and 4.5 where gravel and debris accumulate and intact riparian habitat extends over both left and right banks with Quamichan Road in the foreground (May 08).

Legend

- Dikes
- Stream Network
- Waterbodies

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 2004 Orthophotos from CVRD
- 2006/2007 MNC Quadrand Orthophotos from North Cowichan

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Key Features Associated with Fisheries and Wildlife

Scale - 1:35,000

1 0.5 0 1 Kilometers

N E S W

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 3-4878	September 2009

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Figure A.1

Disturbance within the lower Cowichan and Koksilah riparian corridor downstream of the Trans-Canada Highway has resulted primarily from the construction of dikes for flood control, from agricultural development, and historical development by the CN railway and WestCan (Figure A.1).

A.1.1.2 OFF-CHANNEL HABITAT

Off-channel habitat consists of a matrix of side-channels, backwatered channels, off-channel ponds and sloughs which provide high quality fish habitat. Off-channel fish habitat typically provides a high quality refuge area during peak flows as well as stable overwintering habitat when the mainstem is subject to high flow periods. During summer low flows, off-channel fish habitat offers refuge to juveniles that migrate into the well-vegetated and groundwater fed habitat (Photo A.2 to Photo A.5).

A total of 159 side-channels have been catalogued throughout the Cowichan River watershed and have been categorized according to 4 types: active, relic, flood, and back channels (Burns 2002, Burns et. al. 1988). Active channels have high fisheries value as they support fish year round with sufficient year round flows that provide good quality spawning and rearing habitat. Relic channel represent historical locations of the mainstem and are typically isolated from the mainstem but often have high restoration potential (Burns et. al. 1988). Flood channels and back channels are watered at higher flow but may not remain wetted year-round. For example, Major Jimmy's Channel, Hatchery Channel and Fish gut Alley are all active channel that currently support significant numbers of chum, coho and trout spawners.

Photo A.2. Upstream view of Major Jimmy's side-channel where year round flows support high quality spawning and rearing habitat (June 08).

Photo A.3: Downstream view of the Hatchery side-channel illustrating high value summer rearing habitat, intact riparian canopy with a bankfull width of 10 m and channel gradient of approx 0.5% (June 08).

Photo A.4: Lateral view of one of the Five Fingers rearing ponds illustrating stable, high quality year round rearing habitat, with enhanced LWD cover as well as wildlife habitat enhancement including bird and bat nesting boxes (June 08).

Photo A.5: Overbank flooding at right bank near km 5.1 and flooding into Fish gut alley at discharge of 33 m³/s. (February 17 09).

The importance of off-channel habitat in the Cowichan River was verified through a juvenile downstream trapping program at the five fingers channel. This program was undertaken during the spring of 2009 by the Living Rivers Advisory Goup in partnership with the Cowichan Tribes. A total of over 6,000 coho, 800 chinook, 100 cutthroat trout, and 175 rainbow trout smolts as well as approximately 2,500 coho fry and 49,000 fry were captured and counted (Rutherford, Tom, Living Rivers Advisory Group. 2008. Personnel communication).

Another study was conducted in 1987 to examine standing crop and habitat characteristics of juvenile salmonids. Side-channel and slough habitat were found to have the smallest fry and the highest densities of coho fry during the late summer, fall and early winter season relative to mainstem habitat (Fielden and Holtby 1987). As well, a greater proportion of coho fry were found to reside in the side-channel habitat during the winter compared to the summer (Fielden and Holtby 1987). The most evident shift in coho fry distribution from late summer to early winter was the migration of fry from the Cowichan mainstem into the Somenos system and the lower reaches of Priest's Marsh (Fielden and Holtby 1987). Therefore marginal summer rearing habitat in Somenos Creek has the potential to provide important winter rearing habitat if suitable conditions are available by late fall when fry outmigrate from the mainstem.

In the lower Cowichan Valley, limiting factors for fish production in off-channel habitat include the availability of summer and early fall flows, and fish access. Wood debris was found to be the most important type of cover in off-channel habitat for both trout and coho (Fielden and Holtby 1987). Spawning potential in off-channel habitat is also limited by the presence of suitable substrates.

Off-channel habitat within the Koksilah River is less abundant relative to the Cowichan River. The majority of these channels are seasonally wetted and provide good quality winter rearing habitat. Salmonid production within side-channel habitat is currently limited by low summer and early fall flows, fish access, adequate cover, and suitable spawning substrates. Wood debris is the most important cover type in off-channel habitat for both trout and coho (Fielden and Holtby 1987).

A.1.1.3 ESTUARINE HABITAT

The complex ecology of the estuary provides the foundation for a critical food supply and unique, year round habitat for fish, shellfish, mammals and bird species. The estuary also provides valuable migration and year round rearing habitat for salmonids and trout species (Law 2008, MELP 1994).

The Cowichan River estuary is one of the largest estuaries in BC encompassing approximately 4.9 km^2 with 277 hectares of intertidal area (Figure A.1; CETF 1980, Williams and Langer 2002).

The estuary provides year-round habitat for fish, shellfish, mammals, and at least 229 bird species (Law 2008) and valuable migration and year round rearing habitat for 4 salmon and 3 trout species (Law 2008, MELP 1994). It also provides a nursery area for many species of fish (including salmonids, sole, herring, sand lance, *Cottidae* species) and invertebrates during their early life stages. The majority of naturally spawned and reared chinook fry outmigrate during March and April (as age 0+ fry), with highest levels of utilization in the estuary occurring from April to June (Nagtegaal et al. 2004, Healey 1991). After they outmigrate, the chinook fry can rear along the shores of Cowichan Bay for up to another 5 months (Sparrow 1968, Argue et al 1986).

The Cowichan estuary is a regionally important migratory bird staging area within Georgia Strait as well as an overwintering site for waterfowl that nest in Alaska and northern B.C. (MELP 1994). An estimated 16,000 waterfowl overwinter or utilize the estuary and lower floodplain habitat during migration (Lill et. al. 1975). On a year-round basis, the estuary supports at least 12 waterfowl species (including loons, grebes, ducks, gulls, cormorants) as well as numerous shorebirds, herons and raptors. The estuarine habitat at Khenipsen Road also provides significant wildlife habitat for migrating waterfowl as well as an abundance of sites for breeding and nesting birds (Figure A.1; Jones, 2005).

The wetland located on both sides of Khenipsen Road and that extends north along Page Road has been altered by road development that has bisected the estuarine wetland (Jones 2005). The flapper valve at Khenipsen Road has limited both tidal influences and anadromous fish access to the north portion of the wetland (Jones, 2005). According to the CVRD atlas, this system supports both anadromous and resident salmonids species.

A.1.1.4 MARSH AND WETLAND HABITAT

A healthy marsh can support abundant life including grasses, birds, fish, and invertebrates.

Somenos Lake is surrounded by a marsh ecosystem that encompasses approximately 200 hectares (Figure A.1). In 2000, the Somenos wetlands were internationally recognized as an Important Bird Area (IBA) and provide the second largest overwintering habitat for Trumpeter Swans on Vancouver Island (up to 1,000 birds) (IBA 2004). The Somenos lake and wetland system also provides high quality, nesting and foraging habitat from fall through spring for waterfowl, songbirds, and raptors. The nationally vulnerable *fannini* subspecies of the Great Blue Heron utilize the Somenos IBA for breeding and overwintering (IBA 2004).

The estimated 62 ha Priest’s Marsh supports abundant bird habitat and is known to provide year-round off-channel rearing for salmonids within the eastern portion where an estimated 5.1 ha of backwater channels occur (Burns, 2002).

Based on reconnaissance level field sampling completed in 2008, soil and vegetation characteristics within Priest’s Marsh are consistent with wetland ecosystems. Most of this community falls within the CWHxm1-09 (Black cottonwood, Red-osier dogwood), which is a floodplain site series

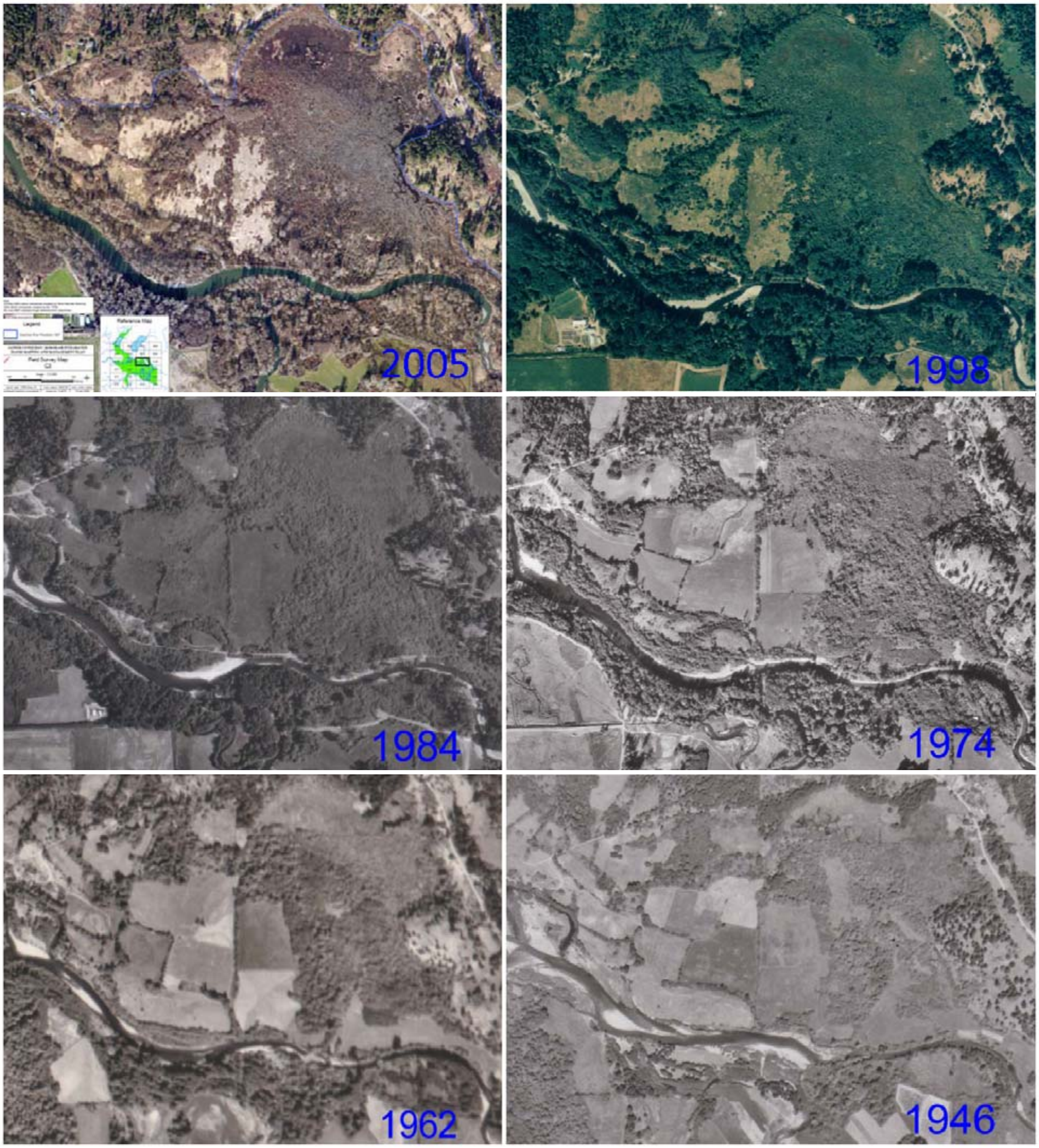
In the early 1900’s, farm settlement in the Priest’s marsh area resulted in changes in land cover and drainage within the wetland (Figure A.2). Priest’s Marsh was historically dominated by facultative hydrophytes in the vegetation community and received seasonal inundation from mainstem flooding. The most significant changes to the wetland ecosystem occurred between the 1940's and 1980’s during agricultural development, which included wetland drainage alterations, clearing, and the construction of Quamichan Dike. Cessation of agricultural activity in Priest’s Marsh occurred in the late 1980's.

A.1.2 FISHERIES RESOURCES

The Cowichan River is recognized as one of the most important and productive fish bearing rivers on Vancouver Island based on the abundance and variety of salmonid species.

Anadromous fish species present in the study area include a fall run of chinook salmon (*Onchorhynchus tshawytscha*), coho salmon (*O. kisutch*) and chum salmon (*O. keta*). There is a strong run of winter run steelhead (*O. mykiss*) and limited presence of sea run cutthroat trout (*O. clarki*) (Burns 2002). A small run of summer run chinook is present and both sockeye (*O. nerka*) and pink salmon (*O. gorbuscha*) are typically rare. However, during the fall of 2007, a small run of pinks were observed in the lower Cowichan River.

Indigenous resident fish species include rainbow trout (*O. mykiss*), cutthroat trout (*O. clarki*) and Dolly Varden char (*Salvelinus malma*). Brown trout (*Salmo trutta*) were introduced during the 1930’s and have successfully colonized the system, but with limited presence in the lower reaches of the flood study area (LGL 2005). Landlocked



LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Historic Changes
Priest's Marsh

Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 1946 air photo from BC Integrated Land Management Bureau.

northwest hydraulic consultants	project no. 3-4878	September 2009

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Figure A.2

sockeye (kokanee) are resident to Cowichan Lake (Burt and Wightman 1997). Introduced species within the study area include the pumpkinseed fish (*Lepomis gibbosus*), three spine stickleback (*Gasterosteus aculeatus*), prickly sculpin (*Cottus asper*) and various lamprey species (*Lampetra spp.*) (Hanelt 2002).

Fish habitat values are high or very high throughout the entire lower Cowichan/Koksilah flood management area due to the extensive system of accessible, low gradient channels that are interconnected with sloughs and backwatered ponds. The abundance of high quality mainstem and side-channel spawning habitat is primarily utilized by chum salmon, coho salmon and trout species with a small number of the chinook spawners in the mainstem Cowichan during some years as well.

There are 4 fish hatchery facilities located in the lower Koksilah/Cowichan Rivers and include the Vancouver Island Hatchery operated by the Freshwater Fisheries Society of B.C. adjacent to the EcoCenter, a Fisheries and Oceans Canada hatchery operated by the Cowichan First Nation and two private hatcheries raising Atlantic salmon (Figure A.1).

The limiting factors to fish production in the Cowichan and Koksilah Rivers are associated with water quality and water quantity caused primarily by high water temperatures during the summer low flows and suspended sediment loads.

A.1.2.1 COWICHAN RIVER

The lower reaches of the mainstem Cowichan River provide high value spawning habitat, a critical migration corridor for chinook, chum, steelhead, coho and trout as well as high value year round rearing habitat for coho and trout (Photo A.6). Numerous side-channels, tributaries and sloughs create favourable conditions for high quality year round rearing habitat that supports juvenile salmonids (Lill et al. 1975).

Photo A.6. Lateral view of the mainstem Cowichan River at km 5.1 illustrating high quality spawning habitat that continues to support chum and coho spawners. The mature and intact riparian habitat is dominated by Black Cottonwood and provides high quality wildlife habitat. This site is also a proposed gravel removal site as part of the flood maintenance program. Approximately 1800 m^3 of gravel was removed in June 2007 as part of emergency works to the JUB outfall (Nov 2008).

