Environmental Protection
in Flood Hazard Management

A GUIDE FOR PRACTITIONERS

April 15, 2010

Prepared by

The Fraser Basin Council

Fraser Basin Council

Acknowledgements

This report was made possible with funding provided through the Fraser Salmon and Watersheds Program, which is co-managed by the Fraser Basin Council and the Pacific Salmon Foundation. The content of this report is based on a literature review as well as interviews with practitioners responsible for designing and implementing flood management practices, particularly those who have also advanced environmental protection. The Fraser Basin Council would like to generally acknowledge the leaders and innovators that have advanced this work over the past decade, as well as those who will continue to implement environmentally sound innovations while reducing community vulnerability to flood hazards.

This report would not have been possible without a team of researchers, writers, editors and technical advisors including Steve Litke, Jillian Merrick, Alan Thomson, Tracey Hooper, John Pattle, Alan Jonsson, and all of those who provided resource materials and/or were willing to participate in interviews to the development of the case studies that are profiled within this report.

British Columbia boasts a wide diversity of waterfowl and shorebirds that rely on wetlands for survival. Finding a way to safeguard communities from flood hazards while also protecting our natural heritage is the new challenge.

Executive Summary

The purpose of this report is to examine the issues, challenges and opportunities associated with flood management practices and policies in ways that protect and enhance the natural environment. The objectives for this report are:

- to provide an overview of integrated flood hazard management;
- to outline past challenges and emerging principles and practices related to flood protection and the environment; and
- to share experiences, lessons learned, case studies and other resource materials to guide practitioners.

The report is intended to inform local governments, diking authorities, and other stakeholders and organizations about recent experiences and evolving best management practices related to flood management. It is also intended to aid in the development of policies, procedures and management strategies in the future.

Section 1 provides an introduction and background for the report. It acknowledges that traditional approaches to flood management have resulted in a variety of adverse environmental impacts and it recognizes that there are growing interests and requirements to improve environmental performance.

Section 2 provides an overview of flood hazard management. It highlights the importance of an integrated approach to management, and describes several common principles and practices, as well as pros and cons from a flood management perspective. The section describes four primary approaches to flood hazard management, including:

- flood hazard information and planning;
- floodplain management;
- flood protection works; and
- emergency management.

Section 3 focuses on environmental stewardship. It describes several flood management principles and practices that are being utilized to improve environmental performance, including planning, design, construction, operations and maintenance. The pros and cons of these alternative flood management approaches are described from an environmental perspective.

Section 4 profiles a variety of case studies to illustrate different best practices and innovations that are improving environmental performance, compared with traditional approaches to flood management. These case studies include a variety of different types and sizes of communities from different parts of British Columbia with different kinds of flood hazards.

The case studies demonstrate leadership and innovation by many local authorities, regulatory agencies and other partners as they pursue numerous options to improve the environmental performance of flood hazard management practices and policies. The following are some examples of these innovations:

- environmental assessments and monitoring to improve understanding about the species, habitats and other environmental features and functions that interact with, or are impacted by, flood management strategies;

- broad planning processes to better understand flood risks, related environmental issues and other community interests to inform a comprehensive analysis of recommended management options;

- land use change to direct the development of buildings and infrastructure away from rivers and floodways and to restore river corridors to more natural landscapes that are less vulnerable to flood damages;

- setback dikes, which are located inland away from riverbanks and riparian habitats;

- fish-friendly pump and flood gate designs, which enable safe migration of fish between off-channel habitat in the floodplain and habitat within the mainstem of the river;

- alternative approaches to channel maintenance such as the use of sediment ponds to limit the footprint of sediment removal operations, and manual maintenance of vegetation within and along streams and drainage ditches; and

- incorporating habitat restoration features, such as riparian vegetation, intertidal benches, off-channel habitat and stormwater detention ponds, into the design of flood protection and drainage systems.

Several Appendices have also been developed to provide additional information for the reader. These include an overview of key legislation, a listing of relevant resource materials, flood management terms and definitions, as well as references that were used in preparing the report.

Considerable progress has been made by some communities in recent years to improve the environmental performance of flood hazard management policies and practices. However, across the Lower Mainland and throughout BC, we have a long way to go to more fully implement the available and emerging suite of environmentally sound policies and practices.

For the most part, technical designs, policies, and procedures are available. It is a matter of adapting and adequately funding the solutions that emerge, bringing people together and building common understanding, trust and collaborative working relations. This will increase the likelihood of success in identifying the options that are best suited to local circumstances, are technically feasible, are supported by public and political will, and are within the financial resources available.

Through creative problem solving, innovative design and best management practices, environmental objectives may be achieved while maintaining a high standard of flood protection and public safety. However, these innovations may be associated with increased costs, or may require additional research or technical support. This can be particularly challenging for local governments with limited capital budgets. Therefore, there is a need to develop and promote the use of environmentally sound designs and practices that are both technically and economically viable.

There is a need for existing infrastructure funding programs to assist with environmentally sound approaches to flood protection. There is also a need for new funding opportunities through habitat stewardship or green infrastructure programs, which would help offset any incremental costs associated with environmental protection. A variety of existing financial instruments have been used by different organizations to help fund the best practices that are profiled within this report. Some examples include:

- Infrastructure grants;
- Environmental stewardship grants;
- Collaboration, cost-sharing and in-kind contributions;
- Development cost charges;
- Diking and drainage utility fees; and
- Annual operations and maintenance budgets.

In addition, there may be a broader suite of innovative funding approaches. For example, different financial incentives or disincentives could be developed to encourage, enable and facilitate the implementation of best practices. There may be opportunities to refine existing policies to create a favourable financial environment. Habitat compensation projects could be directed to improving fish access to high quality, under-utilized off-channel habitat. This might be more effective, cost-effective and technically viable than traditional approaches to habitat compensation, which have often relied upon construction of new habitat features. Land trusts might be one mechanism to facilitate the return of prime habitat along river corridors to a more natural state. There is a need to explore these and other financial instruments to better enable the alignment of environmental protection within flood hazard management practices and policies.

This report presents a compilation of existing guides, reports, studies and projects. It is intended as a resource guide for practitioners to support continued discussion and collaboration so that environmentally sound approaches to flood hazard management will be developed, adapted and implemented long into the future.

There are threats of flooding in almost any given year in British Columbia. Perhaps the greatest vulnerability to flood risk is in the floodplain of the Lower Fraser River. The Fraser Valley and other parts of the Fraser Basin have experienced two major floods of record, the largest in 1894 and the second largest in 1948.

Contents

1.0 Introduction

1.1 Purpose and Objectives

The purpose of this report is to examine the issues, challenges and opportunities associated with flood management practices and policies in ways that protect and enhance the natural environment. The report provides an overview of the adverse environmental impacts of traditional flood management practices. It also outlines general principles and practices of flood management as well as case studies of innovative flood management techniques that can help communities and flood managers protect the environment while ensuring public safety and reducing future flood damages. The report is intended to inform local governments, diking authorities, and other stakeholders and organizations about recent experiences and evolving best management practices related to flood management. It is also intended to aid in the development of management strategies in the future.

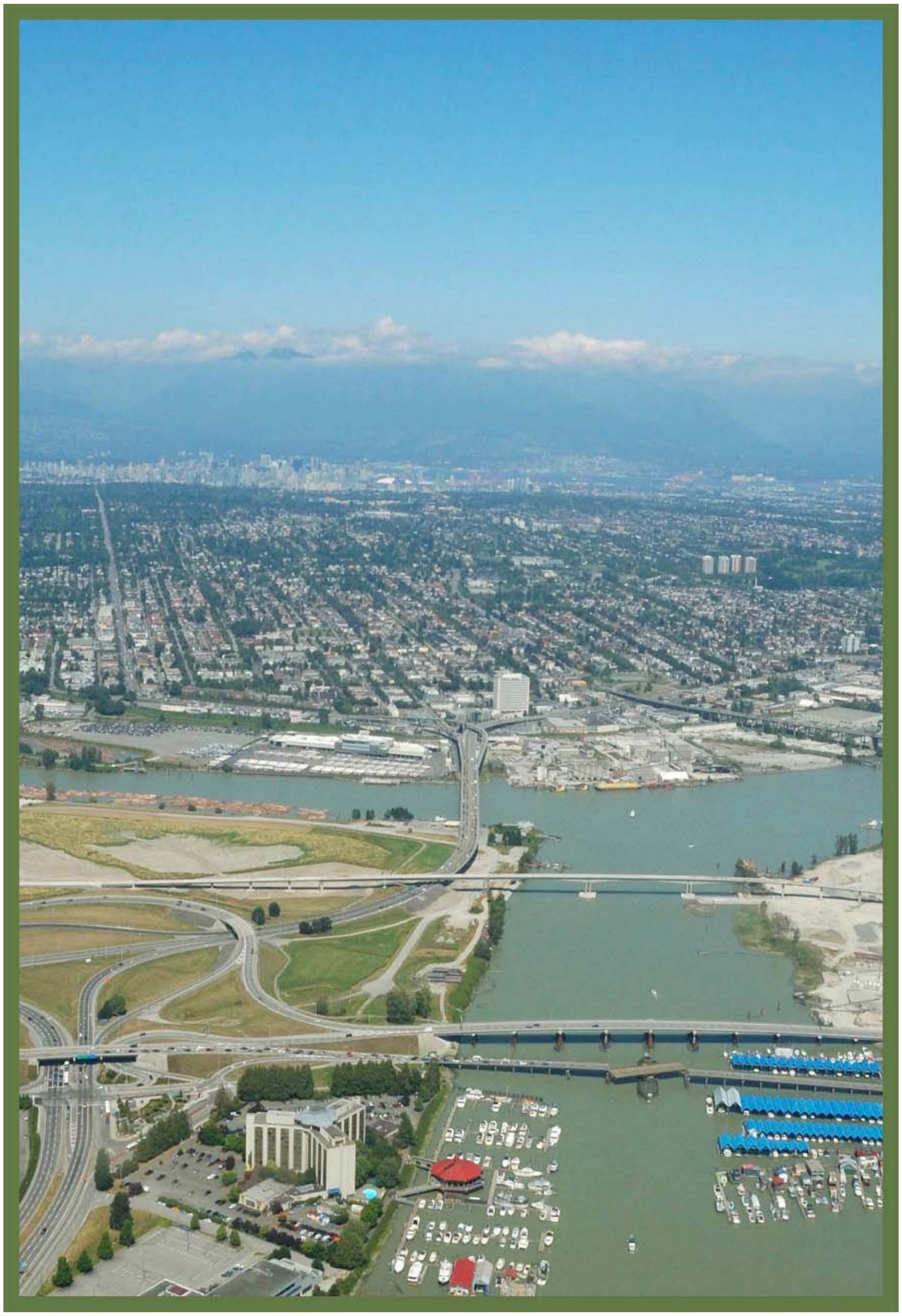
The objectives for this report are:

- to provide an overview of integrated flood hazard management;
- to outline past challenges and emerging principles and practices related to flood protection and the environment; and
- to share experiences, lessons learned, case studies and other resource materials to guide practitioners.

1.2 Background

Many communities throughout BC, particularly along the lower Fraser River have long been protected from flooding by dikes and related works, including pumps, flood gates/flood boxes and erosion protection, such as riprap. The flood protection system along the lower Fraser was significantly upgraded and rehabilitated through the Fraser River Flood Control Program, which was implemented following the last great Fraser River flood in 1948 but was terminated in 1995.