Chinook

Annual escapement estimates for fall run chinook are complex with details available in LGL (2005). A remnant spring run chinook stock continues to return to the Cowichan River during the winter and spring months. The spring run chinook run arrives in the river in March and April with a peak observed in June or July (Burns 2002). Historically, this early run may have been more abundant than the fall run stock. The fall run chinook migrate into the Cowichan River with the first significant increase in river discharge during October and typically peaks during mid-October to early November (Lill et. al. 1975).

In 1991, FOC initiated an enumeration and outmigration timing study of naturally reared juvenile chinook salmon in the Cowichan River. Most chinook fry in the Cowichan were known to be of the “ocean type” that typically migrates to sea within 3 months of emergence. Study results indicated that most (85%) chinook fry belong to an early group that outmigrates in March/April and a late group (15%) that migrates during May and June (Lister el al. 1971). Hatchery migrants were found to move downstream more quickly than naturally spawned chinook fry, moving in a large pulse and captured in the estuary within one week after release (Nagtegaal and Carter 2000, Candy et al. 1996). Therefore there is minimal interaction between natural and hatchery rearing chinook juveniles in the Cowichan River (Nagtegaal and Carter 2000).

Chum

Chum escapement to the Cowichan River exhibits a high degree of variability, ranging from 15,000 in 1960 and 1971 to 250,000 in 1951 annually (LGL 2005). It is important to note that the Cowichan River escapement estimates have been completed in an inconsistent manner, with incomplete time series and uncertain precision. Therefore, escapement estimates should be considered an index of abundance rather than an absolute value (LGL 2005).

Coho

Annual escapement estimates for coho are complex with details also available in LGL (2005). Coho migrate into the river from late October to mid-November during periods of increased discharge (Lister et al 1981). The entire mainstem length is accessible by anadromous species but passage through Marie Canyon chutes at km 32.5 and cascades at km 35 are difficult during periods of low flows. In 1955, a vertical slot fishway was constructed to facilitate upstream passage through the Skutz Falls area at Km 36 (LGL 2005, Burns 2002). A study undertaken by Fielden and Holtby (1987) in the fall/early winter of 1986 confirmed the highest densities of coho fry were found in side-channel habitat.

Trout

Resident spawners in the Cowichan River have been estimated at approximately 400 brown trout and over 500 rainbow trout (Burt and Wightman 1997). The Cowichan River also supports a strong winter run and a significant spring run of steelhead that utilize the lower river primarily as a migration corridor as the majority of steelhead production occurs upstream (Burns 2002).

Resident cutthroat and rainbow trout were once abundant in the Cowichan River system but are now very sparse due to heavy fishing pressure during the early decades of this century (Burns 2002). Anadromous cutthroat are present within the flood study area with limited distribution upstream of the white bridge. The majority of production occurs in tributaries to Somenos Lake as well as the lower river side-channel including Rotary Park and Fish Gut Alley as well as Major Jimmy’s and Hatchery Channel. The most likely limiting factor to cutthroat production in small tributaries and side-channel habitat is competition by coho juveniles.

One of the primary limiting factors to fish production in the Cowichan River and Koksilah River is associated with **water quality** as summer water temperatures are known to exceed target and lethal levels for salmonids. In some years, Cowichan mainstem water temperatures rise to 20 - 24C for several weeks between early July and late September (Burns 2002). During these periods, salmonid fry vacate large stretches of mainstem rearing habitat to seek cool water refugia where high water temperatures are moderated by groundwater seepage and cooler upwelling flows (Burns 2002). Increased suspended sediment loads in the Cowichan River originating from the eroding Block 51 area and the Stoltz slide also affect water quality in the lower river. Efforts to reduce erosion and sedimentation have been ongoing with Phase 1 major stabilization works initiated at the Stoltz slide in 2000/2001. Salmonid production in the Cowichan River is dependant on ocean survival rates that likely have equal effect on overall survival as freshwater habitat conditions particularly for coho and chinook (Burns 2002).

The Cowichan River is a regulated system and one of the primary limiting factors to fish production is **water quantity**. One of the main concerns is the provision of adequate maintenance flows during the summer low flow period for migration, spawning, incubation and rearing (LGL 2005). At the current time, maintenance rearing flows of 7.08 m^3/s (250 cfs) are in place until September 15m after which they are increased to 9.91 m^3/s (350 cfs) *IF* lake levels are sufficient to assist migration of spawning chum (Burt and Wightman 1997, LGL 2005). Experimental pulse flows were released in 1988 and 1990 and were found to be successful in facilitating upstream migration of chinook as well as reducing the length of time to reach the spawning grounds (KPA 1991). A study by KPA Engineering in 1991 suggests that a 0.57 m increase in weir height would ensure sufficient storage to support both rearing and spawning maintenance flows (LGL 2005). There is an abundance of high quality spawning habitat primarily for chum and coho salmon but production is also limited by flow conditions during the fall and winter and subsequent winter survival rates (Burns 2002).

A.1.2.2 SOMENOS CREEK

The Somenos watershed supports productive runs of coho salmon, cutthroat trout and brown trout. The lower sub-basin including Somenos Creek and Somenos Lake is primarily utilized by salmonids as a migration corridor and seasonal (winter) rearing habitat due to marginal water quality conditions from mid-summer through fall.

Historically, Somenos Creek provided important coho rearing habitat during the fall and early winter when juveniles migrated from the mainstem into Somenos Creek in search of stable overwintering habitat. However a more recent study in 2005 found that coho juveniles would likely avoid overwintering in Somenos Creek as suitable oxygen levels are not observed until late fall/early winter when water temperatures decline (Guimond and Sheng 2005). Anadromous and resident salmonids utilize tributary systems upstream of Somenos Lake for spawning and rearing, including Richardson Creek to the north, and Bings and Averill Creek to the west.

Primary limiting factors for fish production in the Somenos watershed include summer water quality and quantity as well as fish access (Burns 2002). Fish access to Quamichan, Richards, Bings and Averill Creeks is limited by barrier falls in the lower reaches as well low summer flows in the late summer and early fall period (Burns 2002).

Located immediately to the east of Somenos Creek is Quamichan Creek, where the lowermost 125 m are located within the Flood Management Planning Area (Figure A.1). Quamichan Creek is 1.4 km long with anadromous barrier falls (2.3 m high) located 370 m from the mouth as well as a 2 m high dam 725 m from the mouth. The lower creek provides year round habitat for coho, anadromous cutthroat and chum as despite low summer flows, salmonids survive in isolated pools that are groundwater fed (Burns 2002). Anadromous production is limited by low summer flows and accessible stream length (Burns 2002). Quamichan Lake also supports rainbow trout as well as a unique population of resident cutthroat trout known for their large size and ability to survive in marginal rearing conditions.

A.1.2.3 KOKSILAH RIVER

The Koksilah River is the largest tributary to the Cowichan River and encompasses approximately 325 km^2 over a mainstem length of 44 km (Burns 2002, Tutty 1984). The Koksilah River primarily produces coho and chum salmon but also supports smaller runs of chinook, steelhead, anadromous and resident cutthroat trout, resident rainbow trout and dolly varden char (Lill et. al. 1975, Tutty 1984). The lower Koksilah River mainstem downstream of Marble falls provides spawning habitat for coho, chum and steelhead with chum spawning in the lowermost reaches of the Koksilah River and tributary channels (Tutty 1984, Lill et al 1975).

The lower Koksilah provides a critical migration corridor for anadromous salmonids with high value mainstem summer rearing habitat. Stream flows are significantly colder during the summer relative to the Cowichan R mainstem and therefore provides opportunities for high quality rearing habitat. Instream cover is limited but the lower reaches provide suitable spawning habitat for chum salmon.

Anadromous distribution is limited by a partial obstruction at Marble falls located 13.4 km upstream from the mouth (upstream of the Flood Management PlanningArea) (Burns 2002, LGL 2005). In 1990, a vertical slot fishway was constructed through the Federal/Provincial partnership salmonid enhancement program but has not been very successful in facilitating upstream migration of anadromous species (Burns 2002). In some years, steelhead migrate past the falls with distribution upstream to Koksilah Falls located at km 26.

Existing impacts on salmonid production in the lower river includes the alteration of natural stream flow patterns from upstream forestry and agricultural development as well as land clearing and drainage improvements from agricultural activity in the lower reaches. Forestry development is prevalent in the upper watershed with no headwater lakes large enough to buffer mainstem flows so the tributary is more susceptible to flash flooding, sedimentation issues and low summer flows (Lill et al. 1975; Tutty 1984).

Fish production in the lower river is also likely limited by low summer flows, unstable winter flows, increased peak flows and lack of high water refuge habitat. Critically low flows occur in the mainstem during the summer and early fall months (Tutty 1984). Substrates within the study area are dominated by fines due to the dominance of Cowichan Soil Type within the lower 9 km that contribute large amounts of fine grained marine sediment to the channel (Burns 2002).

A.1.3 ENVIRONMENTAL IMPACTS OF PAST LAND USE ACTIVITIES

Resource development, flood management activities, and land use within the Cowichan Flood Management Planning Area have altered natural flood characteristics as well as natural ecological features and function of the floodplain. Historical impacts of resource use on ecological values include the loss or damage of sensitive estuarine habitat due to diking for agriculture and flood protection dating back to the 1860's, decreased water quality from sewage treatment facilities, marinas and agricultural runoff, infilling for industrial/commercial purposes, damage due to log storage/booming activities since the 1880's (Law 2008).

Historical impacts of resource use on ecological values within the Flood Management Planning Area include:

- **Channelization and loss of flood capacity**: Construction of standard engineered dikes (south side and north side dikes) as well as non-standard or orphan dikes (Quamichan, Hatchery dike) has resulted in channelization and a reduction of flood capacity of the Cowichan mainstem (Figure A.1). Habitat complexity, connectivity and riparian function have been altered with the loss of floodplain connectivity affecting available stream flows and fish access to off-channel habitat. Within the lower Cowichan and Koksilah Rivers, there is an abundance of both isolated and connected off-channel and remnant channel habitat.
- **Loss of natural flood and flow regimes**: The Cowichan Lake dam and flow control has altered the natural flood regime in the lower river. As well, forest harvesting in the upper and middle reaches of the Cowichan and Koksilah River watershed have increased peak and flood flows and at the same time, reduced available summer flows in both systems during the low flow period. Within the lower Koksilah River area, agriculture (~20% of landbase within the 50 m contour), and urban/light industrial development (Koksilah Industrial Park and commercial strip along the Trans Canada Highway) (Burns 2002) are the primary causes of landuse change and alteration in storm runoff.
- **Loss or alteration of sensitive estuarine habitat**: Since 1962, European settlers have constructed dikes for agricultural purposes and flood protection (Williams and Langer 2002). Diking and development of cultivated fields has altered natural flow patterns over the floodplain and tidal habitat. As early as the 1880's, there has been infilling for industrial

and commercial development, log storage and booming activities (Law 2008). Long term log storage activities result in anoxic conditions and compacted sediments within the estuarine substrates that reduces the abundance and diversity of aquatic plants (i.e. eelgrass) and benthos, thereby decreasing the overall productivity of the estuary. The majority of log handling and storage activities occurred in the north estuary and may therefore have affected the colonization of high value eelgrass beds. A subtidal habitat study identified accumulations of organic debris where the presence of a sulphur reducing bacteria Beggiatoa was observed, indicating the presence of oxygen poor sediments (Clarke 2005). Estuarine habitat has also been infilled for land reclamation as well as dredged to sustain access to port facilities.

- **Loss of functional riparian habitat**: Historically, there has been a loss of functional riparian habitat within the Flood Management Planning Area. Starting in the 1920's, the CN railway line was constructed along the Koksilah River as well as the Westcan Terminal roadway constructed in later years to connect inland logging to the estuary (Law 2008). More recently, agricultural and rural residential development has altered natural riparian and shoreline habitat features by removal of the native riparian canopy for construction of roadways, flood protection dikes and other erosion control features. Loss of natural riparian habitat features reduces shade, food supply, recruitment of LWD to the stream channel. Furthermore, nesting, foraging and roosting habitat for shorebirds, songbirds and raptor is lost and important migration and foraging habitat for deer, black bear and other furbearers is reduced. Over time, impacts to riparian habitat have recovered with a few permanent alterations within the Flood Management Planning Area.
- **Decreased water quality**: Water quality within the mainstem Cowichan River and estuary has decreased as a result of high summer water temperatures, non point sources of pollution, runoff from agricultural areas, increased sediment loads from upstream sources and potential impacts from sewage treatment facilities. Approximately 10% of the Somenos basin area has been developed for high density urban use and 20% for intensive agricultural purposes (Figure A.1; Burns 2002). Extensive urban and rural development, including agricultural activity within the lowlands surrounding Somenos Lake and Somenos Creek contributes nutrient rich runoff. This runoff when combined with warm summer temperatures and low flows results in anoxic conditions that further reduces the rearing capacity of Somenos Creek and lower tributaries to Somenos Lake (NHC 2005, Guimond and Sheng 2005).
- **Loss of channel stability, increased bank erosion**: Channel stability along the mainstem Koksilah and Cowichan Rivers has decreased due to increased peak flows from historical logging and agricultural development upstream of the Flood Management Planning Area. In some cases, shoreline flood protection dikes have channelized stream sections and increased bank erosion downstream (LGL 2005).

A.1.4 CONSERVATION AREAS

Several ecological parks and conservation areas have been established within the Cowichan Flood Management Area to sustain valuable and sensitive ecological features (Figure A.1). To date, these include:

- **Cowichan Bay Farm:** In 1990, the Nature Trust and partners in the Pacific Estuary Conservation Program acquired the 51 ha farm. The goal of this managed farm is to improve wildlife habitat while providing the opportunity to farm to the local agricultural community. The seasonally flooded cultivated fields provide prime foraging opportunities for waterfowl during the critical migratory and wintering periods.
- **Maple Grove Park**: In 2002, the park was designated as a CVRD park in a management partnership between Nature Trust of BC, MWLAP, CVRD and the CB Improvement Project. Located on the Nature Trust Cowichan Bay Farm property, Maple Grove Park includes Koksilah Grove, a 2 ha park of old growth native Big Leaf Maple Trees (*Acer macrophyllum*).
- **Blackley Farm:** As an agricultural improvement, a dike was constructed around the farm in 1978
- **Somenos Marsh Wildlife Refuge:** In 2000, an IBA was established over an area of 2 km^2 including Somenos Lake, the lower reaches of 4 creeks as well as a wildlife refuge and heronry on the west side of the Trans Canada Highway (IBA 2004). Managed by the Somenos Marsh Wildlife Society (since 1989), Nature Trust BC, and Ducks Unlimited (since 1994) the Somenos Lake, wetlands, marsh, and cultivated fields collectively provide high quality habitat for wildlife, birds and fish. As well, Somenos Marsh provides regionally significant foraging and staging habitat for waterfowl including overwintering habitat for Trumpeter swans as well as one of the major Canada Goose nesting areas on Vancouver Island (Lill et. al. 1975).
- **Somenos Garry Oak Protected Area:** Established to protect one of the most endangered ecosystems in Canada, the protected area is 10.5 hectares in size and located on the edge of Somenos Lake and Marsh, southwest of the lake outlet (Figure A.1, Williams et. al. 2003). Prior to the 1850's, Garry Oak ecosystems covered tens of thousands of acres in the Cowichan Valley. Restoration of Garry oak ecosystems in ongoing through partnership efforts between the Nature Conservancy of Canada, BC Parks and the Garry Oak Ecosystems Recovery Team.

A.1.5 KNOWN SPECIES AT RISK

According to the existing SARA and COSEWIC database maintained by Environment Canada and Williams et. al. (2003), a minimum of 26 endangered species have been confirmed or are likely resident to the Cowichan Flood Management Planning Area. Detailed information on known species at risk is included in Table A.1. The status of wildlife species is continually being assessed with species at risk designated within 5 categories that include; special concern, threatened, endangered, extirpated and extinct.

Table A.1: Species identified by SARA and/or COSEWIC as regionally significant, endangered, threatened or of special concern (GOC 2009, Williams et. al. 2003).

Common Species Name	Latin Name	Status under SARA, BC List or COSEWIC
Western Toad *	*Bufo boreas*	Special Concern
Red legged frogs	*Rana aurora*	Special Concern
Great blue heron (fannini subspecies) *	*Ardea herodias*	Special Concern
Barn Owl *	*Tyto alba*	Special Concern
Peregrine falcon anatum subspp	*Falco peregrinus anatum*	Threatened
Western screech owl kennicottii subspecies	*Otus kennicottii kennicottii*	Special Concern
Northern Goshawk laingi subspecies	*Accipiter gentiles laingi*	Threatened
Marbled Murrelet	*Brachyramphus marmoatus*	Threatened
Sharp-tailed snake	*Contia tenuis*	Endangered
Dun skipper (BF)	*Euphyes vestries*	Threatened
Monarch (BF)	*Danaus plexippus*	Special Concern
Common Ringlet insulana subspecies (BF)*	*Coenonympha California insulana*	Endangered
Propertius Duskywing (BF)*	*Erynnis properties*	Threatened
Common Wood-Nymph (BF)*	*Cercyonis pegala incana*	Special concern
Western Pondhawk (DF)*	*Erythemis collocata*	Threatened
Blue Dasher (DF)	*Pachidiplax longipennis*	Threatened
Yellow-legged Meadowhawk (DF)*	*Sympetrum vicinum*	Threatened
Dense spike primrose	*Epilobium densiflorum*	Endangered
Howell's triteleia	*Triteleia howellii*	Endangered
Purple sanicle	*Sanicula bipinnatifida*	Threatened
Yellow montane violet*	*Viola praemosa var. praemorsa*	Endangered
Tall woolley-heads*	*Psilocarphus elatior*	Endangered
Needle leaved navarretia*	*Navarretia intertexta*	Endangered (BC)
Red-rooted cyperus*	*Cyperus erythrorhizos*	Endangered (BC)
Water Pepper*	*Polygonum hydropeperoides*	Threatened (BC)
Vancouver Island beggarticks*	*Bidens amplissima*	Special concern

* = Confirmed presence in the Somenos Basin

BF = butterflies

DF = dragonflies

A.1.5.1 Birds

Both the mature and older forested habitats within the Flood Management PlanningArea have the potential to support marbled murrelets, northern goshawks, screech and barn owls, and peregrine falcons.

Marbled murrelets nest up to 75 km inland, with some birds remaining at breeding sites year-round. Their southern range extents over mid and southern Vancouver Island. They require old growth forests as they typically nest on large limbs covered with deep moss that serve as a platform for their eggs (GOC 2009).

The northern goshawk is distributed throughout Vancouver Island and nests primarily in western hemlock and douglas fir trees in mature or old growth forests with high canopy closure and small canopy openings (GOC 2009).

Screech owls are found throughout Vancouver Island in varied habitats including low elevation semi-open woodlands frequently close to water. They nest in natural cavities of large trees or nest boxes without nesting material (GOC 2009). Barn owls inhabit low elevation, open fields and pasture where small rodents are abundant and nest in tree or cliff cavities as well as abandoned or unused buildings. They reside in BC year round and their survival is dependant on food supply and availability of suitable habitat for nesting.

Both Somenos Marsh and Priest’s Marsh support a high diversity of avian species. Somenos Marsh is recognized for providing internationally significant bird habitat and was designated as an Important Bird Area (IBA) in 2000. A total of 219 birds species are listed in the Cowichan Valley Bird Checklist in Simeon (1974).

A.1.5.2 Amphibians

Within the Flood Management Planning Area, the two amphibians designated as species at risk include the red legged frog and the western toad.

Red legged frogs inhabit low elevation stream, pond and marsh habitat as well a moist forest conditions isolated from open water. Eggs are laid on emergent vegetation during the spring, are slow to develop with tadpoles metamorphizing by August (GOC 2009).

Western toads have been observed within the lower Cowichan mainstem and off-channel areas. Western toads spend 90% of their time in terrestrial habitat, typically in forested habitat, wet shrub ecosystems and meadows. The adults congregate to breed in the spring and females lay 5,000 to 15,000 eggs but breed once every few years (GOC 2009).

Survival of these amphibian species is dependant on, habitat degradation from urban and agricultural development, predation by the American bull frogs as well as disease/predation by introduced trout species. The presence of American bullfrogs has been confirmed through observations during field reconnaissance during this study.

A.1.5.3 REPTILES

The rare Sharp Tailed Snake is reddish brown to gray, is 20 to 45 cm in length and lives along forest edges within the Coastal Douglas fir zones along south facing rocky slopes. There are only seven known sites in the province with their distribution fragmented and therefore more widespread historically (GOC 2009). The Garry Oak Woodland ecosystem located adjacent to the Flood Management Planning Area is a unique ecosystem that is likely associated with the Sharp Tailed snake (GOC 2009).

A.1.5.4 PLANTS

The Garry Oak Woodland ecosystem is a unique ecosystem found within the coastal Douglas fir zone and located in upland habitat adjacent to the Cowichan floodplain. Within the Flood Management Planning Area, this ecosystem is located north of Somenos Creek and the Cowichan mainstem (Figure A.1). Howells' Triteleia, Purple sanicle, and the Dense Spike-primrose are associated with the Garry Oak Ecosystem multi-species association (GOC 2009) as well as six other red or blue listed plants.

Howell's Triteleia is a perennial herb belonging to the lily family with only 12 known sites in Canada and located on Vancouver Island (http://www.geog.ubc.ca/biodiversity/eflora/plantgroups.html, GOC 2009). Suitable habitat for Howell's Triteleia within the Flood Management PlanningArea includes the lower 3 km of mainstem, the estuary and the Somenos lake/wetland area.

Purple sanicle is a perennial herb that grows on southeast Vancouver Island and Gulf Islands, with only 18 populations confirmed in Canada (GOC 2009). The herb is distributed throughout the Flood Management Planning Area and typically grows in meadow opening, on eroding sandy banks, seashore cliffs and shrubby grassy knolls in very dry to moderately dry, nitrogen rich soils.

Dense Spike-primrose is an annual herb that grows in open meadows that are moist in spring but very dry for most of the summer with only four remaining Canadian populations (GOC 2009). Their habitat requirements are precise and therefore survival is sensitive to changes in hydrology.

There are an additional six known red and blue listed plants species documented around Somenos Garry Oak Ecosystem that include the yellow montane violet, tall woolly-heads, needle-leaved navarretia, red-rooted cyperus, water pepper and Vancouver Island beggarticks (Williams et. al. 2003). Additional details about rare and threatened habitat types in the Somenos sub-basin can be found in Williams et. al 2003.

All of these species are susceptible to increasing pressure to develop land in the Cowichan Valley for residential and commercial purposes as well as colonization of invasive species (i.e. Scotch broom).

A.1.5.5 INSECTS

The Dun Skipper is a rare species of butterfly and its presence within the Flood Management Planning Area has been verified by sightings of single individuals. It is a small, dark purple-brown butterfly with a wingspan of 23-27 mm and a faint pale purplish crescent on the underside of the hind wing (GOC 2009). The butterfly is found in open moist areas or dry sites that are wetted by spring floods or permanent springs where the larval food plant (*Carex spp* and *Cyperus esculentus*) is present (GOC 2009).

Monarch butterflies seasonally inhabit the lower Cowichan River and exist primarily where milkweed (Aschlepius) and wildflowers are abundant.

Three other species of concern have been confirmed in the Somenos basin and include the common ringlet, Propertius Duskywing and the common Woodnymph (Williams et. al. 2003).

Within the Somenos sub-basin, 3 blue listed species of dragonflies have been confirmed and include the Western pondhawk, blue dasher and the yellow-legged meadowhawk.

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APPENDIX B

GIS DATABASE – HABITAT MAPPING AND SENSITIVITY

B.1 OVERVIEW

The purpose of the habitat sensitivity mapping is to provide a tool for practitioners to use at the strategic planning level. For example, the habitat sensitivity mapping could be used to identify habitat that would benefit from future management as a conservation zone or be used to assign a classification that would minimize and/or discourage further resource and land development. Conversely, the GIS based habitat classification system could be used to plan and guide future development in areas with a low flood risk with an existing degree of previous disturbance. The GIS mapping and habitat attribute data can be used to assist practitioners in evaluating potential environmental impacts of flood management or flood maintenance activities by illustrating areas with high or low sensitivity to disturbance according to known ecological values.

The habitat sensitivity mapping component of the Integrated Flood Management Plan was intended to identify and highlight important fisheries and wildlife habitat features and then develop a three-tiered ranking system for freshwater, estuarine, foreshore and riparian ecosystems. This data was integrated into GIS to illustrate potential interactions between sensitive habitat features and the existing flood protection infrastructure as well as existing/proposed urban, industrial, agricultural and commercial development. This is an important tool in the development of a fully integrated flood management plan.

A pilot project has been undertaken to identify and highlight sensitive fisheries and wildlife habitat features, develop a habitat sensitivity indices and to illustrate this information through a GIS based Habitat Sensitivity Mapping program. The habitat pilot study area for the habitat mapping component includes a portion of the Cowichan mainstem starting south of the City of Duncan and continuing downstream along the North branch to roughly 1 km upstream of the Pimbury Bridge. The habitat pilot study area lies within the highest priority habitat mapping area where a high flood risk area geographically overlaps with areas having high ecological values.

B.2 HABITAT MAPPING CATEGORIES AND SENSITIVITY RATINGS

There are several unique, sensitive and critical habitat types within the Cowichan Flood Management Planning Area including intact riparian ecosystems, off-channel floodplain habitat, estuarine habitat and wetland/marsh habitat. A description of each habitat value is provided and is based on known ecological features as briefly outlined in Section 2.5 of the main report. For each habitat category (riparian, instream and shoreline), a three-tiered habitat value or sensitivity rating (Very High/High, Moderate and Low) system has been developed. The GIS mapping and habitat attribute data can be used to assist practitioners in evaluating potential environmental impacts of flood management or flood maintenance activities by illustrating areas with high or low sensitivity to disturbance according to known ecological values.

Along with the proposed habitat sensitivity ratings available for the habitat pilot study area are proposed management recommendations relevant to requirements for habitat protection, habitat inventory, habitat compensation and post-construction monitoring. These requirements should be considered prior to future flood protection or flood maintenance works as well as proposals for future urban development. The management recommendations for each classification in the habitat pilot study area have been derived and modified based on the Fraser River Estuary Management Plan (FREMP) shoreline habitat classification system that has been applied to the Fraser River and Courtenay River estuaries (ECL 2000).

The proposed habitat sensitivity ratings and management recommendations require review and discussion amongst key local practitioners and interested user groups involved with resource planning and resource management activities within the lower Cowichan River. The review process should include:

- Demonstration and/or review of the user friendly habitat pilot study area GIS mapping and database files
- Ensure known sensitive habitat features have been included and identify additional information needed
- Review, discuss, modify and agree upon sensitivity ratings
- Review and discuss acceptable management of the three sensitivity types within the shoreline, riparian, and instream categories
- Discuss integration of habitat restoration data
- Develop a plan to complete the remaining habitat mapping in the Flood Management Planning Area
- Develop an iterative process to revise and update the sensitivity ratings and mapping tool

B.2.1 METHODOLOGY

A review of existing habitat inventory references, including database files and digital habitat atlases, provided a starting point for known habitat inventory information for the habitat pilot study area. Principal documents included the provincial Sensitive Ecosystems Inventory (SEI) indices, fisheries sensitive zones identified in Burns 2002, CVRD Atlas, Cowichan Tribes Sensitive Habitat Atlas, and the Cowichan River Riparian Mapping Project (Roberts 2005). Supplemental habitat inventory information was collected through interviews and field reconnaissance done during the summer of 2008 through to the spring of 2009.

The field data for the habitat mapping was collected to a level of detail that would allow the identification of ecological features from which a relative habitat value can be determined. For example, riparian field data was collected to identify community types rather than a comprehensive inventory that enumerates species composition and % abundance. Therefore, the level of detail of field data was not intended to fulfill the requirements of a comprehensive habitat inventory.

B.2.2 HABITAT FEATURES

Sensitive fish and wildlife habitat features were identified according to documented and anecdotal information as well as observations during field reconnaissance trips. The data was collected/organized and summarized into data matrices and mapped using a GIS system.

The three primary categories used to illustrate habitat features include: **Riparian** Features, **Instream** Features, and **Shoreline** Features. For all three habitat categories, the majority of features included in the attribute database files were photographed in 2008/09 to document existing conditions at the time of the study.

B.2.2.1 RIPARIAN HABITAT

Within the Flood Management Planning Area, riparian polygons boundaries were derived from existing information. From these baseline polygons, adjustments to the polygon boundaries were made as necessary to reflect changes in riparian habitat types over time, natural changes to the mainstem channel configuration as well as variations between the two data sources. Additional attribute data relevant to vegetation type, community type, age class and dominant canopy and understory species are recorded based on aerial interpretation and field reconnaissance. The % fragmentation is estimated for each riparian polygon. Table B. 1 lists the attribute data associated with riparian habitat features.

The habitat inventory data collected for **riparian** polygons was derived from a combination of the Sensitive Ecosystem Inventory (SEI) framework (http://www.env.gov.bc.ca/sei/index.html) and the Fraser River Estuary, Riparian and Intertidal Habitat Classification system (Williams & Adams 2006). The FREMP classification system is more detailed and classifies overall fish and wildlife habitat value of the shoreline area and is based on the collection of comprehensive ecological data, collected over several years. Due to the scope and availability of resources for the Cowichan IFM project, the level of detail acquired for the FREMP classification was not possible. The habitat categories used for the mapping were expanded to include floodplain riparian habitat. Descriptions of the SEI sub-classes and the FREMP classification system are found in Section B.5 of this Appendix.