The historic approach to flood protection has been largely successful in protecting communities, including residents, businesses, farmers, and utilities and other critical infrastructure. However, it has also had various adverse impacts on the natural environment, including the creation of barriers to fish migration from the Fraser River into Fraser Valley tributaries, and the loss or degradation of riparian and instream habitat. The flood protection works were designed and implemented during a time when stewardship of the natural environment was not recognized as an important responsibility of communities and government agencies. More recently, public interest, legislation and regulatory requirements have evolved, challenging local governments, diking authorities and management agencies to undertake environmental protection while maintaining a high level of flood protection for communities.



A major flood today would result in severe social, economic and environmental impacts, including billions of dollars in damage to private and public property, temporary loss of infrastructure and community services and disruption of business and trade,

2.0 Overview of Flood Hazard Management

Flooding is a common natural hazard in BC and occurs as a result of heavy rainfall (flash floods), snowmelt (spring freshets), ice jams, log jams, debris flows, sediment deposition and even tsunamis. Tidal cycles can also influence flood waters when storm surges coincide with high tides or when high tides cause rivers and streams to back up. Flooding is a natural event that replenishes the groundwater and revitalizes the soil through the deposit of sediments.[1] However, when communities settle within floodplains, flooding can cause adverse social, economic and environmental impacts. Flood risk can be considered to be a function of both hazard and vulnerability. This is to say that flood risk is related to the natural sources of a flood hazard as well as the particular vulnerabilities of communities, organizations and individuals that are exposed to flood hazards.

Because of the different types of flood hazards and risks faced by BC communities and the significant impacts associated with flooding, an integrated approach to management is required, including:

- flood hazard information and planning
- floodplain management
- flood protection works
- emergency management

Compiling and analyzing flood hazard information is necessary to gain an understanding of the causes, extent, and depth of potential flooding in and around a community. This information is also needed to inform flood management practices and policies, including engineering works such as dikes, land use planning and floodproofing techniques, pre-flood emergency measures and post-flood recovery efforts.

The most effective and affordable method of reducing the risk of flood damage is to employ floodplain management (i.e., managing and limiting development on the floodplain). Land use decisions by local governments should take into account flood risks to ensure that development occurs on lands that are the least susceptible to flooding. Building designs and construction practices can also help reduce flood damages.

Flood protection works, such as dams and dikes, can further reduce flood risk. These structures are particularly relevant in protecting historic communities that were settled before floodplain management policies were implemented. However, it is technically and economically impossible to completely eliminate flood risk with dikes, dams and other engineering works. During severe floods, dike failures may occur due to erosion, overtopping or seepage.

Emergency management involves the planning and preparedness before flood events occur to help reduce the impacts of potential flooding. This includes building an understanding of the different vulnerabilities of people, infrastructure, buildings and other assets within the community and developing plans to reduce those vulnerabilities. Emergency management also includes a range of response activities such as sandbagging, urgent flood mitigation works and evacuation. In cases where all defenses have been exceeded, disaster recovery is necessary, which involves cleanup, repairs, and restoration of flood damages.

[1] www.env.gov.bc.ca/wsd/public_safety/flood/brochur3.html (accessed March 2010).

Evaluating flood hazard management alternatives requires an understanding of existing floodplain use, a clear vision of future use, and a review of current floodplain management practices. An evaluation of alternatives should also take into consideration the following:

- ease of implementation
- cost-effectiveness
- potential for success in solving the issue and providing public benefit
- environmental considerations
- applicable policies and regulations

(Upper Yakima Comprehensive Flood Hazard Management Plan, 2007).

2.1 Flood Hazard Information and Planning

Flood hazard information and planning is needed to inform a wide range of management practices, policies and related decisions. Local authorities and senior government agencies undertake technical studies to better understand specific flood and erosion hazards. Depending on local or regional needs, this may involve calculating design flood profiles, monitoring changes in river channels or along riverbanks, identifying areas with erosion hazards, or quantifying erosion and sedimentation processes. In some cases, long-term river processes such as riverbank erosion, sediment deposition, or channel shifting and avulsion are beyond the management capabilities of local diking authorities. In these situations, it may be necessary to pool financial resources and technical expertise on a regional scale in order to collect sound technical information, develop management recommendations and implement appropriate solutions. Sometimes a river management plan or flood hazard management strategy may be developed following the completion of technical studies (Fraser Basin Council 2001).

2.1.1 Principles and Practices - Flood Hazard Information and Planning

To fully understand flood hazards and risks, many different types of information are needed, including:

- **Hydrological Models** – These models show how the characteristics of a river, stream and/or watershed can influence streamflows, including peaks and seasonal variations (i.e., how much water is likely to be flowing, and when).
- **Hydraulic Models** – These models show how a specific streamflow, such as a design flood event, can influence water levels (i.e., for a given flow, how high is the water likely to rise, and where).
- **Flood Hazard Evaluations and Assessments** – These studies help identify the factors or circumstances that are likely to result in flood events, and they may be used to calculate the return frequency and/or magnitude of a design flood event (i.e., what are the causes of flood events for a community and how significant is the potential for a flood).
- **Flood Risk and Vulnerability Assessments** – These studies can enhance understanding of how communities are vulnerable to flooding and the risks they may

face from one or more flood events (e.g., flood damages, injury or risk to life, risk of infrastructure disruption, or risk of disruption in the continuity of businesses or community services).

- **Floodplain Maps and Flood Hazard Maps** – These maps delineate the area or extent of land that can be expected to flood and the potential depth of flooding during a specific flood event. These maps can be used to determine appropriate setbacks from floodways or floodplains, and flood construction levels, which can be incorporated into land use policies and/or development practices. Floodplain maps can also be used in the preparation of emergency plans. For example, by understanding the predicted extent and depth of flooding, emergency response routes and vulnerable assets can be identified.

- **Flood Hazard Management Plans and Strategies** – Plans and strategies include all available information about flood hazards, risks and community vulnerability, which can be used to develop a wide range of recommended management practices and policies.

- **Public Education** – Public education materials and programs inform the public about flood risks and what they can do to protect themselves, their families and their properties. It is important that complex technical information is translated into a format that the general public can use and understand.

2.1.2 Pros and Cons - Flood Hazard Information and Planning

For each of the different approaches to flood hazard management, there are a variety of pros and cons to be considered. These are described in the following section.

Pros:

- Flood hazard information is necessary for identifying the types and sources of flood hazards, quantifying the extent and depth of potential flooding, considering relevant management options, and assessing appropriate design standards and management practices.

- The financial costs of compiling and analyzing flood hazard information are relatively low compared with actual capital works costs, flood damage costs and related disaster recovery costs.

Cons:

- The development of flood hazard information requires considerable technical expertise, including in-house staff capacity and contractors.

- Flood hazard studies may require significant financial resources, but there is little financial support for communities to undertake this type of work.

2.2 Floodplain Management

2.2.1 Principles and Practices - Floodplain Management

Floodplain management is a critical strategy for reducing or preventing injury, human trauma and loss of life, and minimizing property damage during flooding events. Experience has shown that regulating land development to keep people, property, infrastructure and other community assets out of harm's way is the most practical and cost-effective way of achieving these goals.

Flood hazard land use management objectives have been incorporated into several aspects of provincial legislation respecting land development, including: [2]

- *Community Charter* — which provides for the issuance of building permits;
- *Land Title Act* — which provides for approval of the subdivision of floodplain lands;
- *Local Government Act* — which enables local governments to consider the impacts of flooding in their land planning and management responsibilities, including:
    - development of Official Community Plans for future land use;
    - development of flood hazard bylaws; and
    - adoption of appropriate floodplain building standards;
- *Flood Hazard Statutes Amendment Act, 2003* — which amended the Acts identified above;
- *Miscellaneous Statutes Amendment Act (No. 2), 2004* — which clarifies bylaw authority; and
- *Environmental Management Act* – which clarifies MoE's responsibility for the provincial *Flood Hazard Area Land Use Management Guidelines.* The guidelines are required to be considered by local governments under the *Local Government Act* when making land use and development decisions in flood hazard areas.

The two most common floodplain management policies are floodplain setbacks and flood construction levels.

Floodplain Setbacks – Setbacks are used to keep buildings, other development and land fill away from flood and erosion hazards. These are established to avoid damages from flooding and erosion and also to avoid restricting the flow capacity of the floodway. Keeping the floodway clear of development can reduce the risk of damage to neighbouring properties and reduce disruptions to natural river processes. Setbacks are measured from the natural boundary of the river, stream, lake or other water body unless otherwise specified.

Flood Construction Levels – Flood Construction Levels (FCLs) are the Designated Flood Level plus an allowance for freeboard and are used to establish the elevation of the underside of a wooden floor system or top of concrete slab for habitable buildings.

[2] www.env.gov.bc.ca/wsd/public_safety/flood/brochur3.html (accessed March 2010).

In the case of a manufactured home, the ground level or top of concrete or asphalt pad, on which it is located shall be equal to or higher than the above described elevation. These are used to keep living spaces and areas used for the storage of goods that could be damaged by floodwaters above predicted flood levels. In some locations, specific FCLs have been established in relation to a particular benchmark, such as the geodetic datum. Otherwise, FCLs are typically referenced as an elevation above the natural boundary of the water body in question. The designated flood and the designated flood level are used in determining the FCL. In cases where the FCL has been determined, it should be taken into consideration together with an appropriate setback requirement.

2.2.2 Pros and Cons - Floodplain Management

Pros:

- In most cases, guiding community development outside of flood prone areas or above predicted flood levels can provide the most effective and affordable protection against flood hazards.

Cons:

This approach may be less practical in the following circumstances:

- Setbacks may not be palatable in communities with limited developable land outside of flood hazard areas.
- Floodproofing poses many challenges for infill development in areas that were previously developed without floodproofing.
- Areas with soft, compressible soils have significant challenges when implementing floodproofing with fill.

2.3 Flood and Erosion Protection Works

2.3.1 Principles and Practices - Flood and Erosion Protection Works

Flood protection works are an integral part of flood hazard management in BC. Collectively throughout the province, these works have likely averted hundreds of millions of dollars in flood damages. Current approaches to management of flood protection works have been largely successful. However, many flood protection works have not been significantly tested by a flood event equal to, or larger than, the design flood (e.g., 1 in 200 year flood event or flood of record).

Diking in BC started as early as 1864. Today, there are 140 diking systems in British Columbia with a total length of over 1000 km protecting 120 000 ha of valuable land. In the Lower Mainland area alone, over 50% of the population, together with $13 billion in development, are dependent on the integrity of 600 km of diking, 400 floodboxes and 100 pumpstations.[3]

The roles and responsibilities described in the following section are excerpts from the report *Comprehensive Management for Flood Protection Works* (Fraser Basin Council 2001).

[3] www.env.gov.bc.ca/wsd/public_safety/flood/brochur2.html (accessed March 2010)

These roles and responsibilities are in accordance with the *Guidelines for the Management of Flood Protection Works in BC* under the authority of the *Dike Maintenance Act*.