Table B. 1: Riparian Habitat Attribute Data

Site ID	R – Riparian # - river km RB or LB		
Photo Pt	PhotoID#		
Riparian Subclass	RI: 6:5		
Vegetation Type	Trees and shrubs > 6m or Swamp	Grasses, shrubs and herbs	Marsh
Community Type	Deciduous Forest (>6 m) Coniferous Forest (>6 m) Mixed Forest (>6 m) Tall Shrub Woodland (2-6m) Low Shrub Woodland (<2m)	Tall Shrub Woodland (2-6m) Low Shrub Woodland (<2m) Dry grass/herbs Wet grass/herbs	Reed Canary Mixed RC and other grasses Other grasses Sedges or rushes or cat tails
Age Class	0-30yrs, 30-90 yrs, 90 yrs +		
Dominant Species and Understory Composition	% and species		
Fish Habitat and Wildlife Features	Description of off-channel habitat features, restoration efforts, utilization for spawning and rearing, elevation		
% Fragmentation	Estimated %: <5%, 5-25%, >25%		
Disturbance Features	Anthropogenic and natural disturbance including inundation, flood debris, beaver activity, invasive species, dikes, trails, roads		
Other	Adjacent land use and jurisdiction, recommendations for restoration or further assessments		

The High, Moderate, and Low habitat sensitivity ratings are primarily based on the degree of fragmentation and the level of ecological complexity and diversity (Table B. 2). As well, the ratings are based on the presence of known critical wildlife and/or fish habitat features and/or unique ecological features. The presence of past fish habitat restoration projects or fish habitat compensation sites results in a High habitat sensitivity value. An “unknown” habitat value or sensitivity rating was assigned if further assessment is needed to determine the habitat value and site sensitivity.

Proposed management recommendations for future development are designed to sustain or increase existing fish and wildlife habitat values within the polygon. Development and/or disturbance within a polygon with a High sensitivity rating should be kept to a minimum and only if necessary as a safety measure for flood management or maintenance and if alternate siting has been investigated. Management recommendations include consideration of habitat inventory, habitat compensation, and post construction monitoring requirements as part of the planning, permitting, and construction phases. As a minimum, the “No Net Loss” policy is recommended throughout riparian habitat within the Flood Management Planning Area.

Table B. 2: Riparian Features - Habitat Sensitivity Ratings and Management Recommendations.

Habitat Sensitivity Value	Fill Color Code	Description	Management Recommendations
High	Dark Green	>90% of polygon is intact, with high ecological complexity and high structural and functional diversity, stable. Supports high value and/or critical wildlife and fish habitat, high priority for protection. May possess unique ecological features. Includes past restoration or compensation sites.	*Candidate areas for habitat conservation and protection.* Disturbance for resource development or urban development should generally not be permitted. Habitat compensation is not an option as a rule. If works are necessary for public health and safety, for flood management or maintenance works, and alternate siting is not an option, the works should include a comprehensive habitat inventory, the most conservative mitigative measure, No Net Loss approach, compensation requirements of $\geq$ 2:1 and a min 3+ year post construction monitoring plan.
Moderate	Light Green	5-25% fragmentation, moderate level of ecological complexity, integrity may be affected by development but overall riparian function has been retained. Supports moderate value fish and wildlife habitat. May contain segments of high ecological complexity.	*Prime candidates for habitat restoration.* Resource development discouraged to sustain the integrity of adjacent high value fish and wildlife habitat. Disturbance for flood maintenance or flood management should proceed with appropriate mitigation and compensation measures (1:1) and min 2 year monitoring plan. Could benefit from riparian restoration to increase habitat value
Low	Yellow	Modified biophysical environment with >25% fragmentation due to anthropogenic disturbance, partially functioning riparian habitat but with low productivity. Significant and permanent development that is limiting ecological structure, diversity and function of the riparian zone. Integrity of the polygon has been affected by urban or industrial encroachment and/or linear development. May contain segments of high ecological complexity.	*Good candidate areas to be considered for future development if located outside the floodway zone.* Development can proceed with appropriate mitigative measures and adoption of No Net Loss policy Good potential for habitat restoration to increase habitat value

B.2.2.2 Instream Habitat

The instream component of the habitat mapping identifies the type and location of known instream attributes primarily for mainstem habitat and also for side-channel habitat. Some of the features provide accessible year round habitat while other features may provide critical seasonal habitat including high water mainstem refuge habitat or stable off-channel rearing habitat that are utilized during flood flows.

For each instream habitat feature, a unique site identifier is assigned with habitat type and known fish habitat features described that include spawning habitat, rearing habitat, holding pools, backwatered pools, high flow channels, mid-channel bars and debris jams.

Additional descriptions of year round or seasonal habitat is provided for some of the habitat features. Biophysical data included in the attribute tables include gradient, substrate type, bankfull width and wetted width. Known natural and anthropogenic disturbance including bank erosion, gravel removal, bank stabilization, aggradation, and avulsions are also described. Adjacent land jurisdiction and recommendations for habitat improvements have been included where applicable.

Table B. 3: Instream Habitat Attribute Data

Site ID	I – Instream CR – Cowichan River SF– South Fork/Branch of the Cowichan River NF – North Fork/Branch of the Cowichan River K – Koksilah River # – river chainage (km)
Photo Pt and Tidal Position	Photo ID # FW (Freshwater) Est (Estuarine) Tidal Position (indicates if site is influenced by tides since sites that are inundated with nutrient rich sea water are typically more productive)
Habitat Type	Description or code i.e. HP = Holding Pool
Known Fish Habitat Features	Spawning habitat, rearing habitat, holding pools, backwater alcoves, LWD complexes, excessive debris accumulation, mid-channel bars/gravel accumulations, bankfull width, past restoration efforts
Biophysical Data	Substrate type, bankfull width, wetted width
Disturbance Features	Anthropogenic and natural disturbance features (i.e. gravel removal, bank erosion, aggradation, avulsions, excessive debris accumulations etc.)
Other Features	Land jurisdiction, recommendations and comments
Comments	Tidal and freshwater segments of the mainstem and off-channel areas

Each feature is assigned a habitat sensitivity value according to the instream attribute, utilization of the feature, fish access, and limitations to fish production (Table B. 4). Based on the sensitivity values, proposed management recommendations for future development have been outlined. The goal of the management recommendations is to sustain or increase existing aquatic habitat values within the instream features. Development and/or disturbance within a High or Very High sensitivity rated area should be kept to a minimum and only if necessary as a safely measure for flood management or maintenance and alternate siting has been investigated. Management recommendations include consideration of habitat inventory, habitat compensation and post construction monitoring requirements as part of the planning, permitting and construction phases. At minimum, the “No Net Loss” policy is required throughout known fish habitat within the Flood Management and Planning Area.

Table B. 4. Instream Features - Habitat Sensitivity Ratings and Management Recommendations.

Habitat Sensitivity Value	Color Code	Description	Management Recommendations
Very High	Red (spawning and rearing)	High utilization of high quality year round fish habitat. Includes all point data instream features. Deep holding pools, known spawning habitat, high quality year round rearing habitat that supports high densities of juvenile salmonids. Provides critical habitat features and may include deep pool habitat, functional LWD cover, boulder cover and overhanging vegetation. Support critical fish and wildlife functions on-site or as part of a more regional context. Includes habitat restoration that provide spawning habitat.	*Candidate areas for habitat conservation and protection.* Disturbance for resource development or urban development should generally not be permitted. If works are necessary for public health and safety, for flood management, or maintenance works, the works should require a comprehensive habitat inventory, the most conservative mitigative measures, a No Net Loss approach, compensation requirements of $\geq$ 2:1 and a min 3+ year post construction monitoring plan. Must demonstrate that the overall functional capacity of the site will not be affected. Habitat compensation is not an option as a rule
High	Amber (primarily rearing)	Seasonal off-channel rearing habitat. Includes all fish habitat improvement or restoration sites.	*Prime candidates for habitat restoration.* Moderate to good habitat complexity with opportunities, some sites may benefit from habitat restoration or habitat improvement to increase utilization and habitat quality. Resource development discouraged to sustain the integrity of adjacent high value fish and wildlife habitat. Disturbance for flood maintenance or flood management should proceed with appropriate mitigation and compensation measures (1:1) and min 2 year monitoring plan. Could benefit from instream restoration to increase habitat value
Moderate		Moderate quality fish habitat, may be lacking in adequate stream flows, habitat complexity, fish access may be limited or limited to certain flows. Includes altered sites including riprap bank protection works along north and south Cowichan River dikes. Stream restoration works would likely result in high utilization.	*Good candidate areas to be considered for future development if located outside the floodway zone.* Good potential for habitat restoration to increase habitat value. Limited current utilization by salmonids. Development can proceed with appropriate mitigative measures and adoption of a No Net Loss policy.

B.2.2.3 Shoreline Habitat

Shoreline attribute data includes assigning the site a unique site identifier, current photos to document existing conditions and a site description regarding the existing intact or disturbed condition and shoreline features (vegetation type, presence of functional LWD, etc.). Alterations to the shoreline, including the presence of flood protection dikes, are described along with biophysical characteristics of the bank (height, slope, and materials) and erosion where available. The quality of habitat is rated based on the absence or presence of natural shoreline features with recommendations for riparian habitat improvements.

Table B. 5: Shoreline Habitat Attribute Data

Site ID	S – Shoreline # – river chainage (km) RB or LB
Photo Pt	Photo ID #
Site Description	Intact or disturbed condition and shoreline features: vegetation, alcoves, LWD/SWD debris accumulations etc
Alterations	Modified features including shoreline flood dikes, bank protection structures, riprap, aggradation or natural shoreline habitat features.
Biophysical	Bank height, bank slope and bank materials
Habitat Features	Description of riparian and instream features, dominant vegetation types, habitat complexity, presence of shoreline rearing habitat
Erosion	Unknown, Minimal, Moderate, High, or Aggrading
Other	Jurisdiction, adjacent land use, general comments, data sources, observed overbank flooding.

Habitat sensitivity for shoreline habitat is based on the level of disturbance/alteration as well as the existing stability and condition of the shoreline habitat features (Table B. 6). A high sensitivity value is associated with an undisturbed (<5% disturbance or fragmentation), stable shoreline habitat adjacent to an intact riparian area. In contrast, a moderate or low habitat value indicates altered shoreline features due to the presence of riprap or the removal of adjacent riparian vegetation.

Proposed management recommendations include minimal disturbance to high value shoreline habitat unless necessary for public health or human safety. Within a moderate shoreline habitat area, if shoreline disturbance is aged and shoreline vegetation/features are recovering to natural conditions and the site is adjacent to high value fish and wildlife habitat, disturbance should be discourage to sustain the recovery of natural shoreline, instream and riparian features. Otherwise, disturbance within a Moderate value shoreline habitat can proceed with appropriate assessment, compensation, and monitoring requirements in place as developed by an environmental professional on a site specific basis.

Table B. 6. Shoreline Features - Habitat Sensitivity Ratings and Management Recommendations.

Habitat Sensitivity Value	Color Code	Description	Management Recommendations
High	Dark Green	Stable, natural shoreline with intact adjacent riparian habitat providing good overhead cover, having minimal disturbance (<5%) or fragmentation. High value instream features including holding pools, LWD cover, backwater pools, undercut banks etc. Includes habitat restoration or improvement works.	*Candidate areas for habitat conservation and protection.* Disturbance for resource development or urban development should generally not be permitted. If works are necessary for public health and safety, for flood management, or maintenance works, the works should require a comprehensive habitat inventory, the most conservative mitigative measures, a No Net Loss approach, compensation requirements of ≥ 2:1 and a min 3+ year post construction monitoring plan.
Moderate	Light Green	The length of the shoreline has been altered from its natural state, may include presence of shoreline flood protection dikes, or riprap. Riparian habitat may be moderately altered but continues to provide overhead cover. Shoreline features have been ***temporarily*** altered with minimal natural diversity including backwatered alcoves, deep holding pools, lateral gravel bars etc and is providing limited overhead and instream complexity.	*Prime candidates for habitat restoration.* Shoreline disturbance features are recovering to resemble natural features and the site is adjacent to high value instream or riparian habitat. Resource development should be discouraged to sustain the integrity of adjacent high value fish and wildlife habitat. Dike maintenance activities will require a maintenance plan that outlines specific works, mitigation and compensation measures as well as proposed monitoring for review and approval by environmental permitting agencies. Disturbance for flood maintenance or flood management should proceed with appropriate mitigation and compensation measures as agreed by permitting agencies with minimum 2 year post-construction monitoring plan. Could benefit from shoreline/instream restoration to increase habitat value
Low	Yellow	Shoreline features have been altered with little or no natural features remaining, shoreline flood protection dikes may be present. Adjacent riparian habitat has been fragmented or ***permanently*** altered (i.e. by roadway) thereby providing limited overhead cover. Altered or unstable shoreline habitat that may be adjacent to fragmented and modified riparian habitat. Low productivity associated with a modified biophysical environment.	***Good candidate areas to be considered for future development if located outside the floodway zone.*** Development can proceed with appropriate mitigative measures and adoption of a No Net Loss policy with the aim to increase the productive capacity of the site. May have good potential for riparian restoration to increase habitat value. Limited current utilization by salmonids. Would benefit from shoreline improvement/restoration works. Dike maintenance activities will require a maintenance plan that outlines specific works, mitigation and compensation measures as well as proposed monitoring for review and approval by environmental permitting agencies.

B.3 OVERVIEW OF GIS PROCEDURES FOR HABITAT MAPPING

The Flood Management Planning Area is broken down into 1:2500 scale grid panels (mapsheets) and layers are stored in a geodatabase. As the data is collected and developed by the consulting biologists, it is added to the database.

The **Habitat2008.mdb** geodatabase has the following components:

- a feature data set, **Habitat2008**, that contains most of the data layers:
  - Riparian Polygons
  - Placename Points
  - Photo Points
  - Instream Points
  - Channel Banks (for displaying mainstem and side-channel banks, and for mapping mainstem Shoreline Habitat Value)
  - Side-channel Centrelines (for mapping side-channel Instream Habitat Value)
  - Side-channel Centreline Routes and Route End Points (for showing chainage on selected side-channel centrelines)
  - Restoration Sites Points and/or Polygons
- an Event Table, **Mainstem_InstreamHabitat** domain for some of the field values in the attribute tables

The consulting biologists provide tabular data in an excel spreadsheet with point coordinates and accompanying data to the GIS specialist. Lines and polygons are marked-up on paper maps and/or PDF files. Common unique ID values are applied to the points, lines and polygons and enable joining of tabular data with the digitized features.

In certain cases where the data addresses the instream environment, the centerline can be symbolized using linear referencing. This allows the line feature to be symbolized in sections while maintaining a constant reference chainage value for the mainstem and selected side-channel centrelines.

Once the geodatabase is populated with all of the required data, a map set can be produced using the map book tool which divides the study area according to the 1:2500 scale map grid. The mapsheets can display typical layers for general reference or the user can produce thematic maps which bring in additional information such as flood hazard polygons or political areas. These mapsheets can be displayed at varying scales and extents of the study area. Using SQL and other sorting and selecting techniques, specific analysis can be performed on the data and specialized maps and tables can be produced. An example might be an overlay analysis of the flood hazard polygon with the riparian polygon to see where a flood might affect deciduous forest habitat. Additional functionality of the software enables images to be linked with photo points that are displayed in the map document. The database is an excellent way to keep many different types of data in one place and allows for ongoing updates and development.

B.4 HABITAT PILOT STUDY - HABITAT MAPPING AND SENSITIVITY

A habitat pilot project has been undertaken to identify and highlight sensitive fisheries and wildlife habitat features, develop a habitat sensitivity indices and to illustrate this information through a GIS based Habitat Sensitivity Mapping program. The habitat pilot study area for the habitat mapping component includes the Cowichan mainstem from km 6.3 (near Rotary Park) to km 3.0 at the North and South Cowichan confluence and continuing downstream along the North branch to km 1.1 upstream of the Pimbury Bridge. The habitat pilot study area lies within the highest priority habitat mapping area where a high flood risk area geographically overlaps with areas having high ecological values.

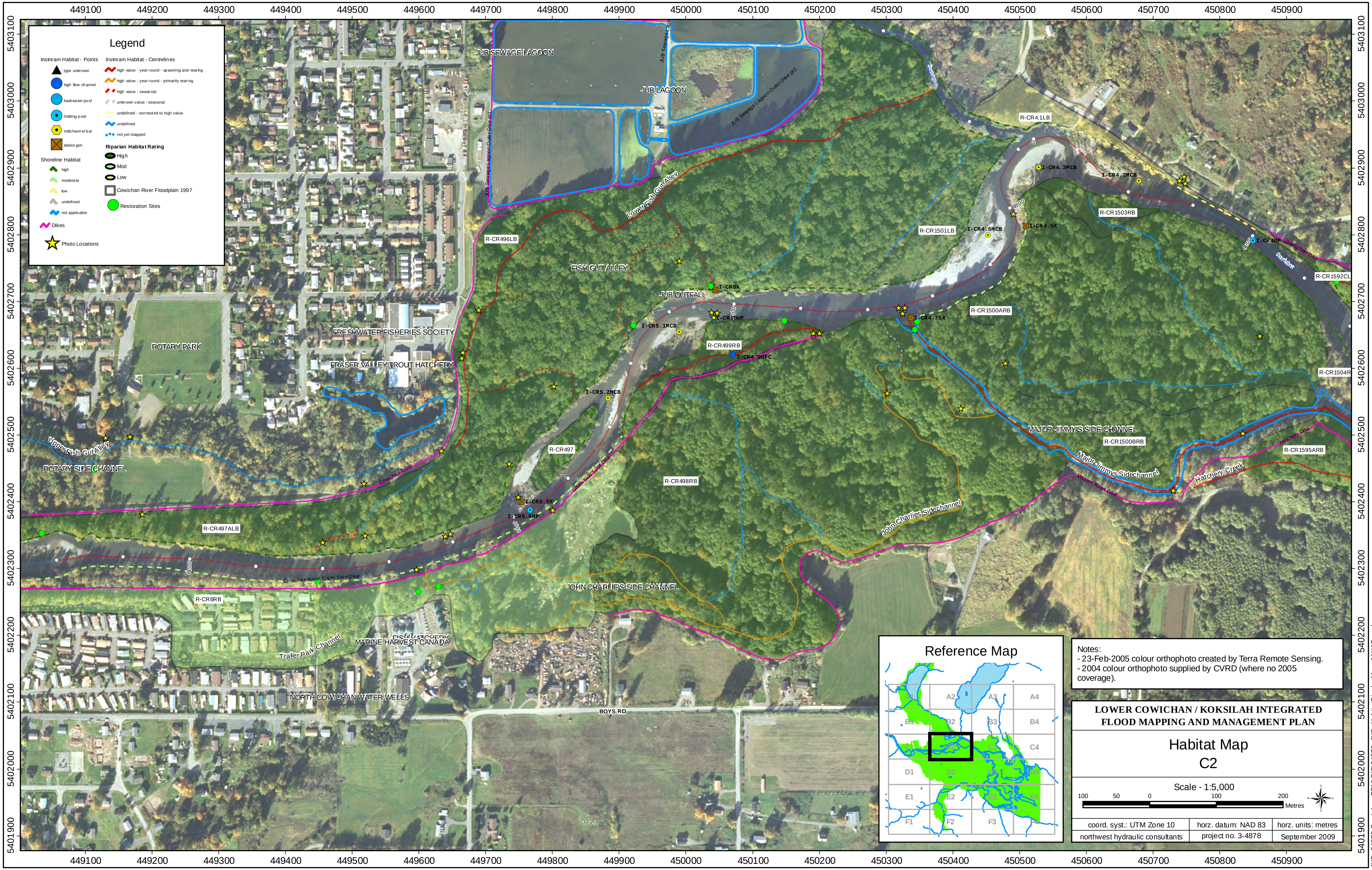
The habitat pilot project is intended to be an iterative product that will be reviewed and updated with collection of new data or integration with other mapping products. The intent of the habitat pilot mapping tool is to provide a starting point as a tool for land and resource management that illustrates known fisheries and wildlife habitat values and conceptual habitat restoration opportunities. Two mapsheets (Figure B.1 and Figure B.2) of the Habitat Mapping Planning Area were completed as part of the habitat pilot study which is described in the following section.

B.4.1 HIGH OR VERY HIGH HABITAT SENSITIVITY

Within the habitat pilot study area, there is an abundance of high or very high value instream and riparian habitat (Table B. 7). Approximately 86% of the instream habitat assessed was rated as having a high or very high value and 81% of the riparian habitat was rated as having a high value and high sensitivity to future development or disturbance (Figure B.1 and Figure B.2).

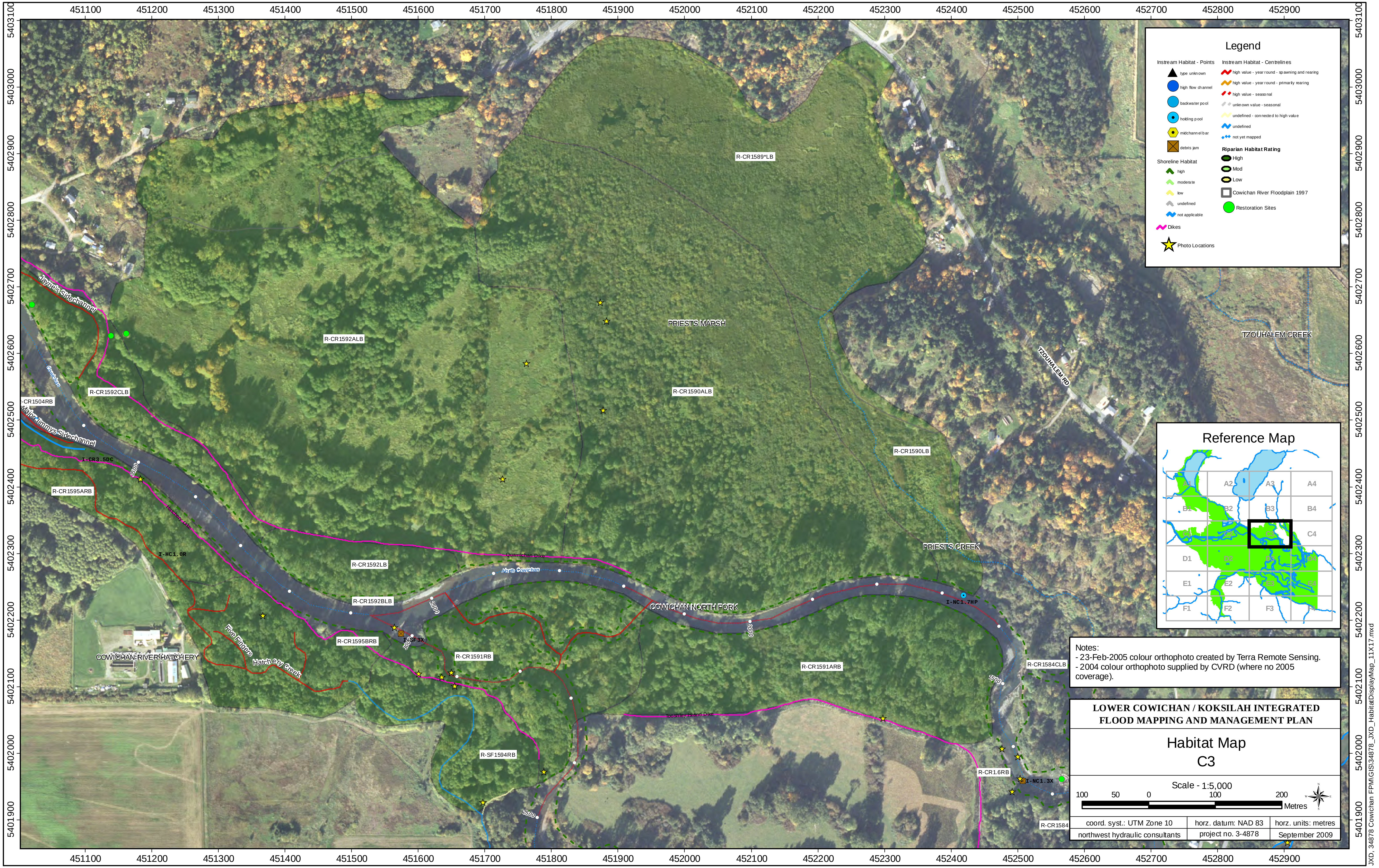
Table B. 7. Summary of Habitat Sensitivity Ratings for the Habitat Pilot Study Area.

Category	Total Assessed (km or ha)	Proposed Habitat Sensitivity Ratings				
		High or Very High (area/km)	Moderate (area/km)	Low (area/km)	UNK (area/km)	Comments
Instream *(mainstem and side-channels)*	9.1km	7.8 km / 86%	0	0	1.3 km / 14%	
Riparian	198 ha	178 ha / 90%	9 ha / 0.5%	1.0 ha / 0.5%	10 ha /5%	
Shoreline *(mainstem only)*	12.4 km	10.0 km / 81%	1.9 km / 15%	0.5 km / 4%	0	Shoreline dikes primarily located on Mapsheet C2



JXD, 34878 Cowichan FPM\GIS\34878_JXD_HabitatDisplayMap_11X17.mxd

Figure B.1



Legend
Instream Habitat - Points
type unknown
high flow channel
backwater pool
holding pool
midchannel bar
debris jam
Instream Habitat - Centrelines
high value - year round - spawning and rearing
high value - year round - primarily rearing
high value - seasonal
unknown value - seasonal
undefined - connected to high value
undefined
not yet mapped
Shoreline Habitat
high
moderate
low
undefined
not applicable
Riparian Habitat Rating
High
Mod
Low
Cowichan River Floodplain 1997
Restoration Sites
Dikes
Photo Locations
Reference Map
A2
A3
A4
B1
B2
B3
B4
C4
D1
E1
E2
F1
F2
F3
PRIESTS MARSH
TZOUHALEM CREEK
TZOUHALEM RD
PRIESTS CREEK
COWICHAN NORTH FORK
COWICHAN RIVER HATCHERY
Jaynes Sidechannel
Major Jimmys Sidechannel
Five Fingers
Hatchery Creek
Quamichan Dike
Hatchery Dike
Tzouhalem Island Dike
R-CR1589*LB
R-CR1592ALB
R-CR1592CLB
R-CR1590ALB
R-CR1590LB
R-CR1504RB
R-CR1595ARB
R-CR1592LB
R-CR1592BLB
R-CR1595BRB
R-CR1591RB
R-CR1591ARB
R-CR1584CLB
R-SF1594RB
R-CR1.6RB
R-CR1584
I-CR3.5DC
I-NC1.0R
I-NC1.7HP
I-NC1.3X
I-SF3X
Notes:
- 23-Feb-2005 colour orthophoto created by Terra Remote Sensing.
- 2004 colour orthophoto supplied by CVRD (where no 2005 coverage).
LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN
Habitat Map
C3
Scale - 1:5,000
100 50 0 100 200
Metres
coord. syst.: UTM Zone 10
horz. datum: NAD 83
horz. units: metres
northwest hydraulic consultants
project no. 3-4878
September 2009
451100 451200 451300 451400 451500 451600 451700 451800 451900 452000 452100 452200 452300 452400 452500 452600 452700 452800 452900
5403100 5403000 5402900 5402800 5402700 5402600 5402500 5402400 5402300 5402200 5402100 5402000 5401900
JXD, 34878 Cowichan FPM\GIS\34878_JXD_HabitatDisplayMap_11X17.mxd

Figure B.2

The predominance of high or very high instream habitat value is due to the extensive distribution of and utilization by salmonids in both seasonal and year round habitat. High or very high value zones should be considered as candidate areas for ***habitat protection where permanent development and/or disturbance is minimized***.

These areas include:

Cowichan Mainstem and side-channels:

- Provides extensive, good quality spawning opportunities for chum, coho and trout species as well as high quality year round rearing habitat in the mainstem.
- Good overhanging vegetation over much of this reach and abundant off-channel areas.
- Outer meander bends typically offer deep pool habitat, overall LWD cover is low to moderate.
- Very low gradient riffle pool morphology from the Trans Canada highway downstream to the Tzouhalem estuary with an average gradient of 0.18% (NHC 2008) with stream gradients observed in the field between 0-1%.
- Shoreline habitat through the habitat pilot study area is relatively stable with active bank erosion observed through channelized sections and outer meander bends (Photo B.1 and Photo B.2).
- Abundant sidechannel habitat with year round utilization in Fish Gut Alley, John Charlie's, Major Jimmy's, and Hatchery Channels, and Five Fingers that provides high quality rear round rearing habitat and spawning habitat for chum and coho.
- Off-channel areas are inundated by numerous high flow channels during mainstem discharges of 94 m^3/s (Photo B.3).
- High value forage habitat is provided on exposed mid-channel bars for birds including bald eagle, high densities of red crested mergansers, marine diving ducks, seagulls (Photo B.4).
- Mid-channel bars are vegetated with shrubs (scoulers willow and red osier dogwood) as well as grasses and forbs.

Photo B.1: Downstream view of high value shoreline habitat at Cowichan River km 3.7 where functional LWD structures adjacent to mature riparian vegetation are created high value instream habitat (May 5, 08).

Photo B.2: Downstream view in the North Branch at km 1.7 illustrating mature riparian habitat and natural shoreline features that are providing high quality, stable instream habitat (May 5, 08).

Photo B.3: Overbank flooding (right bank) at km 5.1 over floodplain and into Fish Gut Alley at discharge of 33 m^3/s. (February 17 09).

Photo B.4: Upstream view of mid-channel bar in the Cowichan mainstem at km 4.2 providing good quality foraging habitat for bald eagles, diving ducks and seabirds (Nov 2008).

Cowichan Riparian Corridor:

- A 5 km section located over the north and south banks of the Cowichan River mainstem between river km 5 to km 1 at the Pimbury Bridge.
- Mature deciduous dominated riparian habitat polygons extend up to 400 m from the river margins, is largely undeveloped and supporting a matrix of high value side-channel and off-channel ponds (Figure B.1 and Figure B.2).