The Inspector of Dikes, under powers conferred by the *Dike Maintenance Act*, regulates dikes and diking authorities, and is responsible to establish provincial standards for the design, construction, operation and maintenance of dikes through the provincial Dike Safety Program. The provincial Dike Safety Program is delivered through the Deputy Inspector of Dikes in each region. Provincial responsibilities include:

- approval of all works in and about dikes;
- monitoring and auditing the owner's dike management program;
- issuance of orders to protect public safety (where necessary); and
- regulating Diking authorities.

The following are a few examples of the relevant legislation pertaining to flood hazard management:

- Provincial *Dike Maintenance Act*
- Provincial *Emergency Program Act*
- Provincial *Water Act*
- Federal *Fisheries Act*

BC has published several guides and reports to assist local diking authorities in carrying out various management activities (see Appendix 6.2 and/or www.env.gov.bc.ca/wsd/public_safety/flood/structural.html for more information or to download relevant documents.

Flood Protection Dikes

A dike is "an embankment, wall, fill, piling, pump, gate, flood box, pipe, sluice, culvert, canal, ditch, drain, or any other thing that is constructed, assembled, or installed to prevent the flooding of land (*Dike Maintenance Act*). In some cases, dikes are located near or along riverbanks; in other cases, they are set back some distance from the river. Dikes are designed and constructed to meet engineering standards, taking into account the design flood level, which is typically a 1 in 200 year return frequency. In the lower Fraser River, the design flood is equivalent to the 1894 Fraser River flood of record.

A standard dike is a flood protection structure that meets, or has met, established provincial dike standards as regulated by the Inspector of Dikes under the *Dike Maintenance Act.* However, because of morphological, hydrological and other ongoing changes in and about river systems, a dike may or may not continue meeting current standards. The Deputy Inspector of Dikes office should be contacted to verify a standard dike's current status.

A non-standard dike is a flood protection structure that has a lower level of protection than that provided by a standard dike. Flood protection works that conform to this classification often protect rural agricultural lands and are sometimes referred to as agriculture dikes.

Flood Pumps and Flood Gates/Flood Boxes

Dike construction and development of lowlands requires "internal" drainage behind the dikes to be managed. For example, streamflows from tributary streams and drainage ditches that once flowed freely into the Fraser or other rivers, must now be collected and released through flood boxes or pumped through the dike system using pumps during high water periods.

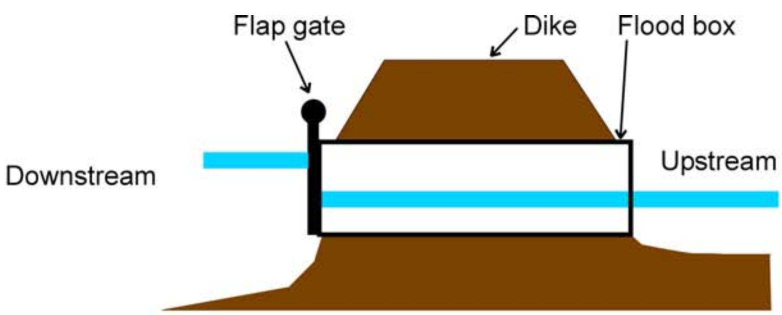
A flood box is a culvert or set of culverts that provides hydraulic connectivity through dikes that separate internal drainage areas and the receiving waters. Flood boxes are located where small watercourses intersect a dike or where estuaries have been reclaimed and isolated from tidal influence by a dike. They are also found at most pumping stations on larger streams. A flap gate mounted at the discharge end of the culvert allows the gravity discharge of flow in a downstream direction only, thereby acting as a check valve by preventing back flow from the mainstem when the mainstem water level exceeds that behind the dike (Thomson 2005).

Flood box with a top mounted gate. Photo courtesy of Alan Thomson

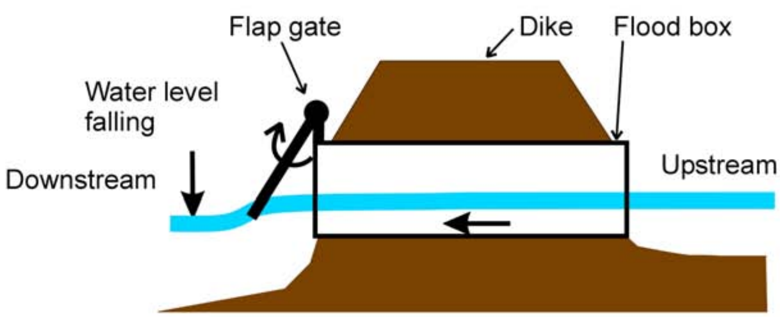
When flood gates are closed to prevent the mainstem water from passing through the dike, pumps are used to move water from the internal drainage system through the dike into the mainstem. Typical pumps found throughout the lower mainland are high speed vertical axle types whose operation is automatically controlled by water level sensors on both sides of the dike. Pumps will only turn on when water levels behind the dike reach a predetermined elevation. If there is more than one pump at a pump station, the pumps will cycle on as programmed and required to lower the water level behind the dike.

Pump stations are a particular challenge for both flood management and environmental protection (See Section 3.3). There may be significant operational costs such as hydroelectric costs of pumping water. There can also be significant maintenance costs such as cleaning debris from pump intake screens and/or trash racks. Pumping capability is particularly important to address seepage from the Fraser River during the freshet. A long period of high water (e.g., several weeks) may result in water seeping through diking systems or through the native soil profile. This water collects in drainage ditches and natural watercourses and must be pumped back into the mainstem. Pump stations are also required to manage drainage associated with storm events. Alternative stormwater management practices and master drainage planning are two approaches that may mitigate the demands on pump stations and other internal drainage infrastructure (Fraser Basin Council 2001). For example, by increasing stormwater retention and infiltration with wetlands preservation, catch basins, and groundwater recharge areas, less runoff enters the drainage system that is required to be pumped over the dike.

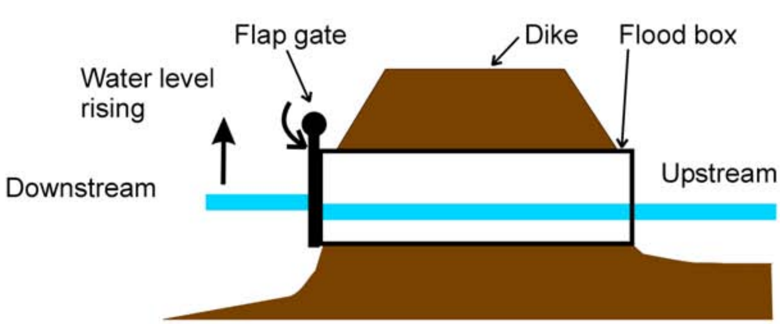
Basic Floodgate operation (illustration courtesy of Alan Thomson)



Flapgate remains closed when downstream water level is higher than the upstream water level. No water discharges through the flood box.



As downstream water level falls, or upstream water level rises, the gate slowly opens when upstream water level becomes higher than downstream water level.. Water then discharges through the floodbox into the downstream waterbody.



As downstream water level rises, or upstream water level falls, the flapgate closes when downstream water level rises above upstream water level. Upstream water pools behind the floodbox until the hydraulic head is again positive and the flapgate opens.

Erosion Protection

In locations where dikes are vulnerable to erosion because of their proximity to fast flowing rivers, erosion protection works such as riprap are used to prevent or reduce erosion and to ensure the integrity of the dike. Significant sections of dikes have been hardened with erosion protection. One study has estimated that “More than half of the outer banks of the Fraser River have been hardened in one form or another in the various sub-reaches (of the Fraser River) between Hope and Mission. The armouring ranges from 54% in the Hope sub-reach to a remarkable 73% in the Sumas sub-reach” (Rosenau and Angelo 2007).

Channel Maintenance and Modification

In order to pass flood waters more efficiently, historically authorities and private individuals have channelized watercourses. Channelization refers to the realignment, relocation, levelling and deepening of natural streams. Currently, channelization is not often used as a flood management strategy in BC as it has significant environmental implications and can have the opposite desired affect (NOAA 2004). Channelization however does still occur in smaller drainages in agricultural areas. In addition, in areas where localized accumulation of gravel or sand is understood to increase flood risk, removal of the sediment can occur. Management of river sediments must take into consideration the long-term patterns and rates of sediment deposition — i.e., the sediment budget. Generally, sediment removal should not exceed the average annual rate of deposition.

Channelization can cause some significant environmental and physical impacts, including:

- shortening of stream length;
- loss of wetted area;
- conversion of pool/riffle sequences into deep glides;
- loss of undercut banks;
- loss of floodplain-based habitats;
- loss of lateral heterogeneity, such as meanders and side channels;
- changes in sediment transport; and,
- channel erosion.

Channelized watercourse in Surrey, BC. Photo courtesy of Alan Thomson

All of these outcomes reduce the availability of suitable habitat for fish (Barrett 2006) and can destabilize the river channel, resulting in shifts in the location of the main channel and changes in erosion and sedimentation patterns.

Straightening channels and reducing stream or riverbed roughness allows for greater volumes of water to pass through the system more quickly. Roughness refers to the amount of friction or resistance that the stream or riverbed applies to the flow of water in the watercourse. Less roughness equates to higher water velocities. This results in higher peak episodes over shorter periods of time than would occur naturally. Less water is dissipated to underlying aquifers or evapotranspires through riparian vegetation (Lyle 2001). Heightened flood peaks can also cause severe erosion along banks.

Sediment Management Plans are often integral components of Dike Operation and Maintenance Manuals to ensure the conveyance of the design flood event and protect public safety and property. The sediment management plans are prepared with input and agreement of the environmental agencies. In the Lower Fraser River the Fisheries and Oceans Canada entered into a long-term Fraser River Gravel Removal Plan Agreement with the province to ensure a sustainable multi-year sediment management program. For the Vedder River, the Vedder River Management Authority oversee a management plan to ensure the integrity of the Vedder River floodway while maintaining and enhancing the fish and wildlife resources.

Dams, Reservoirs and Water Diversions

Dams, reservoirs and water diversions are not typically used as a flood management strategy in BC. However, when flood risks are elevated, such as when above average snow pack conditions occur, there may be an opportunity to operate dams and reservoirs in a way that helps manage the flood risk by holding back water and releasing it after peak flood flows have passed.

2.3.2 Pros and Cons - Flood and Erosion Protection Works

Pros:

- Properly located, designed, constructed and maintained flood protection dikes can provide effective and reliable protection against flood events that are within design standards.
- Flood protection works are beneficial in protecting development and historic settlements that were established within flood prone areas before floodplain management policies were developed.

Cons:

- Construction, operation, maintenance and rehabilitation of flood protection works are very costly.
- The effectiveness of flood works is limited by design standards (i.e., diking systems can be overtopped, undermined and fail due to erosion, seepage, saturation and collapse). A lack of regular maintenance could increase the likelihood of a dike failure.
- The existence of dams and dikes can exacerbate a flood hazard, particularly during flood events greater than the design of those structures. A dam or dike failure can result in a large volume of water being released at one time. If flood waters have entered a floodplain behind a dike, the dike holds the flood waters on the floodplain because the water cannot freely flow back into the main channel. Pumping is required, and the flood event may last for an extended period.
- Riverside dikes restrict the flow capacity and conveyance of the channel, which can result in higher flood levels and increased flood risk to communities upstream compared to setback dikes, which allow more room for the river.
- "Although permitting of individual (erosion protection) projects may attenuate localized negative effects to streambanks, it may not effectively curtail cumulative effects to a watershed" (Schmetterling et al. 2001).