- Off-channel habitat provides very high value spawning and both seasonal and year round rearing habitat for salmonids.
- High value wildlife habitat, mature deciduous canopy provides high value habitat for numerous avian species including songbirds, raptors (bald eagles), great blue heron, woodpeckers, songbirds, Stellar's jays and ravens.
- Several species of diving ducks and amphibians including the western toad along the natural shorelines and throughout flooded overbank depressions and channels.

Somenos Mainstem and Wetlands:

- High wildlife values along the Somenos mainstem wetlands as well as the wetland to floodplain boundary around Somenos Lake (Figure B.1).

Priest's Marsh:

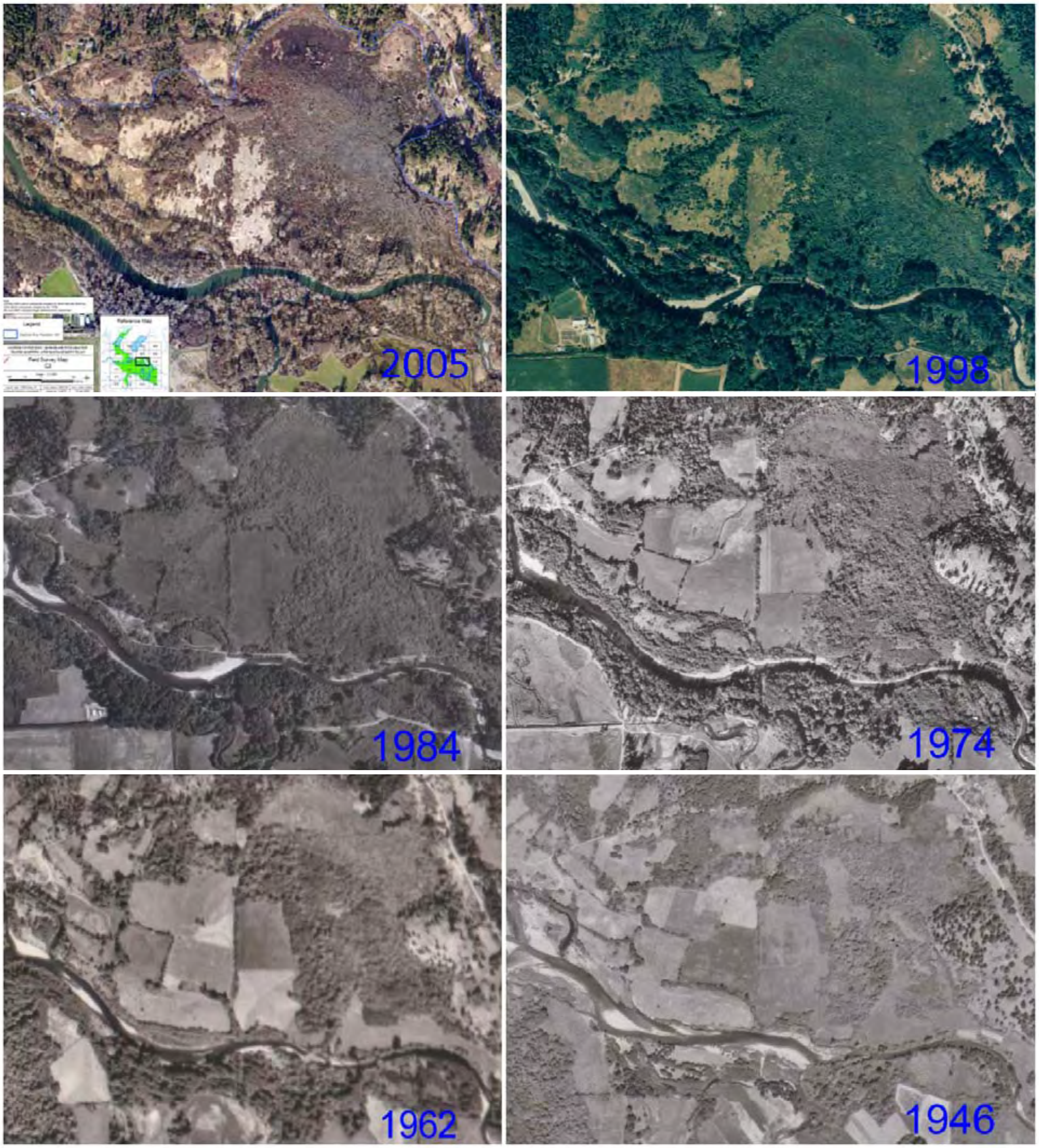
- Largest wetland complex in the lower Cowichan River providing high value wetland habitat.
- The most significant change to the wetland ecosystem occurred in the 1940's during agricultural development, which included wetland drainage alterations, clearing and construction of Quamichan Dike (Figure B.3).
- While the historic disturbance to Priest's Marsh dates back to the 1940's land use activities were limited to agriculture development over an estimated 50 years within the western portion.
- Cessation of agricultural activity occurred in the late 1980's with the wetland regenerating to a natural state.
- Lower reaches of low gradient tributary system provide high value rearing habitat for salmonids

B.4.2 MODERATE HABITAT SENSITIVITY

The Moderate habitat sensitivity rating applies to riparian and shoreline features only in the habitat pilot study area as all of the instream habitat is rated as High or Very High. Within the Cowichan Flood Management Planning Area, there are approximately 0.5% of the riparian habitat and 15% of shoreline habitat with a Moderate habitat sensitivity rating.

For riparian features, a Moderate habitat value indicates that the polygon has been subject to 5-25% permanent fragmentation. ***These areas are good candidates for restoration*** and may assist in improving marginal habitat or water quality conditions for rearing and migrating salmonids during the summer and fall.

For shoreline features, a moderate rating indicates that the shoreline has been temporarily altered due to the placement of riprap but through habitat restoration and/or shoreline works, the site could be rehabilitated to provide natural shoreline characteristics. Areas with a moderate rating may also indicate short (i.e. 40-50 m) bank protection works with natural shoreline features both upstream and downstream of the site.



Notes:
- 2005 TerraRS from CVRD (to match LiDAR)
- 1946 air photo from BC Integrated Land Management Bureau.

LOWER COWICHAN / KOKSILAH INTEGRATED FLOOD MAPPING AND MANAGEMENT PLAN

Historic Changes
Priest's Marsh

northwest hydraulic consultants	project no. 3-4878	September 2009

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Figure B.3

B.4.3 Low Habitat Sensitivity

Within the habitat pilot study area, there is a limited amount of low value habitat. Approximately 4% of shoreline habitat and 0.5% of riparian habitat have a "low" value habitat rating. In riparian polygons with a "low" habitat sensitivity value there has been a permanent level of fragmentation (> 25%) and/or disturbance due to urban, agricultural, commercial or industrial development (Figure B.1 and Figure B.2).

Therefore, as the ecological structure, function and diversity within these areas has already been altered due to existing development, when combined with being located within a lower flood risk zone, ***these areas are good candidate areas to be considered for future development.***

The habitat pilot study area represents a small portion of the Flood Management Planning Area. If the remainder of the area were included in the habitat mapping, areas most suitable for further development could be defined by overlaying the habitat sensitivity mapping with the flood hazard map. Candidate areas for future development include areas outside the floodway zone (Map 1: Flood Hazard Map).

B.4.4 Pilot Area – Shoreline Habitat Attribute Tables

The shoreline habitat GIS attribute tables are shown in Table B. 8 and Table B. 9 for Mapsheets C2 and C3 of the habitat pilot study area.

Table B. 8: Cowichan River GIS Habitat Attribute Data – Shoreline C2

Site ID	Photo ID	Description	Shoreline Alterations	Bank Height	Bank Slope	Bank Material	Habitat Features	Erosion	Hab Rating	Jurisdiction	Comments
S-CR5.3 to6.3RB	14	South Side Dike extends for appoximately 1.5 km immediately adjacent to right bank of mainstem (to Trans Can Hwy.	engineered dike with riprap along sideslopes into wetted margin of the mainstem	high (4.8 m)	mod	predominantly fines	riprap shoreline feature vegetated with mature Cottonwood (CT) to 40 cm diamter and well established riparian veg including Scoulers' willow.	min	mod	managed by District of North Cowichan and within Riparian Polygon R-CR6 RB	presence of riverside dike results in overbank flooding along left bank (3.0 m) as observed at discharge of 94 cms. Bank height from nhc XS data 5765
S-CR4.75to5.3RB	31	dike is setback (average 50 m) from LB of mainstem Cowichan and thereby allows for more natural shoreline features including overhanging vegetation, functional LWD, backwatered alcoves etc.	relatively natural shoreline and dike does not appear to be constructed to engineering stds.	low	low	60% gravel, 40% fines	high value shoreline habitat features include mature CT trees that provide critical roosing sites for bald eages during the fall (obs 25 eagles/tree) with 250 m long high flow channel at km 4.9 RB and backwater alcove at km 5.	site is aggrading	high	adjacent to intact and forested Cowichan Tribes land	nhc XS 5179
S-CR4.5to4.75RB	2	LWD and SWD accumulations along length of outer meander bend	excessive woody debris extending into riparian at km 4.5	low (2 m)	unk	predominantly fines	shoreline features are compromised by acclerated accumulation of woody debris.	unk	mod	adjacent to intact and forested Cowichan Tribes land	if instream restoration works are planned for this site, opportunities for LWD placements and/or debris removal should be considered while equipment is onsite.
S-CR4.3to4.5RB		natural shoreline adjacent to intact and relatively undisturbed riparian habitat in polygon 1503.	natural but aggrading	mod (2.7 m)	low	unk	shoreline area is aggraded within upper 200 m with a high flow channel through the gravel bar.			adjacent to intact and forested Cowichan Tribes land	nhc XS 4300
S-CR3.7to4.5RB	24	natural shoreline adjacent to intact and relatively undisturbed riparian habitat in polygon 1500A.	natural	mod 3.5 m at km 4.06	steep	predominantly fines	Between km 4.3-4.2 shoreline features: BW pool habitat, limited LWD cover, OV vegetation. Between km 3.9 - 4.1, channel bank is vertical, minor erosion, channel confined by LB bank protection works, limited shoreline complexity and cover features.	mod	high	adjacent to intact and forested Cowichan Tribes land	site of recent channel changes, accumulation of gravel along mid channel bars, LWD along LB is no longer present at km 4.3. Nhc XS data at 4066
S-CR4.35to6.3LB		natural shoreline features along LB from the Somenos confluence to Rotary Pk.	natural	mod (ranging from 1.5 - 3.5 m)	low to mod	fines	established riparian veg providing good OV cover, stable pieces of LWD along shoreline also provides good rearing habitat for salmonids during low flows.	min	high	Cowichan First Nation owns adjacent land from km 4.35 to km 5.6, with land upstream managed by the Town of Duncan.	overbank flooding at 98 cms observed along the shoreline at km 5.5 with numerous flood channels flowing to the north and into the Rotary Park channel and lower Fish Gut alley.
S-CR4to4.35LB	23	riprap bank protection along length (~360 m) of Quamichan Rd.	very modified from natural conditions due to riprap and ashphalt road located less than 5 m from the wetted LB at flow of 66 cms.	high (4.4 m)	mod	riprap	marginal	min	low	adjacent to Cowichan Tribes land, site of Long House and Quamichan village	RB ht = 3.5 m with overbank flooding (nhc XS data 4066)
S-CR3.7to4LB		Quamichan dike is setback ~ 30 m from shoreline and therefore allowing for more natural shoreline characteristics	relatively natural	low (1.4 m)	low	fines	high value shoreline habitat with intake to Jayne's channel at km 3.9.	min	high	adjacent to Cowichan Tribes land, Quamichan village and Quamichan Dike	nhc XS 3880, bank ht of 1.4 m represents natural LB elevation along floodplain rather than LB elevation of 4.1 m on the Quamichan Dike.

Define bank slope:	steep:	>1:1
	moderate:	2:1 - 1:1
	gradual:	> 3:1
bank height	high	>4 m
	med	2-4 m
	low	<2 m

nhc

Table B.9: Cowichan River GIS Habitat Attribute Data - Shoreline C3

Site ID	Photo ID	Description	Shoreline Alterations	Bank Height	Bank Slope	Bank Material	Habitat Features	Erosion	Hab Rating	Jurisdiction	Comments
S-NC1.15BP		Bank Protection	Riprap bank protection over 75 m along outer bend of LB at Tzouhalem	UNK	UNK	riprap	Natural shoreline and riparian habitat features have been disturbed due to bank protection works. Shoreline is unvegetated, no aquatic habitat values observed.	controlled	low	adjacent land belongs to Cowichan First Nation, residential development for Tzouhalem village.	
S-CR3.5HD	58	Hatchery Dike adjacent to RB between km 2.6-3.6 within 5m TOB	Not a standard constructed dike. Observed 120 m of riprap sideslopes into RB of mainstem channel along riverside of dike, inland side is unprotected, both sideslopes are well vegetated.	UNK	UNK	riprap	Hatchery Dike is well vegetated, CT dominated, young forest. Shoreline is vegetated.	N/A	N/A	adjacent land is owned and managed by Cowichan FN.	
S-SF2.9BP		Bank Protection	Minimal fish habitat value, riprap bank protection feature for ~40 m along RB of the south fork west branch adjacent to the Hatchery Dike.	UNK	UNK	riprap	bfw = 20 m	Hatchery Dike constructed within 5 m of the SF right bank. Erosion has been addressed by an engineered riprap bank protection structure.	low	primarily undeveloped and intact riparian forest over both banks is owned and managed by the Cowichan First Nation.	bfw estimated from 1:2500 Hab Map.
S-SF2.6BP		Bank Protection	Riprap bank protection over 40 m along outside meader of left bank of South Fork with rock spur.	UNK	UNK	riprap	bfw = 21 m		low	adjacent land is owned and managed by Cowichan FN.	bfw estimated from 1:2500 Hab Map.
S-NF1.2 to 2.5		Natural shoreline features	Quamichan Dike is adjacent to the LB shoreline for 200 m across the channel from the N/S fork confluence. At this section, the dike is not to engineered standards	UNK	UNK	primarily fines	Mature riparian habitat, stable shoreline features.	primarily stable with site specific bank erosion observed along outer meander bends	high	adjacent land is owned and managed by Cowichan FN.	
S-CR3 to 3.5		Majority of this reach illustrates natural shoreline features	Quamichan Dike is primarily setback over LB between km 3.5 downstream to km 3.	UNK	UNK	primarily fines	High value shoreline habitat, functional LWD along LB at km 3.7 creating very high quality fish habitat. Confluence of north fork and south fork at Cowichan R km 3 with 3 main channels conveying flow to the south fork.	bank erosion observed along RB through channelized sections	high	adjacent land is owned and managed by Cowichan FN.	

bfw = bankfull width

B.5 SEI AND FREMP CLASSIFICATION SYSTEMS

The purpose of the FREMP classification system is to provide an initial tool for agency personnel, planners and other practitioners/decision makers to use when determining the feasibility of a development proposal and if appropriate, what are reasonable constraints to the design, construction and operation of that development. In general, the development proposal would include a detailed habitat inventory that provides the framework for required mitigative and compensation measures.