2.4 Emergency Management

The following is intended as a general overview of emergency management. There are relatively limited opportunities to integrate environmental protection and stewardship into emergency management responsibilities; therefore, a detailed explanation it is beyond the scope of this report. However, emergency management is an important part of integrated flood hazard management, and there is some potential for environmental stewardship, so an overview is included in this section.

2.4.1 Principles and Practices - Emergency Management

Emergency Planning and Preparedness

Emergency planning and preparedness involves government, the private sector, utilities and infrastructure owners, non-government organizations, and families and individuals. The underlying principle is to plan and prepare for a flood event. It involves understanding the risks and vulnerabilities associated with flooding and putting plans in place to minimize them. Some generic practices, such as preparing emergency kits, apply across a wide range of disasters. However, there are also practices that apply specifically to flood hazards, such as removing vulnerable materials, equipment and property from flood prone areas prior to a flood event.

Emergency Response and Urgent Flood Mitigation Works

Emergency response and urgent flood mitigation works involve many activities and initiatives to respond immediately prior to and during a flood event. For example, sandbags and gabion baskets may be used to protect communities by augmenting or strengthening and reinforcing pre-existing flood protection works. During severe flood events when there is a high probability of damage, emergency response may also involve evacuation of people and animals such as pets and livestock through the extraordinary powers of a declared (local or provincial) state of emergency under the *Emergency Program Act*.

Emergency Recovery (Disaster Financial Assistance and Flood Insurance)

Emergency recovery after a flood event involves the replacement and restoration of uninsured essential property (homes, businesses and communities) to pre-event conditions. Depending on the severity of the flood, this may involve clean up efforts, repairs and rebuilding of properties, buildings and infrastructure. A number of activities may also be required to restore the continuity of services provided by businesses, infrastructure, government and community organizations. Flood insurance is available for commercial and industrial operations but not private residences. However, the Disaster Financial Assistance program provides assistance to properties that cannot be privately insured against flood damages. The program is administered by the BC Ministry of Public Safety and Solicitor General.

2.4.2 Pros and Cons - Emergency Management

Pros:

- Emergency management provides many important functions and benefits when preventative approaches to flood mitigation are overwhelmed or exceeded by a flood event.
- Even when a flood is imminent, many emergency management activities can be undertaken to protect public safety and property.

Cons:

- Emergency management is reactive, and although it can mitigate the impacts of flooding, it cannot be expected to prevent flood damages and other adverse impacts.
- Emergency management can be very costly, particularly recovery efforts such as clean up and rebuilding after flooding has occurred.

In 2008 a self-regulating tide gate at Nelson Creek. Self-regulating tide gates are now proposed for five lower Fraser River tributaries.

3.0 Environmental Stewardship

Not surprisingly, historic approaches to flood hazard management have primarily focused on protecting public safety and reducing flood damages to public and private property as well as critical infrastructure. Flood management policies and practices were developed and implemented with little or no consideration of the natural environment. More recently, public interest, legislation and regulatory requirements have evolved, and there are now evolving roles and responsibilities for flood hazard managers to undertake environmental protection while maintaining a high level of flood protection for communities. This section of the report profiles the different management approaches through the lens of environmental stewardship. The section describes different principles and practices that can help improve environmental performance and it also describes several pros and cons from an environmental perspective.

3.1 Flood Hazard Information and Planning

3.1.1 Principles and Practices - Flood Hazard Information and Planning

Environmental Monitoring and Assessments

These studies can be used to gain an understanding of the environmental values, features and functions of water bodies that pose a flood risk. They may also be used to identify the positive or negative environmental impacts of different flood management options, as well as policies or practices to help mitigate adverse environmental impacts.

3.1.2 Pros and Cons - Flood Hazard Information and Planning

Pros:

- Environmental monitoring and assessments provide managers with a better understanding of the environmental features and functions, including fish species presence and habitat values, that may be impacted by flood hazard management policies and/or practices.
- In most cases, environmental monitoring and assessments are a required component of the permit approval process.
- Environmental monitoring and assessments can used to design, construct and implement flood management policies and practices in a way that optimizes flood protection and minimizes environmental impact.

Cons:

- There are no obvious environmental disadvantages associated with environmental monitoring and assessments. However, these activities can increase the costs of a flood management study or project.

3.2 Floodplain Management

3.2.1 Principles and Practices - Floodplain Management

Setbacks and Floodproofing

As described in section 2.2, the two most common approaches to floodplain management include setbacks and floodproofing. Setbacks from flood hazards can reduce flood and erosion damages while also conserving environmental features and functions, particularly along riparian corridors and within floodways. Directing development away from flood prone areas can provide net benefits for habitat features within the floodplain. Building habitable living space above predicted flood levels through the use of floodproofing practices can help prevent or reduce flood damages and can also prevent pollutants from entering floodwaters during a flood event.

Retention of Floodplains and Wetlands

Floodplains and wetlands can disrupt the energy of flood waters by allowing water to spread out spatially and temporally over vegetation. Floodplains also provide connections to abandoned streambeds, sloughs, and wetlands thereby reducing the amount of water in the mainstem of rivers and streams. Floodplains reduce flood volumes in three ways:

1. precipitation is intercepted by floodplain vegetation, which results in decreased surface runoff;

2. water stored on a floodplain will partially evapotranspire into the atmosphere; and

3. water can percolate back into aquifers (Lyle 2001).

Alternative Stormwater Management

In some cases, flood protection works are intended to manage flooding from stormwater runoff. Traditional approaches to stormwater management involve collecting rainwater and conveying it into receiving water bodies as quickly as possible. This can adversely affect water quality and quantity and aquatic habitat. Stormwater can pick up a variety of pollutants from roadways and parking lots. The presence of impervious surfaces and storm sewer systems can cause natural hydrological systems to become more “flashy” systems with higher and more frequent peak flows and periods of lower flows. Increased peak flows can cause increased erosion and downstream sedimentation. Many of these impacts can be reduced by using alternative stormwater management practices. Source control measures such as rain gardens, swales and enhanced soils, stormwater retention ponds, wetlands preservation, limiting impervious surfaces and protecting groundwater recharge areas all provide environmental benefits and reduce demands on traditional stormwater management and flood protection systems.

3.2.2 Pros and Cons - Floodplain Management

Pros:

- Floodplain areas include important and sensitive habitat features such as streams, wetlands and riparian corridors; therefore, limiting or avoiding development in floodplain areas can help protect the natural environment.

- Setbacks from watercourses and water bodies can help maintain the quality and quantity of aquatic and riparian habitat.
- Keeping development out of floodplain areas can help to maintain natural hydrological cycles.
- Keeping development out of floodplain areas can help prevent pollutants and hazardous materials from entering watercourses generally and also from entering floodwaters during a flood event.

Cons:

- Concentrating development outside of floodplain areas (e.g., on uplands and hillsides) could simply result in redirecting environmental impacts towards other sensitive habitats.

3.3 Flood and Erosion Protection Works

3.3.3 Principles and Practices - Flood and Erosion Protection Works

There are growing interests and evolving regulatory requirements related to improving the environmental performance of flood protection works, and thus, reducing adverse environmental impacts. The federal policy regarding fish habitat is to work towards a net gain in total habitat. Careful planning is required to simultaneously achieve objectives for flood protection and environmental stewardship.

The roles and responsibilities described in the following section include excerpts from the report *Comprehensive Management for Flood Protection Works* (Fraser Basin Council 2001). It should be emphasized that all management activities associated with flood protection works should include consideration of environmental stewardship and related best practices. Fisheries and Oceans Canada and the BC Ministry of Environment have certain responsibilities for protecting environmental features and functions, including:

- reviewing the design, construction and maintenance of flood protection works;
- providing advice regarding environmental impacts; and
- ensuring compliance with relevant environmental regulations.
- authorizing any activity that causes a Harmful Alteration, Disruption or Destruction of fish habitat (HADD) as defined by the federal *Fisheries Act.*

Environment agencies can provide advice and technical support to encourage the protection of fish and wildlife habitat. In some cases, other agencies, such as the Canadian Wildlife Service of Environment Canada, may have an advisory role. All levels of government need to work together to resolve conflicts between flood protection and habitat protection.

A variety of strategic approaches and techniques may help resolve conflicts between flood protection and environmental stewardship. These include:

- improving communication and coordinated management efforts among local, provincial and federal field staff and policy makers;

- developing work plans and conducting on-site visits by multiple agencies and interests (e.g., diking authorities, the Inspector or Deputy Inspector of Dikes, habitat engineers, conservation officers, landowners);

- developing public education programs about the importance of protecting both public safety and the environment; and

- integrating environmental protection into the design and construction of new flood protection works or during the rehabilitation of existing works.

Different solutions may apply in different circumstances; therefore, collaboration and creative problem solving will be necessary to resolve environmental protection issues in relation to specific flood protection projects.

Flood Protection Dikes

Many of the adverse environmental impacts associated with dikes are related to their location. Dikes located along riverbanks often include erosion protection works such as riprap because they are exposed to the river's erosive forces. Opportunities to retain riparian vegetation in these locations are limited. By comparison, setback dikes allow a more natural river corridor to be maintained.

Setback Dikes: The following section is based on excerpts from the report *Comprehensive Management for Flood Protection Works* (Fraser Basin Council 2001).

Setback dikes (Figure 1) are constructed some distance inland from the riverbank and from the erosion hazards of the river. These dikes offer all of the flood mitigation benefits of riverside dikes, although the amount of area protected is reduced. Numerous additional benefits are associated with setback dikes, but there are also some challenges, namely the high cost of land, and competition for a limited land base (i.e., any land on the riverside of a setback dike is unprotected and therefore is less developable). However, unprotected floodplain lands can be used as natural and recreational corridors, and for some agricultural activities.

There are several barriers to overcome when retrofitting or changing the existing alignment from riverside dikes to setback dikes. These include increased capital costs, acquiring new right-of-ways, and dealing with opposition from landowners who are currently protected by a riverside dike but may be outside of the flood protection system if dikes are relocated inland.

Nevertheless, the construction of setback dikes should be considered because they provide a number of social, economic and environmental benefits:

- they allow for a wider floodway and increased channel capacity (i.e., flood waters can spread out across a wider channel, which results in lower water surface levels and reduced probability of flood damages, evacuation and associated social hardship);

- they are removed from sustained river forces and require less erosion protection, which results in reduced costs for dike maintenance, restoration and flood fighting; and

- they improve environmental stewardship by protecting the quantity and quality of available habitat (e.g., retention of riverbank vegetation, sloughs, and back channels).

A setback dike with mature vegetation retained in the river corridor.
It is also important to retain understory vegetation.

The environmental and technical benefits of setback dikes could be better addressed if land and right-of-way costs were eligible for cost-sharing through existing infrastructure funding programs. Setback dikes may be perceived as being impractical and costly. However, the benefits outlined above suggest they may be less costly and more beneficial in the long term, particularly if environmental costs and benefits are factored in, and if life-cycle analysis is undertaken. The initial cost of land acquisition for setbacks could be considered part of the legitimate cost of good dike design and alignment. Further, the initial capital costs of setback dikes could, over time, be offset by savings in maintenance costs, flood damage compensation payments and possibly by generating revenue by providing public access to greenways or other recreational amenities.