The methodology developed for the FREMP utilizes an Ecological Features and Functions Approach (EFFA). The FREMP Habitat Inventory Framework is based on tidal position, vegetative cover, community type/substrate and dominant species. "*The framework provides a systematic listing of the critical features of the shoreline habitat observed from which the ecological functions can be determined*" (Williams and Adams 2006).

Table B.10: Fraser River area habitat productivity classification (ECL 2000).

Colour Code	Productivity	Description
Red	High	High biological productivity, complex biophysical environment with diverse habitat features that support critical fish and wildlife functions on-site or as part of a more regional context. Includes habitat compensation and restoration sites. Development is not permitted unless project design, construction and operation can demonstrate that the functional capacity of habitat is not negatively impacted by development. Development in red coded areas is restrictive but may occur provided that mitigation is applied through site location and/or design to avoid impacts on habitat features and functions of the area. Habitat compensation is not an option as a rule. Exception considered in the interest of public health and safety but must pursue alternative siting and design mitigation to the maximum extent possible.
Yellow	Moderate	Intermediate biological productivity, simple biophysical environment, habitat features that are of moderate value in structure or diversity due to existing conditions (e.g. surrounding land uses or productivity) and support moderate fish and wildlife functions. Development is permitted contingent upon the satisfactory mitigation of the development associated impact. Unmitigable impacts require compensation.
Green	Low	Low productivity associated with a modified biophysical environment to an extent that the biological productivity is not significant from a habitat resource perspective. Habitat features and functions are limited due to existing conditions (e.g., developed for port or other urbanized uses). Development may occur in green coded areas provided that environmental impacts are mitigated through appropriate location, scheduling, design and operation and No Net Loss, and where possible a Net Gain, in the productive capacity of the site is achieved.

Sensitive Ecosystem sub-classes for riparian areas are outlined in Table B.11. Polygons containing more than one habitat type will have more than one designation.

Table B.11: SEI riparian sub-classes for riparian areas.

Subclass	Description
FS	Seasonally wetted field
RI:1 (sparse/bryoid)	Moss and lichen dominated, <10% treed, <20% shrub/herb
RI:1a	<10% vegetation
RI:1b	Bryophyte and lichen-dominated communities
RI:2 (herb)	Herb dominated, <20% shrub, <10% treed
RI:3 (shrub/herb)	>20% shrub, <10% treed
RI:3a	<2 m tall
RI:3b	2-10 m tall
RI:4 (pole/sapling)	Trees >10 m tall, densely stocked, may be coniferous, deciduous, or mixed stand between 10-40 yrs old
RI:5 (young forest)	Natural thinning has occurred and structural diversity increases, uniform age and lack of snags or downed logs; trees are generally less than 80 yrs old
RI:6 (mature forest)	Distinct layering of the canopy, understory more developed as canopy opens up; generally 80 to >200 yrs
RI:7 (old forest)	Trees >250 yrs old, structurally complex stands with shade tolerant tree species; snags and coarse woody debris in various stages of decay
Urban/Industrial	>50% of the polygon is altered for urban and/or industrial development
WN:ms	Marsh
WN:wm	Wet meadow
WN:sp	Swamp

ADDITIONAL HABITAT PHOTOGRAPHS

Photo B.5. Lateral view of the mainstem Cowichan River at km 5.1 illustrating high quality spawning habitat that continues to support chum and coho spawners. The mature and intact riparian habitat is dominated by Black Cottonwood and provides high quality wildlife habitat. This site is also a proposed gravel removal site as part of the flood maintenance program. Approximately 1800 m^3 of gravel was removed in June 2007 as part of emergency works to the JUB outfall (Nov 2008).

Photo B.6. Aerial view of the Cowichan River mainstem illustrating mid channel bars at km 4.3 and 4.5 where gravel and debris accumulate and intact riparian habitat extends over both left and right banks with Quamichan Road in the foreground (May 08).

Photo B.7. Upstream view of Major Jimmy's side-channel where year round flows support high quality spawning and rearing habitat (June 08).

Photo B.8. Downstream view of the Hatchery side-channel illustrating high value summer rearing habitat, intact riparian canopy with a bankfull width of 10 m and channel gradient of approx 0.5% (June 08).

Photo B.9. Lateral view of one of the Five Fingers rearing ponds illustrating stable, high quality year round rearing habitat, with enhanced LWD cover as well as wildlife habitat enhancement including bird and bat nesting boxes (June 08).

Photo B.10. Lateral view of wetland habitat at Km 0.6 RB of the Somenos mainstem adjacent to the JUB outfall dike Section 2 (Feb 09).

Photo B.11. Aerial view of the Somenos mainstem illustrating an latered riparian habitat along both sides for the channel at km 1.7. The cultivated field is SEI polygon V1509* (May 15, 08).

Photo B.12. Lateral view of south side dike at km 5.7 adjacent to the right bank shoreline where proposed dike maintenance will require removal of vegetation along both sideslopes. Riparian vegetation is currently providing overhanging cover, refuge and food supply to salmonids. Dike maintenance activities will require consultation with FOC and likely require details of the proposed maintenance along with a compensation plan and monitoring plan (Nov 2008).

Photo B.13. Downstream view of excessive woody debris that has altered natural shoreline values in the lower Cowichan mainstem between km 4.5 and 4.75 (September 2008).

Photo B.14. Mature deciduous dominated vegetation along the old Westcan Terminal Road (Oct 2008).

Photo B.15. Downstream view of the mainstem Koksilah illustrating shallow water conditions, with minimal instream or overhead cover for migrating spawners or juvenile salmonids (Oct 22 2008).

Photo B.16. Upstream view of the mainstem Koksilah where the right bank is actively eroding and immature riparian trees are collapsing into the channel (September 2009).

Photo B.17. Upstream view of the LB debris jam restricting fish passage and flows in the Koksilah mainstem at approximately km 2.1 (Sept 08).

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APPENDIX C

REVIEW OF FLOOD HAZARD MANAGEMENT IN OTHER JURISDICTIONS

C.1 INTRODUCTION

C.1.1 FLOOD HAZARD MANAGEMENT

Floods are among the most common of natural hazards and are likely to become more frequent, more prevalent and more serious in the future due to the effects of climate change and urbanization. Flood hazard (H) is defined as the probability of occurrence of a potentially dangerous event in a fixed time range and in a fixed area (Varnes et al 1984). Flood risk (R) is considered to be the expected damage caused by a specific flood event and is calculated as:

$R = H \times V \times E$ where:

> V is the vulnerability of the system meaning its tendency to suffer damage when exposed to an extreme event. A resilient development or community is planned in such a way that it will not experience significant damage if exposed to a flood. A vulnerable community will experience severe damage if exposed to the same event;
>
> E is the exposure, which can be represented as the sum of the persons, homes etc potentially subject to the flood event.

It is much more difficult and costly to make quantitative assessments of flood risk (which requires detailed socio-economic information on land-use and human settlement) than flood hazard. The study on the Cowichan-Koksilah River system is focused primarily on assessing flood hazards and does not attempt to calculate the economic losses associated with flood damages or to determine the cost-benefit of particular alternative developments.

Over the last century societies have developed a range of strategies to deal with flood hazards. These approaches are generally categorized as “structural” (dikes, dams, culverts) and non-structural (flood hazard identification, land-use controls, flood warning, flood proofing, emergency response and evacuation) methods. Flood risk management generally aims to use the most effective combination of structural and non-structural measures within a given budget or resources.

Traditionally, flood control dikes (also called embankments or levees) have been used to prevent flooding. However, experience has shown that dikes often fail during extreme events so that flood damage continues to occur after flood control works are implemented. The main difficulty is that dikes provide protection up to a certain level, then, when a failure occurs the land behind the dike is exposed to very rapid flood flow and erosion. In many cases the resulting damage is higher than if no dikes were constructed at all. If very high construction and maintenance standards are followed then there is some basis to judge when failure will occur. If construction and maintenance standards are lower, then there is very little basis for determining a safe capacity for a dike. In these situations the dike may fail even when the flood level is well below the crest of the dike. Recent studies reported that only 60% of dike failures in Europe occurred as a result of overtopping. The remaining 40% occurred as a result of embankment saturation, slope stability failure, excessive leakage and erosion (Nagy, 2008). Therefore, the trend is to not rely on dikes to protect new developments from flooding (Choles et al 2008). Any new developments behind dikes should be flood-proofed to minimize damage from a failure.

The floodway is the higher hazard portion of the floodplain that conveys most of the flood water and is subject to relatively high velocities and water depths. The flood fringe is that part of the floodplain that is subject to relatively shallow inundation and lower velocities and is considered to be exposed to significantly lesser hazards. Development in the floodway is generally restricted, while development may be allowed in flood fringe areas subject to adequate flood-proofing. The boundary between the floodway and flood fringe zones is determined on the basis of site-specific hydraulic modelling analysis. One significant advantage of this approach is that it limits encroachments that cause increased flood levels and flood damage to other areas upstream of the development.

C.1.2 FLOOD HAZARD MANAGEMENT AND GOVERNANCE

Governance emphasizes "process". It recognizes that decisions are made based on complex relationships between many actors with different priorities. It is the reconciliation of these competing priorities that is at the heart of the concept of governance.[1]

Technical solutions – structural and non-structural measures for flood hazard management – are available. However, sustainability of these measures is to a large part determined by the institutional framework that is in place (i) to ensure these measures are understood by and accurately reflect the interests of the majority of stakeholders, (ii) to engage stakeholders such that on-going support, both monitoring and maintenance is provided, and (iii) to make certain that adequate funds are provided on an on-going basis to undertake requisite maintenance and improvements.

One of the challenges associated with multi-stakeholder approaches to addressing sustainability issues is that, in many cases, there is no organization that can or will take on the role of bringing all interests together (Marshall 1998). With the diversity of interests, jurisdictions and mandates involved, many participants in multi-stakeholder processes may not be perceived, by other participants, as being unbiased enough to lead such a process. In other instances, there may be conflicting interests between participants (Marshall 1998) in the process. This makes it difficult for participants to initiate and maintain such processes. In the case of some issues, there is simply no organization with the jurisdiction or mandate for addressing an issue.

The structure and mandate of an appropriate river basin organization would allow it to play the role of an impartial facilitator that can bring all interests together to develop solutions that recognize the diversity of interests involved, and would have sufficient authority to ensure that decisions are implemented.

[1] United Nations Human Settlements Programme.

C.2 FLOOD HAZARD MANAGEMENT IN CANADA

C.2.1 FLOODPLAIN MAPPING STANDARDS

Flood risk mapping commenced in Canada in 1976 under the auspices of the Canada-provincial Flood Damage Reduction Program (Watt, 2000). This agreement was terminated in 1999 and since then each province has carried on independently. The standards and methods for defining flood hazards vary across the country (Table C.1). Design flood events typically have return periods ranging from 100-years to 200-years. It is now becoming common to adopt more severe standards in highly developed areas or to protect critical infrastructure. For example, Alberta sets a 500-year flood protection standard for critical "lifeline" facilities that are important to the health and safety of a community such as administration buildings, schools, seniors residences, key roads, sewage treatment plants and water supply plants. A 1,000 year flood protection standard is set for hospitals, extended care facilities power plants and critical related maintenance facilities (Alberta, 2001).

Table C.1: Definitions of regulatory floods and floodways in Canada (from Choles et al 2008)

Province/Territory	Regulatory Flood Return Period (Years)	Definition of Floodway
B.C.	200	30 m setback
Alberta	100 (500 to 1,000)[1]	hydraulic analysis[2]
Saskatchewan	500	hydraulic analysis[2]
Ontario	100	100 year flood extent
Quebec	100	20 year flood extent
New Brunswick	100[3]	20 year flood extent
Nova Scotia	100[3]	20 year flood extent
Prince Edward Island	100[3]	20 year flood extent
Newfoundland and Labrador	100[3]	20 year flood extent
Northwest Territories	100	hydraulic analysis
Nunavut	100	hydraulic analysis

Note:

1. 500-year to 1,000-year for critical "lifeline" infrastructure

2. Floodways defined as > 1 m depth, > 1 m/s or > 0.3 m water level rise

3. Atlantic provinces may also use a historic event as the regulatory flood provided the water levels are greater than the 100 year flood.

C.2.2 FLOOD HAZARD DELINEATION

Flood hazard areas are delineated on maps by defining the potential extent of inundation during the adopted design flood event. In addition, virtually all provinces (except for B.C.) attempt to define a separate "*floodway*" zone and "*flood fringe*" zone. Some examples of these maps were reproduced in the Volume 1, Scoping Study (NHC, 2008). Development in the floodway is generally restricted, while development may be allowed in flood fringe areas subject to adequate flood proofing. The boundary between the floodway and flood fringe zones is determined on the basis of site-specific hydraulic modelling analysis.

A number of innovative programs have been carried out to assist in communicating the flood hazards to local residents. This has involved combining web-based tools with GIS software to display in near real time the extent of flooding.

C.2.3 RIVER BASIN ORGANIZATION EXPERIENCE

C.2.3.1 FRASER BASIN COUNCIL

The Fraser Basin Council (FBC) is a unique partnership of public and private interests, assuring broad representation from all sectors of society and emphasizing an integrated approach to realizing social, economic and environmental goals (Marshall 1998). It provides a non-confrontational, consensus-based forum in which no participant is first among equals, and in which the interests of all stakeholders can be presented. The Fraser Basin Council is a means of doing business together across insurmountable boundaries and it allows for inclusive, shared decision making. Governments were made part of Fraser Basin Council's management structure in an effort to allow for greater influence on government policy and programs than is normally generated through traditional non-governmental organizations. No similar organization exists in Canada today.

The Fraser Basin Council is designed to achieve its goals by facilitating cooperative and collective action throughout the basin. It does not duplicate existing governmental and non-governmental mandates and activities. It does, however, act as a catalyst to minimize duplication and facilitate harmonization and collaboration among diverse basin interests. The approach has allowed basin-wide planning and has involved First Nations communities and private stakeholders in ways that traditional government organizations sometimes find difficult. However, the Council can not implement its plans and must constantly work to maintain its funding and resources (Blomquist, 2005).

C.2.3.2 RIVER BASIN ORGANIZATIONS IN ALBERTA

Alberta's Water for Life strategy identifies three types of partnerships to lead collaborative watershed management: (i) the Alberta Water Council, (ii) Watershed Planning and Advisory Councils, and (iii) Watershed Stewardship Groups.

The Alberta Water Council is a multi-stakeholder partnership with members from governments, industry, and non-government organizations. The Council works at a provincial scale to monitor and steward the implementation of the Water for Life strategy.

The Watershed Planning and Advisory Councils (WPACs) are regional organizations with the mandate to engage governments, stakeholders, other partnerships and the public in watershed assessment and planning. These WPACs are formed on the basis of Alberta's major river basins, as defined under the Water Act.[2] WPACs work with government in an adaptive management cycle of basin planning and evaluation; they undertake a variety of actions to benefit watersheds including collaborating with land managers, providing advice and support to Watershed Stewardship Groups, presenting issues to the Alberta Water Council, raising awareness about the state of the watershed, building long-term partnerships that examine watershed issues, and making recommendations to water/land use decision-making authorities.