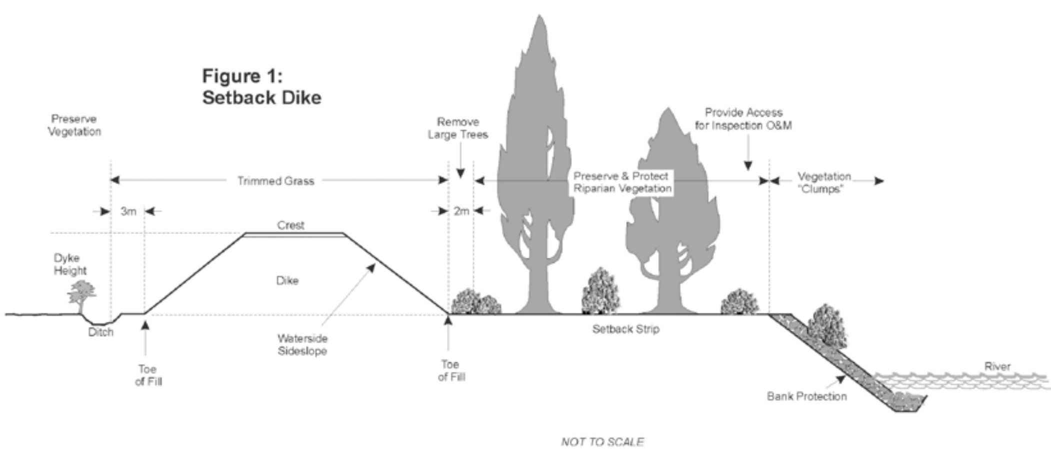


Figure 1: Setback Dike

Vegetation Management

The following section includes excerpts from the *Environmental Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment* (BC MELP and Fisheries and Oceans Canada 1999). These guidelines were published in 1999. It may be timely for a review of the guidelines to learn from the last decade of experience within BC and other jurisdictions. Additional research in this field may also be appropriate.

Vegetation management guidelines for flood protection dikes are determined by the public safety need for visibility during inspection, access for efficient operation and maintenance, and minimization of detrimental effects to dike fills and bank protection. Vegetation management should, where possible, include efforts to preserve and enhance fish and wildlife habitat in the overall stream/river corridor. Vegetation (including roots and canopies) can improve both dike safety and habitat through soil conservation and erosion control.


f

This is an example of vegetation retention along the Cowichan River.

The following are excerpted or paraphrased from the environmental guidelines for vegetation management.

1. Vegetation management (other than removal of noxious weeds) in environmentally sensitive bird nesting areas should be scheduled annually from September 1 to March 31.

2. Dike crests should be kept clear of vegetation other than trimmed grass, and should be accessible, with due regard for inspection sightlines.

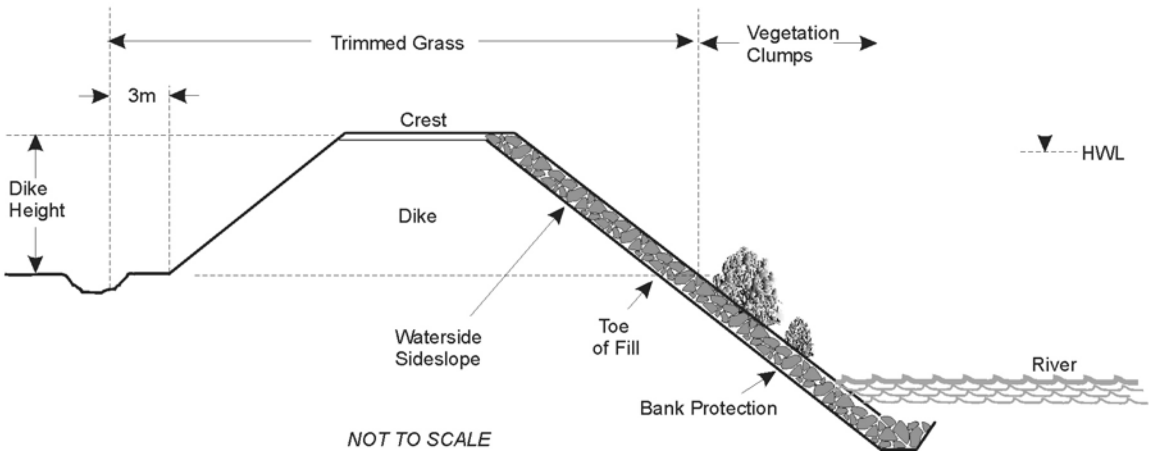
3. Dike sideslopes:

    a) The landside sideslope of dike fills should be kept clear of vegetation other than trimmed grass.

    b) The waterside sideslope of riverside and setback dike fills should be kept clear of vegetation other than trimmed grass to the toe of dike fill as determined by the dike height..

4. Riverside dikes with bank protection: (Figure 2) The waterside sideslope of riverside dikes with bank protection should be cleared above the toe of fill as per guideline 3b. Portions of bank protection extending below the dike height may contain vegetation clumps as per guideline 7

Figure 2: Riverside Dike with Bank Protection



5. Overwidth dikes: Subject to ensuring road safety and road maintenance needs as applicable, vegetation may be retained to maintain or enhance environmental values on the sideslopes of overwidth dikes. Provided dike safety is not affected, trees may be retained on the sideslopes of overwidth dikes without bank protection, provided they are spaced and pruned. Trees should be thinned, topped, or removed (especially if higher than 15 metres) and the lower 1.5 metres of the trees should be regularly pruned of branches to maintain inspection sightlines.

6. Bank Protection: Bank protection located on natural riverbanks and/or on overwidth dikes may contain clumps of controlled vegetation as per guideline

7. Vegetation Clumps: Controlled vegetation clumps, which are devoid of potentially large growth and/or excessive vegetation are acceptable in riprap bank protection or on overwidth dikes. Controlled vegetation clumps may contain shrubs, which do not obstruct inspection visibility, displace riprap, or create holes. To reduce future vegetation maintenance requirements, it is recommended that vegetation be selected that will not exceed 5 to 6 metres in height.

8. Flood Protection Structures: Areas within 5 metres of flood boxes, pump houses and similar flood control structures shall be kept clear of all trees as well as potentially large and excessive vegetation.

9. Overbank: It is generally recommended that vegetation on the overbank strip between a setback dike and the riverbank be preserved and protected with consideration for access for inspection and maintenance of bank protection.

10. Variations: Where environmental agencies have significant concerns for areas of sensitive habitat (such as historically overgrown works and/or FREMP red-coded areas), variations from these guidelines may be considered to increase protection of habitat where practical and economic, provided public safety is not compromised. Such sites will be subject to joint review by the office of the Inspector of Dikes (IOD), DFO and/or Ministry of Environment habitat officers. All variations from these guidelines which may effect public safety must be approved by the office of the IOD.

11. Annual Workplans: To facilitate orderly and timely environmental reviews, it is strongly recommended that annual vegetation management workplans be submitted, particularly for sensitive habitat areas.

Fish Access to Off-Channel Habitat

Small streams are vital to the health and survival of coho salmon and cutthroat trout stocks. Coho in smaller tributaries and side channels have greater growth rates than those in mainstem rivers (Barrett 2006). Spring through late summer is the prime feeding and growth period for coho and cutthroat. It is also the period of highest predation and competition. Small streams with low to medium gradients tend to have larger proportions of edge habitats. These habitats, paired with overhanging riparian vegetation, offer access to food and cover from predation. Small streams also provide critical overwintering habitat by having lower water velocities and warmer water temperatures than mainstem rivers, and by offering cover from predation (Barrett 2006).

The most important practices for improving and maintaining fish access to off-channel habitat include:

- retaining natural hydrological connectivity between mainstem and tributary habitats by not establishing new flood protection dikes;

- retaining natural connectivity between mainstem and side channel/back channel habitats by using setback dike configurations;

- diking off channel habitats (with a setback dike) thus negating the need for barriers at the confluence of the mainstem and side/off channel habitats; and

- restoring habitat connectivity by using engineering designs and operational procedures that better enable fish migration through flood gates and pumps.

Fish-friendly Pumps and Flood Gates/Flood Boxes

The following section is based on excerpts from two comprehensive reports (Thomson 1999, 2005 (see Appendix 6.4 References)).

In recent years, there has been increased interest in building dike infrastructure that is more fish friendly than traditional infrastructure. Several diking authorities in the lower mainland and on Vancouver Island have installed archimedes screw pumps or reconfigured flood boxes to allow for safe fish passage past the dike . However, the vast majority of pumps used at pumping stations are still high speed vertical impellor types that cause significant fish mortalities, especially during the smolting season (spring). Fish passage studies have found that the use of high speed, axial flow propeller-type pumps at several facilities along the Fraser River has resulted in mortality rates of 25–70% for entrained coho salmon smolts. In contrast, large screw pumps whose capacity is comparable to more conventional axial flow or centrifugal pumps inflict injury or mortality on less than 2% of the entrained fish. Variations on the centrifugal pump also hold promise of reducing fish mortality. It may be possible to retrofit existing pump stations by replacing conventional impeller pumps with different designs that can meet both drainage pumping and fish passage requirements. Given that intake structure dimensions and configuration are substantially different for a vertically mounted impeller than an inclined screw pump, it may be significantly more cost-effective to build new facilities (e.g., the Archimedes screw pump installed at Erickson Creek and other locations in Surrey) than to retrofit existing ones. Pump retrofitting is expensive. There are bypass options: structures, fish salvage and transport, and scheduling to avoid conflict with fish migration.

Traditional flood boxes are known to impede fish migration. Several reports (Thomson 1999, 2005; Giannico 2004) recommend that flood boxes incorporate as many of the following prioritized design features to facilitate fish migration:

- the design allows water to flow in either direction at all times except during flood or high water periods (as with self-regulating gates). If this condition cannot be met (as with top or side mounted gates), then the gate should be side mounted;

- the box is installed at an elevation that ensures the water depth in the culvert is always sufficient for fish migration;

- the box is sized and installed at a very low gradient such that velocity barriers do not exist for juveniles and adults both in the gate area and the culvert during most discharge periods; and

- the flood box requires no external power source or human operator to operate effectively and safely and to achieve flood-proofing objectives.

Many diking districts and smaller municipalities do not have the resources to completely replace traditional flood boxes with more fish friendly ones. Fortunately there are options to increase fish migration past the flood box without replacing the entire structure. In the lower mainland, side mounted aluminium gates are now routinely installed. Flood boxes at several of the newer lower mainland pumping stations contain at least one side mounted gate that is often installed at a lower elevation than other top mounted gates. In 2008 a self regulating gate was installed in the Nanaimo River estuary on the Snuneymuxw First Nation Reserve. The gate allows for tidal flushing of channels on the landside of flood protection works. The gate is operated using a passive hydraulic system and is the first installation of its type in British Columbia (Craig Sutherland, pers. comm). Self-regulating tide gates are proposed for five lower Fraser R. tributaries (LGL *et al.* 2009).

A closer look at the self-regulating tide gate installed in the Nanaimo River estuary.
Photo courtesy of Craig Sutherland.