The Watershed Stewardship Groups (WSGs) include a wide range of organizations with diverse mandates. Made up of local governments, stakeholders, interested individuals and residents, these groups undertake actions to raise awareness or physically improve their local watershed or water body. Additionally, within their local watershed, the WSGs:

- Gather information on water quality, quantity, usage, and surface-groundwater interaction;
- Identify goals and priorities for further action;
- Provide local advice and knowledge to municipal, Aboriginal, and other governments;
- Provide inputs to WPACs for state-of-the-watershed reports and watershed management plans;
- Carry out stewardship activities such as educational field days, demonstration sites, habitat planning, and restoration programs; and
- Encourage and promote the use of best management practices.

A review of the experience so far with these watershed partnerships identified key areas that need redress for their long-term sustainability:

- **Financial capacity**. Project-related funding is easier to obtain than operational funding. And, funds are sometimes released too slowly to enable partnerships to make the most of their planning activities. The literature suggests that public sector funding normally accounts for about 75% of annual budgets for organizations of this type.
- **Human resource capacity**. Implementing consensus decision-making requires that the governing boards of partner organizations ratify or endorse consensus decisions. This requires considerable staff capacity since the staff coordination (among the partner organizations) precedes

[2] Several major basins were split into more manageable planning units with a WPAC assigned to each planning unit.

Board action. Related to this is also the difficulty of recruiting and maintaining the interest of volunteers.

- **Data and information capacity**. WPACs and WSGs have stated that data collection, interpretation, and analysis are the most expensive aspect of watershed management planning. They require improved access to improved data, particularly data that has been interpreted or analyzed, some of which may be available from government, industry partners, or other sources.
- **Capacity within government**. Expert and technical support is required from government (Alberta Environment) if the Partnerships are to achieve their intended outcomes.

C.3 FLOOD MANAGEMENT IN THE UNITED STATES

C.3.1 FLOODPLAIN HAZARD MAPPING

In the US, floodplain mapping guidelines are provided by the Federal Emergency Management Program (FEMA, 2003) as part of mandatory national flood insurance program. FEMA divides floodplains into "*floodway*" and "*flood fringe*" areas and uses various flood zone designations relating to hazard type in order to establish flood insurance rates. In general, there is a designated zone for:

1. Floodway: which is the channel itself and any portion of the floodplain that if encroached upon would increase flood levels across the channel and floodplain
2. High risk riparian flood areas: generally the 1:100-year floodplain, with various subdivisions based on the quality of the mapping and the level of hazard
3. High risk coastal flood areas: similar to the riparian designations except relating to coastal hazards
4. Undetermined areas: areas that have a flood hazard, but that have not been studied in detail.

Floodways are generally restricted from development except for specific uses such as parks or for habitat creation. Residential homes may be constructed in the other flood fringe areas provided acceptable flood proofing is carried out. State or local communities may produce more stringent guidelines. For example, some states or counties (such as King County in Washington) impose more severe "zero-rise" restrictions for defining the floodway. This means that any encroachment on the floodplain will be restricted unless some form of mitigation is carried out to ensure that flood levels at other locations are not affected. For example, the King County building code indicates that "*developments in the flood fringe area must not reduce the 100-year flood storage volume on the floodplain*".

C.3.2 LEVEES

Flood embankments or levees may significantly affect the extent of the flood hazard area shown on the FEMA maps. If levees receive certification from the US Army Corps of Engineers (indicating there is reasonable certainty that the levee will contain the base flood event) then the land behind the levee may be considered flood-free. Previously, USACE required a minimum freeboard of 0.9 m (3 feet) to receive certification. This has since been replaced by a more stringent risk-based assessment. Due to these more stringent criteria and other problems related to lack of funds for maintenance there are now very few "certified" levees left in the US.

For the case of un-certified levees, FEMA generally requires that a number of levee failure scenarios be modelled hydraulically to represent potential flood paths. These scenarios are then compared and the highest flood levels from all cases are then used to set the base flood elevation on the floodplain maps.

C.3.3 INTEGRATED FLOOD HAZARD MANAGEMENT

There is now general recognition that annual flood losses have continued to worsen in the United States in spite of 30 years of the National Flood Insurance Program and over 75 years of investment in flood control works by the federal government. Larson and Plasencia (2001) concluded:

> *It is clear the nation has followed a course that has encouraged at-risk behavior, silently allowed practices that increase flood potential and done little to encourage local government innovation.*

There is now a strong interest in implementing integrated flood hazard management policies and programs to reduce flood losses (State of California, 2005). One approach advocated by the Association of State Floodplain Managers involves adapting a "no net adverse impact" floodplain policy. A no net impact floodplain is one in which

> *the actions of one property owner or community does not adversely affect the flood risks for other properties or communities as measured by increased flood stages, increased flood velocity, increased flows or the increased potential for erosion and sedimentation, unless the impact is mitigated as provided for in a community or watershed-based plan. (Larson and Plasencia, 2001)*

The "zero rise" floodway definition adopted by King County in Washington is compatible with this approach. Recently there has also been less reliance on structural flood control works and more efforts to implement multi-objective management approaches for floodplains. This involves incorporating flood protection practices into multi-objective floodplain management projects. This enables floodplain managers to leverage other sources of funding for flood system maintenance. These projects result in habitat enhancement rather than simply mitigating for environmental impacts (State of California, 2005). An example of this new approach is underway in Yakima County, Washington State. The county is currently implementing a program to set-back or breach a number of existing levees in order to reduce flood levels along the Yakima River and to open up portions of the floodplain for fisheries habitat development. This program was developed over a period of 15 years and involved consultation and cooperation amongst a wide range of federal, state, county and local community stakeholders. Levee set-backs and levee breaching has also been successfully carried out in King County along portions of the Nooksack River as part of a program to reduce upstream flood levels and to improve fisheries habitat. Providing financial compensation for residents and farmers affected by the re-locations is an important consideration in these programs.

Implementing complex integrated flood management programs is complicated and requires strong technically specialized institutions. For example, the King County water resources department has an operating budget of $30 million /year and has a staff of hydrologists, planners, fluvial geomorphologists, ecologists and planners who are responsible for river management. Even smaller counties such as Yakima County and Pierce County in Washington State have a strong organization that can focus on river management.

C.4 EUROPEAN EXPERIENCE

C.4.1 FLOOD STANDARDS

Standards for flood risk assessment and design of flood control defence works varies widely within the region. In the United Kingdom a 200-year event is used for tidal defences and a 100-year event is used on non-tidal rivers. In the Netherlands design return periods range from a minimum of 250-years up to 10,000-years for dikes along the coast. Poland used the 1,000-year flood for design of their levee system. The adopted return period may vary depending on the land-use and degree of urbanization, with highly developed areas having higher standards than areas used primarily for agriculture.

C.4.2 FLOODPLAIN MAPPING

The European Union recently published guidelines for flood mapping (EXCIMAP, 2007) to help member countries meet the objectives of the 2007 European Flood Risk Directive. The Directive asks member countries to implement some form of flood mapping to meet at minimum:

Flood hazard maps shall cover the geographical areas which could be flooded according to the following scenarios:

- *Floods with a low probability, or extreme event scenarios*
- *Floods with a medium probability (return period > 100 years)*
- *Floods with a high probability where appropriate.*

For each of these types of flood events, the following elements shall be shown:

- *Flood extent*
- *Water depths or water level, as appropriate*
- *Where appropriate, the flow velocity or relevant water flow*

Flood risk maps shall show the potential adverse consequences associated with flood scenarios:

- *The indicative number of inhabitants potentially affected*
- *Type of economic activity of the area potentially affected*
- *Installations concerning integrated pollution prevention and control which might cause accidental pollution in the case of flooding and potentially affected protected areas.*

The directive is not prescriptive though it promotes the development of higher end mapping such as risk mapping, though with the understanding that simpler maps such as flood extent and depth mapping may be better suited to some areas.

The floodplain maps are used for a range of purposes. Austria, Germany and Ireland use the maps to establish flood insurance rates as part of nation-wide flood insurance programs. Countries such as Switzerland, France, Spain, Italy, Holland and Belgium have sufficient socio-economic data and records of assets that they can compute actual flood risks. Most other countries use the maps to define flood hazards for zoning and emergency planning purposes.

C.4.3 LEVEES AND DIKES

Standards for freeboard on levees and dikes vary widely as shown below:

Germany: the lowest allowable freeboard is 0.8 m and it can go up to 1.5 m to protect populated areas. A variety of sophisticated design procedures are used.

Hungary: A value of 1.0 or 1.5 m is added to the design flood level, depending on wave conditions and the potential for erosion to the dikes.

Ireland: The value for freeboard depends on embankment height and material, vulnerability of the affected property and the degree of exposure. Values typically range between 0.3 to 0.9 m.

Netherlands: The minimum freeboard is 0.5 m for non-critical structures. Very sophisticated methods are used for estimating wave runup and flood levels on all dikes. Besides freeboard, a value for sea-level rise is added to the design height of the dikes to cover a 50-year time period.

Serious flood damages throughout Europe in 2002 highlighted the failure of existing flood control measures. Vinet (2008) described four main factors that contributed to the flood damages:

- The dikes suffer from a lack of maintenance. The authorities then in charge of dike maintenance could not afford the needed repairs;
- Uncontrolled expansion of urbanization behind the dikes. In France, as in many countries, land-use planning failed to control the establishment of houses and activities in flood-prone zones;
- Dikes are built to withstand a certain level of risk. Recent floods have equalled or exceeded the design standards, possibly due to climate change;
- Dike failures were seldom included in warning plans, primarily because river-side residents believed they were safe.

C.4.4 INTEGRATED FLOOD HAZARD MANAGEMENT

Vinet (2008) provided an overview of European experience on flood hazard reduction. Three stages in dealing with flood hazards were described. The traditional approach, which lasted until the 1980’s, involved relying solely on structural defences (such as dikes or dams) against the flood hazard. The continued experience of rising flood damages in spite of significant investments in structural flood control measures led authorities to recognize that “something was wrong” with the traditional approach (de Wrachien et al, 2008).

Starting in the 1980's it was gradually realized that society generates risk through vulnerability and exposure, by developing in hazardous locations on the floodplain. To reduce risk one can reduce vulnerability by identifying flood hazards, implementing restrictive zoning or changing land-use practices.

The third phase, starting in the 1990's involves developing an integrated vision of natural risks and their management. The European Union has termed this the "*room for river and people*" concept (de Wrachien et al, 2008). The approach has led to the adoption of a wide range of structural and non-structural measures. The resulting portfolio of mixed measures is generally known as the "integrated water management approach".

C.5 APPLICATION TO COWICHAN FLOOD MANAGEMENT

This section assesses the key challenges and issues involved in implementing an integrated flood management program on the Cowichan-Koksilah River floodplain, given the present provincial policies and institutional framework in the region. This assessment has been made by identifying the overall strengths, weaknesses, opportunities and threats related to flood management. Table C.2 summarizes the main issues.

Table C.2: Overview of Flood Management Planning Considerations

Strengths • Stakeholder participation and guidance through Cowichan River Stewardship Round Table. • Key goals and objectives defined by Cowichan Basin Water Management Plan. • Floodplain mapping incorporated into bylaws and OCPs • Successful habitat restoration projects completed and underway	**Weakness** • Local governments have inadequate resources to manage flood hazards and undertake new initiatives. • MOE no longer responsible for floodplain management • No institution with authority to carry out comprehensive flood management • Lack of funds available for channel maintenance or adaptive management • Infrastructure is deteriorating over time so risk of damage is increasing
Opportunity • Heritage river designation • New interest in linking flood mitigation with habitat improvement (river naturalization)	**Threats** • Upstream land-use changes could increase debris loading in the future. • Climate change projected to cause more severe flooding and higher ocean flood levels. • Rapid growth may promote more development in hazardous locations

C.5.1 STRENGTHS

Considerable forward planning and coordination has already been accomplished by stakeholders in the region. The Cowichan Basin Water Management Plan provides clear direction towards integrated floodplain management by identifying a mix of non-structural and structural flood management measures. For example, Objective 4a of the Plan involves non-structural measures to establish adequate setbacks to reduce potential flooding risk by updating floodplain mapping standards using state-of-the art hydrotechnical data and analysis techniques. Objective 4b of the Plan involves primarily structural measures to maintain the capacity of the Cowichan channel where it is obstructed by gravel, debris or structures.

The Cowichan River Stewardship Round Table also provides critical guidance and research to many activities related to river restoration and water management. This group would be critical for implementing an integrated flood management plan.

The existing floodplain maps and the by-laws and OCP's provide a means for regulating development on portions of the floodplain.

C.5.2 Weaknesses

In 2004 legislative changes granted local governments the authority to manage land use in flood hazard areas. Key provisions included the removal of BC MOE approval for sub-divisions and floodplain bylaws and the granting of greater authority to local governments. As a result, although BC MOE has great expertise and experience in floodplain hazard assessment and mapping, it will not provide written comments or advice regarding new floodplain hazard maps or flood hazard management[3]. This creates a situation where local governments must assume greater responsibility and liability, without necessarily having the capacity and resources to take on the work. A recent survey of B.C. local government officials involved in flood management found *"fewer than one third of the respondents indicated the legislation and related management tools were sufficient to adequately manage flood hazards"* (FBC, 2008).

Managing the floodplain lands of the Cowichan Tribes is also made difficult by the limited technical resources that are available. There are also inter-jurisdictional issues related to joint funding and implementation of projects. For example, provincial funding of flood works through EMBC exclude First Nations involvement.

Local governments and Cowichan Tribes have limited funds available for maintaining the existing dikes. Consequently, these structures are gradually deteriorating over time causing the risk of failure to increase when a severe flood event occurs.

Although there are a wide range of stakeholders participating in groups such as the Cowichan River Stewardship Round Table and the Water Management Plan, there is no single authority that can implement comprehensive flood management initiatives. There is also no mechanism to fund such initiatives.

C.5.3 Opportunities

There is widespread recognition that flood protection using traditional methods will not work in the long-term and is too expensive to maintain in an era of diminishing funding and resources. There also appears to be support for the concept of multi-objective floodplain management, which can leverage other sources of funding and can provide a wider range of benefits. In this case, future projects will be formulated to achieve habitat enhancement and flood mitigation. An example would involve naturalizing the river channel to lower flood levels and improve habitat

[3] Neil Peters, BC MOE Inspector of Dikes

C.5.4 THREATS

Flood runoff, sediment and debris are generated in the headwater basins, often in areas outside of their immediate control. Land-use changes or other extreme events such as landslides and channel avulsion in these headwater regions could significantly affect the magnitude of flooding and erosion problems on the lower rivers. In addition, there is a general recognition that climate change over the next century will lead to more severe flood discharges and higher extreme ocean levels than in the past. Climate change could also affect forest cover and slope stability in the headwaters; again leading to higher sediment and debris inputs to the floodplain.

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