Other less expensive options to traditional top mounted cast iron gates include gates made of lighter materials and gates that combine top mounted gate features with controlled open periods. In 1997 the Surrey Dyking District replaced an old small flood box with a 600 mm ABS plastic pipe coupled with a top mounted PVC plastic flap gate with metal stiffeners, fiberglass seat and neoprene seals. According to officials, the gate opens easily under low flows, has required no maintenance and satisfies flood proofing requirements, and costs two-thirds the amount for a traditional corrugated steel pipe with a cast iron flap gate (Thomson 2005).

Combination gates are a clever yet simple and very successful alternative to the chaining open of flap gates. The system allows unimpeded fish access to an estuary behind dikes and allows for assured flood protection during high water periods. It combines the attributes of a sluice gate and a flap gate, and is appropriately named a combination gate. The gate of a sluice gate assembly is replaced by a top mounted flap gate. When the flap gate is raised, water and fish can pass unimpeded through the culvert in either direction. When the flap gate is lowered over the end of the culvert, the flood box operates as a typical flood box described earlier in this report. Operations staff can easily and safely raise or lower the gate from an accessible position high on the dyke. It may be desirable to automate the gate’s operation.

A combination gate (Flap gate and sluice gate combined) is installed in Brown Slough, southeast of La Conner, WA. Photo courtesy of Alan Thomson.

As pumps and flood boxes are rebuilt, there may be an opportunity, or perhaps a requirement, to implement fish-friendly technologies such as Archimedes screw pumps, side-mounted flap gates or self-regulating tide gates to better enable fish passage. If fish-friendly pumps can be fitted to existing pump station housing, the costs associated with upgrades of fish-friendly pumps could be significantly reduced.

Channel Maintenance and Modification

In some cases, channel maintenance and modification is identified as a relevant means of providing flood protection. However, there remains much uncertainty associated with this management practice, both in terms of the effectiveness for flood management and the associated environmental impacts. Each watercourse is different. Where removal of sediment within rivers and streams cannot be avoided, certain measures can be taken to mitigate damage to the environment, including the following:

- Environmental assessments are important for determining the presence of fish and other aquatic species and the availability and use of habitat features, and for developing recommendations for mitigating adverse environmental impacts.
- Environmental monitoring during and after sediment removal operations is important for measuring the performance of the operations and for detecting any associated impacts.
- Sediment removal should target localized areas where there is a demonstrated increase in flood risk due to sediment accumulation.

- As a general rule, sediment removal rates should be within the sediment budget (i.e., rates of removal should not exceed rates of accumulation).

- For some watercourses, it may be appropriate to target sediment removal operations toward instream pools that have been identified and/or designated for this purpose. "Such pools are used to minimize the build-up of stream-bed materials in downstream areas by trapping mobilized sediments. These traps are regularly excavated and this can thereby minimize dredging maintenance in downstream areas as the pool then becomes the primary footprint area for cleaning. Deep pools also act as refugia areas for adult and juvenile fish. As a result, this method of ditch maintenance achieves two objectives and helps minimize adverse effects" (Rosenau and Angelo 2005).

- Sediment removal must be conducted "off-line" through the use of flow diversion around the work site.

- The complete environmental impact of sediment removal remains unknown in many cases.

With respect to channel maintenance and modification, Barrett (2006) recommends the following options:

- using rock-weirs to replicate natural pool:riffle ratios of 1:1;

- maintaining channels by hand to target flow conveyance limitations while limiting impacts to habitat features;

- emulating natural channel forms;

- retaining undisturbed areas within maintained reaches to provide important refugia habitat; and

- replanting riparian areas.

3.3.4 Pros and Cons - Flood and Erosion Protection Works

Pros:

- When it comes to environmental stewardship, there are few if any advantages to the use of flood and erosion protection works.

- Flood protection works can be designed, constructed and maintained with consideration of environmental values and benefits; however, there are likely to be adverse environmental impacts in most cases other than setback dikes.

Cons:

Historically, flood protection works have had significant and numerous adverse environmental impacts, including the following.

Flood Protection Dikes, Pumps and Flood Gates

- Dikes, pumps and flood gates create barriers to fish migration from rivers into side channels, sloughs, tributaries, wetlands and other "off-channel" habitat.

- Pumps with high velocity impellors can entrain and kill fish as they attempt to migrate from off-channel habitat to the mainstem.

- Riverside dikes and bank armouring can cause the loss or degradation of riparian habitat.

- Diking systems separate floodplains from the hydrologic system of the mainstem of the river. This results in significant changes to, and/or loss of, natural disturbance regimes, including sediment transport and deposition in the floodplain, and recharge of groundwater aquifers. Fast-moving rivers pick up sediment and deposit it in lower reaches of the river or other receiving water bodies, such as the ocean. As a result, wetlands are not renewed with alluvium during floods, and they can no longer absorb contaminants, which may be transported by flood waters.

- Annual dike maintenance includes control of vegetation and burrowing animals to protect the integrity of dike fills. It also ensures access to the dike is maintained and inspections can be conducted effectively. Vegetation control can greatly enhance the effectiveness of monitoring and controlling burrowing animals; however, it simplifies both aquatic and terrestrial habitat by reducing riparian vegetation and associated cover and food sources for fish and wildlife. Setback dikes mitigate these impacts. If vegetation maintenance occurs when birds are nesting, it can also result in direct mortality.

Water Quality Impacts of Flood Protection Structures

- Dikes and their associated structures affect the way water flows in flood-protected tributaries of mainstem rivers. They also affect water quality. Depending on the specific physical characteristics of the tributary as well as land and water uses, water quality can range from little impact to lethal to many aquatic life forms including fish.

- Pumping stations and/or flood boxes are located at the confluence of all tributaries to mainstem or receiving waters whose floodwaters are contained by dikes. In theory, flood boxes allow for gravity drainage when tributary water levels exceed that of the receiving waters, particularly when the flap gate is in good repair and opens easily, and the culvert is unobstructed. However, studies have found that older heavy top-mounted cast iron flap gates do not open easily under low and lower head conditions (Thomson 2005). As a result, waters behind the dike do not drain efficiently and water stagnation and water quality degradation can result.

- Water quality is further degraded by the common practice of placing stop logs in front of flood box entrances during summer months. In many agricultural areas in the lower mainland, irrigation water is often drawn from local water courses that drain through dikes. Stop logs retain high water levels in the watercourse that would normally drain to the mainstem (e.g. Fraser River) and allow irrigators to pump drainage water onto their fields. This practice results in water stagnation, elevated water temperatures and associated lower dissolved oxygen levels that can stress fish or cause mortalities.

- In areas that are under tidal influence, traditional flap gates can remain closed for extended periods particularly during low flow periods, during high tide cycles or if drainage pumps are activated. Water quality parameters that can change in stagnating water behind the dike include water temperature, salinity, dissolved oxygen and heavy metals concentrations (Giannico 2004). Water temperature in particular typically rises when water pools behind the dike. During summer periods when fish passage requirements are lower, this slug of higher water temperature forms a thermal barrier for inmigrating fish when the gates eventually open (Souder 2006).

Erosion Protection

- "Riprap may provide habitat for juvenile salmonids and bolster densities on reaches of streams that have been severely degraded. However, riprap does not provide the intricate habitat requirements for multiple age classes or species provided by natural vegetated banks. Streambanks with riprap have fewer undercut banks, less low-overhead cover and are less likely than natural stream banks to contribute large woody debris to the stream." (Schmetterling et al. 2001).

- "This hardening of its banks prevents the river from moving laterally, thus interfering with the storage of sediments throughout the reach (Ham 2005) and preventing habitat renewal and maintenance (e.g., recruitment of woody debris, cleaning and sorting spawning gravel, scouring holding areas)" (Rosenau and Angelo 2007).

Channel Maintenance and Modification

Channelization and subsequent maintenance often involves the removal of large woody debris and riparian vegetation, which:

- virtually eliminates an important food source for fish (insect drop);

- converts the channel nutrient sources from allochthanous (terrestrial-based) to autochthanous (instream-based);

- eliminates shade, a temperature-regulating feature for instream water temperature;

- reduces cover that provides protection from avian predators; and

- exposes fish to increased levels of solar radiation; and,

- reduces diversity of flow patterns and velocities in the channel.

Channel Maintenance in the Fraser River

Channel maintenance and/or modification can result in the loss or degradation of instream habitat. For example, the impacts to fish and fish habitat in the Fraser River gravel reach[4] due to extensive bar scalping and instream extraction techniques include:

- increased mobilization of fine sediments, which smother aquatic life, due to the removal of the coarser and cleaner outer layers of gravel and cobble during or immediately after the excavation phase;

- removal of the less common coarser fractions of gravel and cobble from the surface of the streambed, which are preferentially used as rearing habitat by some important species (e.g., juvenile chinook salmon);

- lowering of the surface elevation of the large gravel bars, resulting in losses of relatively rare high-elevation freshet rearing habitats;

[4] The gravel reach is the section of the Fraser River between approximately Hope and Mission where the riverbed is composed primarily of gravel sediment.

- disruption of the normal fluvial processes of gravel bar and island building, which are a particularly rare habitat features in the Fraser gravel reach;
- destabilizing of the stream in the local area, which can result in fish mortalities and habitat losses;
- loss of high value habitat locations, such as side channels, and reduced local recruitment of gravel, which is important for spawning and rearing (e.g., white sturgeon appear to selectively use coarse, stable substrates in the gravel reach's side channels for reproduction [e.g., Minto, Greyell and Herrling channels]) (Rosenau and Angelo 2000, 2007; Perrin et al. 2003).

3.4 Emergency Management

3.4.1 Principles and Practices - Emergency Management

- **Emergency Flood Mitigation Works** – Although there may be little time to consider environmental features during emergency flood preparations, there are still opportunities for environmental protection. This is particularly true when there is some advanced warning of elevated flood risk. For example, in the Fraser River Basin, high snowpack conditions and a cool spring are precursors of flood risk on the Fraser River and may trigger advanced planning over a period of weeks and months. (See City of Richmond example that follows this section of the report). In other cases, flood events manifest very rapidly and there may be only hours or days for planning and construction of urgent mitigation works.
- **Emergency Flood Preparations** – An important practice when making emergency flood preparations is to remove pollutants and hazardous materials from areas where they may be exposed to flood waters. For example, in homes located within a floodplain, household cleaners, paints, solvents, batteries, etc. should be moved from the basement or ground level up to the second storey to reduce the likelihood that they will be exposed to flood waters. The practice of storing or moving hazardous materials outside of flood risk zones also applies to agricultural, commercial, industrial and institutional facilities.
- **Emergency Plans** – When emergency flood plans are developed, they should include an inventory of hazardous materials as well as a plan for proper storage during a flood event to prevent environmental contamination.

3.4.2 Pros and Cons - Emergency Management

Pros:

- Emergency planning and preparedness efforts can help ensure hazardous materials and other pollutants are properly stored so they do not enter flood waters during a flood event.
- If urgent flood mitigation works are successful at preventing flooding, they can reduce environmental impacts by preventing hazardous materials and other pollutants, which may be located in the floodplain, from entering flood waters.
- Urgent works can also help protect natural habitats that might be adversely impacted by flood damages.

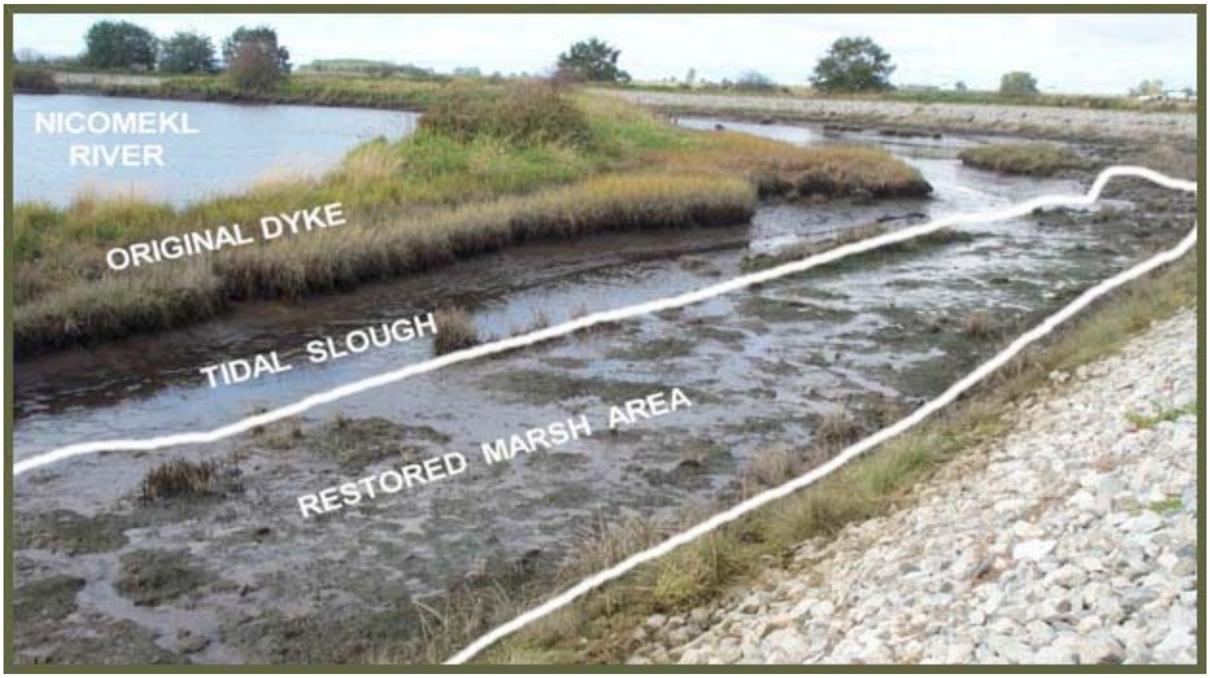
Cons:

- There is typically little or no time for proper environmental assessments of urgent flood mitigation works when a flood event is imminent.

- In the lead up or response to a flood emergency, there is little opportunity to give consideration to the natural environment. For example, the design and construction of urgent flood mitigation works, such as emergency diking, erosion protection, gabion baskets and sandbagging, and associated works, such as emergency access, may have to proceed very quickly. In such circumstances, proper design and construction practices may not be possible and environmental considerations may be compromised.

Cons:

- Concentrating development outside of floodplain areas (e.g., on uplands and hillsides) could simply result in redirecting environmental impacts towards other sensitive habitats.



The City of Surrey has looked at different ways to manage flood risk in the lowlands of the Serpentine and Nicomekl watersheds. Work to date has included creek reconstruction (Latimer Creek); construction of drainage pump stations, offset (setback) dikes, conveyance channels, flood cells and online sediment basins; and agricultural and fisheries enhancement works.

4. Some Best Practices and Innovations

This section of the report profiles a number of different case studies to illustrate several emerging and evolving best practices and innovations whereby flood management is taking into consideration stewardship of the natural environment. The intention is to demonstrate a number of different ways that flood management is being implemented with improved environmental performance compared with traditional or historical approaches. Examples are provided for different approaches to flood hazard management, including:

- flood hazard information and planning
- floodplain management
- flood protection works
- emergency management

Case studies include different sizes and types of communities, different regions of BC and different types of flood hazards. While the initiatives that follow can be characterized as “best practices and innovations”, it is recognized that these practices and policies will continue to improve and evolve over time. For example, twenty years ago, there was not a single fish-friendly pump within the Lower Mainland of BC. Over time a small number of communities like the Township of Langley and the City of Surrey designed and constructed fish-friendly pumps. Now an increasing number of communities are adopting this approach using different designs and operational procedures that best suit their local circumstances.

One of the objectives of this report is to share the knowledge, experience and lessons learned among different flood managers to help them explore and identify solutions and innovations that are applicable in their communities. In many cases, site-specific designs and cost estimates will be required. It is not the intention of this report to document detailed technical specifications, but rather to illustrate innovations that are being implemented, for consideration and adaptation by others.

4.1 Flood Hazard Information and Planning

4.1.1 Integrated Flood Hazard Management Plan

Who: Cowichan Valley Regional District, in partnership with Cowichan Tribes, the City of Duncan and the District of North Cowichan

What: Updated existing floodplain mapping and developed an Integrated Flood Management Plan for the Lower Cowichan-Koksilah River floodplain, including major tributaries.

Why: 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. 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 primary goals were:

- to reduce flood risk to all communities on the floodplain, while protecting aquatic and riparian habitat and addressing the cultural values of the rivers; and
- to 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.

How: The project provided technical information and a variety of management tools to use as a road map for implementing integrated flood management in the Cowichan-Koksilah basin. A hydraulic model was developed to assess the magnitude and extent of flood hazards and a comprehensive GIS database was developed that includes habitat sensitivity and flood hazard mapping. Three mapping products were produced, including:

- updated floodplain maps, which show 200-year flood construction levels, flood extent, and a higher hazard “floodway” zone;
- flood scenario maps to assist in emergency response planning; and
- habitat sensitivity maps to support strategic planning and operational investigations related to habitat and restoration.

Key Elements:

Ten strategies were followed in preparing preliminary concepts and initiatives in support of the plan, including:

- Return the rivers to a more naturalized state;
- Sustain the natural state of existing floodplain;
- Site future development in areas with low flood hazard and low habitat sensitivity;
- Ensure new or upgraded flood protection structures do not adversely increase the overall flood hazard;
- Decrease vulnerability of existing development areas;
- Mitigate impacts of high flows on the mainstem;
- Maintain channel conveyance;
- Create accessible and sustainable tools for flood management;
- Promote basin-wide planning initiatives; and
- Monitor and maintain flood management program.

A portfolio of planning and structural (engineering) measures was developed as part of the flood plan. Twenty specific projects were identified, which include:

- Channel maintenance and improvement programs;
- Gravel removal and maintenance programs;
- Log jam removal and modification programs;

- Selective vegetation removal;
- Dike upgrades or new dike construction;
- Set-back dike construction;
- Upstream sediment and debris control;
- Road modifications;
- Bridge replacements; and
- Recommended compensation projects.

Challenges:

- 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.
- The existing flood protection around critical infrastructure and higher density populated areas in Duncan should be upgraded as soon as possible.
- One of the biggest challenges is the multi-jurisdictional nature of the problem – there are four local governments, each with their own objectives as well as many stakeholder groups (e.g., homeowners, fishermen, environmentalists and others)

Opportunities and Tips:

- Given the broad nature of the study, a phased approach was adopted so the project goals and objectives could be refined over the course of the project.
- The plan adopted an internationally recognized integrated framework for the project, where the strategies and actions are focused on providing benefit to both the environment and flood hazard as opposed to designing compensation works to mitigate the flood works.
- There is a strong base of community stakeholder involvement through the Cowichan Round Table and a Water Management Plan has already been prepared.
- Monitoring and maintenance are essential components of a flood management program, including dikes, bank protection works and the channel as a whole.
- Basin-wide planning is important, particularly since most of the flood water, sediment and debris originates upstream of jurisdictional boundaries in the basin headwaters.
- Ultimately, the stakeholders, local governments and Cowichan Tribes will need to frame their own goals and objectives to implement the final plan.

4.2 Floodplain Management

4.2.1 Land Use Change, Property Acquisition and Relocation

Who: City of Prince George

What: The municipality is reducing future flood damages and improving environmental values by acquiring several floodplain properties between the Nechako River and River Road. Existing structures will be removed and the natural landscape will be restored or used as parking areas.

Why: Following the 2007–08 Nechako River ice jam flood, a technical analysis was undertaken to evaluate flood risks and management options, and a community consultation process was conducted. Land use change was identified as one of the preferred management options, together with the construction of a setback dike along River Road, for this part of the community. This involved consideration of the social and economic hardships associated with future flood impacts, an economic benefit and cost analysis that considered multiple flood management options, the preferences of property owners, existing regulatory requirements and associated environmental impacts and benefits.

How: Multiple benefits of this approach were identified and communicated. The municipality was willing and able to purchase the properties, and property owners were willing to sell. Provincial government funding assisted with the technical analysis as an input to flood protection for the community.

Other Elements:

- Floodplain maps for the municipality are being updated.
- River Road is being raised and reconstructed to ensure emergency access is provided during future flood events.
- A setback dike and related drainage works are being constructed adjacent to the reconstructed River Road.

Challenges:

- Senior levels of government are unwilling to provide financial assistance for the acquisition of private land.
- The municipality does not have the financial resources to purchase all of the properties in the area where this option was considered.

Opportunities and Tips:

- It was very useful to conduct a broad evaluation of multiple flood risks and an analysis of multiple flood management options.
- There was value in complementing the technical analysis with a community outreach and consultation process.

- There may have been a greater willingness of property owners to sell their properties because of the recent ice jam flood event. The ice-related flooding threat lasted several weeks in comparison with freshet flooding threats that last generally one to two weeks.

- An integrated solution was developed, including a combination of land use change for vulnerable properties, road raising for emergency access, and construction of a setback dike.

4.3 Flood and Erosion Protection Works

4.3.1 Vedder River Management Area Plan

Who: Vedder River Management Area Committee (composed of BC Ministry of Environment, Fisheries and Oceans Canada, Fraser Valley Regional District, City of Chilliwack, City of Abbotsford, environmental and technical consultants and the recreational fishing sector)

What: Flood protection is implemented through the use of setback dikes and sediment removal within the Vedder River and Canal.

Why: The plan was developed and is being implemented to manage the flood hazard and to protect fish and habitat. The impetus for the plan and the Vedder River Management Area Committee was a 1975 flood event, which flooded Yarrow and Sumas Flats. There is significant sediment accumulation in the Vedder River and Canal, which reduces the available freeboard allowance.

How: Setback dikes (7 km) were constructed in the late 1970s, and the Vedder River Management Area Plan was developed in 1983.There is an important gravel removal component. Every two years, cross sections of the river channel are reviewed and a flood model is run to assess flood risk (dike freeboard reductions) in relation to sediment accumulation.

Other Elements:

- There is a recognized need to balance different uses of the river, including recreation, fishing, a heron reserve, agriculture and flood protection.

- The Committee uses a collaborative, multi-stakeholder approach.

- The best sites for gravel removal are targeted based on an environmental perspective in conjunction with the flood model results. Monitoring pre- and post-removal ensures consistent information on results is obtained.
- Specific removal strategies are focused on maintaining, and where possible, enhancing fish habitat while meeting targets necessary to maintain floodway capacity. Outcomes from early excavations led to a set of guidelines that are now employed to ensure fish habitat is protected.

Challenges:

- High water levels during gravel removal times have been a challenge.

- Channel configuration changes have occurred during the spring between the time of design and actual gravel removal.

Opportunities and Tips:

- Monitoring and ongoing review helped identify effective strategies.

- A good working relationship has been fostered with regulatory agencies. Trust among different agencies is key.

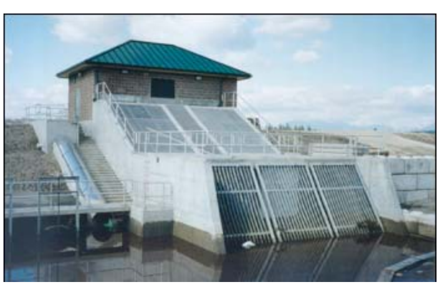
- Opportunities for habitat improvements have been implemented during gravel removal (e.g., large woody debris placement, construction of side channels, etc.). A portion of gravel removed from the river is also donated for fisheries projects.

- Revenues from the sale of removed gravel help cover some expenditures, but the price of gravel can fluctuate substantially.

- Provincial/local cost-sharing supports monitoring, surveying and modelling.

- This approach has been very effective in maintaining channel capacity.

4.3.2 Serpentine-Nicomekl Flood Management



Who: City of Surrey

What: A wide variety of works have been designed and constructed to manage flooding in the lowlands of the Serpentine and Nicomekl watersheds. They include features such as:

- creek reconstruction (Latimer Creek);
- construction of drainage pump stations;
- construction of offset (setback) dikes;
- construction of conveyance channels;
- construction of flood cells;
- fisheries enhancement works;
- construction of online sediment basins; and
- agricultural enhancement works.

The plan for this area was adopted in 1997 and construction began in 1999. The overall project should be completed by 2011 provided that final properties can be obtained. The cost to date has been $35 million; approximately $6 million is required to complete the works.

Why: The primary goal was to establish a consistent level of flood and drainage protection for farmlands within the Serpentine/Nicomekl floodplain while mitigating environmental impact. Existing structures did not provide enough flow capacity and flood protection. The same level of flood protection was not provided to all farmlands. Some farmers were filling in the floodplain, and runoff from upland development areas was increasing flood levels in the lowland areas. Most waterways provide fish habitat; therefore, the overall plan includes offsetting to compensate for habitat impacts in some areas.

How: The municipality brought together a stakeholder/advisory group to develop the overall strategy and implementation plan for the project. The plan was divided into construction cells and involved additional area residents, various farming sectors, a council advisory committee and diking districts. Team members considered issues such as crop and property values, farming practices, engineering design, and biological values, which led to the creation of a more comprehensive plan and assisted in its implementation.

Other Elements:

- The project involved collaboration among many agencies and organizations, including the City of Surrey, BC Ministry of Agriculture and Food, BC Ministry of Environment, Transport Canada, Fisheries and Oceans Canada, Agricultural Land Commission, City of Surrey Agricultural Advisory Committee, three diking districts and the Ministry of Transportation and Highways.
- A public process was undertaken to develop the overall design of the project, and then the project was divided into components and each one was brought to the public process.
- Biologists conducted fish surveys to find spawning habitats in local creeks. This helped identify appropriate placement of fish-friendly pumps.
- The municipality has been monitoring water levels and storm responses in the lowland area and comparing them to preconstruction conditions. Current responses will also be compared to final projected conditions.
- Deposition of fine sediment following winter storms has occurred at the base of the

uplands. The municipality identified deposition zones, built sediment basins (deeper channels, rocks at bottom, etc.) and defined areas for sediment removal, which reduced the need for sediment removal along the entire watercourse. The municipality obtained water licences to clean the sediment basins. No approvals were required; only notifications. Some expense was associated with maintaining the water licences.

- River bank erosion was occurring. Fish-friendly bank stabilization was implemented on vulnerable banks by planting with sierra walls, and/or placing large woody debris in the channel to add complexity. These practices were implemented only when needed to protect property.

- The next step is to consider provincial forecasts for sea level rise (50- and 100-year forecasts) and the potential impact this will have on the lowland areas.

Challenges:

- Addressing private property issues have been challenging in some cases. Most landowners were cooperative but some were not.

- A few dike failures occurred during construction due to soft soil materials.

- Dike construction required small incremental lifts due to settlement and soil strength issues.

- There was a need to educate residents about flood impacts resulting from filling of floodplain lands and/or diking of individual properties.

- Water quality in both the mainstem Serpentine and Nicomekl Rivers continues to challenge salmonid migration and habitat utilization, although water quality is generally improving (BC Ministry of Water, Land and Air Protection 2002).

Opportunities and Tips:

- Flooding has been drastically reduced on the agricultural lands within the floodplain.

- Considerable knowledge has been acquired on construction practices, instream works and riparian zones.

- Funding has been obtained from development cost charges, and the City of Surrey Drainage Utility, which is supported by all city residents. There was a case for applying development cost charges because new developments upstream were affecting flooding due to increased stormwater runoff.

- It is recommended that agencies and organizations begin to work together well ahead of the design stage.

- The Environmental Review Committee (Fisheries and Oceans Canada and the BC Ministry of Environment) was helpful in bringing concepts on project design and other challenges forward for discussion.

- A key to success was having all parties work together and understand each others' needs.

4.3.3 Okanagan River Restoration Initiative (ORRI)

Who: A multi-stakeholder group has contributed towards this initiative, consisting of the following agencies and organizations (listed alphabetically):

- BC Habitat Conservation Trust Fund
- BC Ministry of Environment
- BC Ministry of Transportation
- Canadian Wildlife Service
- Douglas County Public Utility District
- Fisheries and Oceans Canada
- Grant County Public Utility District
- HCP Tributary Committee
- Okanagan Nation Alliance
- Okanagan Region Wildlife Heritage Fund Society
- Priest Rapids Coordinating Committee
- Government of Canada
- The Land Conservancy of BC

The ORRI project is sponsored by the Canadian Okanagan Basin Technical Working Group. For more information see www.obtwg.ca.

What: Following severe flooding between the 1920s and 1940s in the Okanagan River between Penticton and Osoyoos Lake, 84% of the BC portion of the waterway's 70 km was channelized and diked, leaving only a 2.8-kilometre section of the river remaining in its original natural condition, with a further 2.1 kilometres diked but not channelized. As a result the vast majority of riparian habitat was lost to a flood control program that removed natural floodplains and side channels and destroyed critical fish and wildlife habitats.

The project includes two phases. Phase 1 was completed in 2009, which involved placing a setback dike approximately 100 m westward of the mainstem, and re-establishing the river in two relic channels while leaving the existing channel intact to allow passage of flood waters. The new channel configuration will provide habitat for salmon and trout in the newly formed pools and riffles, reduce the risk of flooding of adjacent properties, and improve spawning habitat quality and water quality. The restoration work is expected to double sockeye eggs-to-fry survival, provide complex rearing habitat for steelhead and rainbow trout, and provide six spawning sites for chinook salmon. Placement of the setback dike will also allow for riparian vegetation to establish inside 3.9 hectares of floodplain, which will benefit a wide range of wildlife and birds.

Phase 2 of the project involves re-establishing two meanders immediately north of the existing project.

Why: The original river configuration contained little quality fish habitat and did not allow for floodplain riparian areas to develop. Dikes at the water's edge along both banks confined the river. Re-establishing a natural meander by building a setback dike will increase biological productivity in the reach while increasing flood protection for local properties.

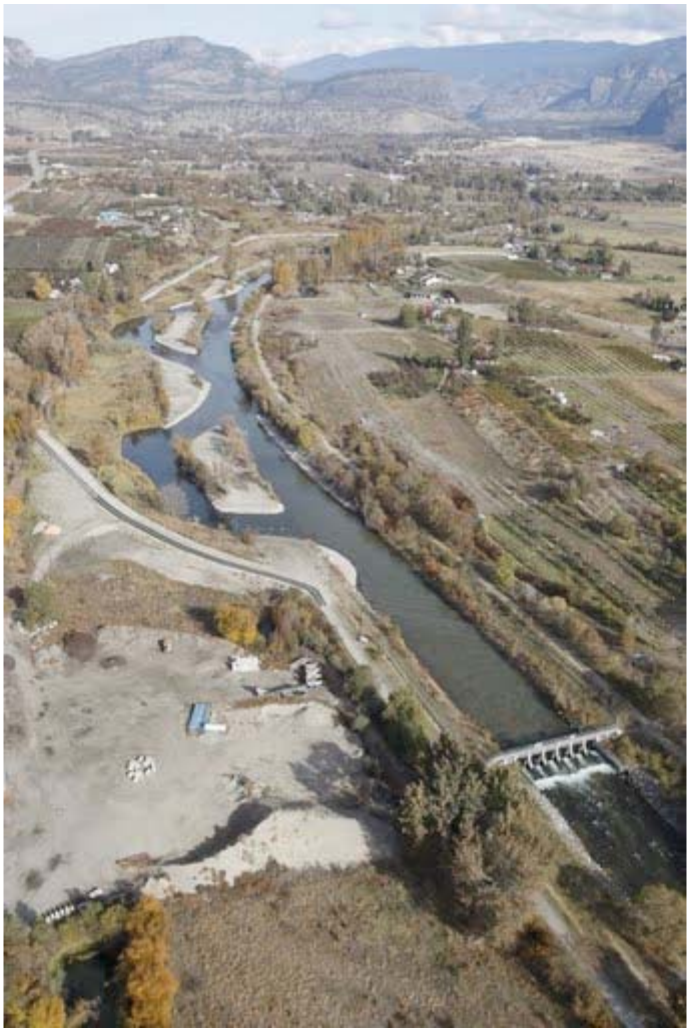
How: Working under the auspices of the Okanagan River Restoration Initiative (ORRI), partnerships began forming with the goal of restoring sections of the river. Two properties owned by the Lougheed and Nemess families and stretching one kilometre along the channelled river just north of Oliver, presented the best possibilities for initial restoration options.

Key Elements:

- A setback dike has been established.
- A natural channel will be re-established.
- Riparian vegetation on the floodplain will be re-established.
- Spawning and rearing fish habitats will be created.
- Challenges:
- The project involved many stakeholders, which required substantial administrative time.
- Phase one is estimated to have cost approximately $2 million.

Opportunities and Tips:

- Two sections of private land totalling nearly 4 hectares were purchased in part with $410,000 from the BC Ministry of Transportation Environmental Enhancement and Habitat Conservation Trust Funds.



Facing north, the Okanagan River Restoration Initiative is shown on the left side. Photo: Kevin Dunn.

Here is a newly created meander on right, looking south. Note the setback dike. Photo: Kevin Dunn.

4.3.4 Fish-Friendly Pump Station for Flood Protection

Who: Township of Langley

What: A fish-friendly pump station was constructed where the Salmon River flows into the Fraser River west of Fort Langley.

Why: The project was implemented to help reduce flooding of the farmlands and golf course in the Salmon River lowlands. The project was intended to increase pumping capacity and flood box relief of the Salmon River pump station in a fish-friendly manner.

How: The project involved various stakeholders. The Township of Langley; Fisheries and Oceans Canada; BC Ministry of Agriculture, Fisheries and Food; BC Ministry of Environment, Lands and Parks; Langley Environmental Partners Society; Fort Langley Farmers Association; and the Belmont Golf Course were all involved in project planning. The multi-interest Salmon River Watershed Management Partnership supported the project.

Other Elements:

- Flood box capacity increased from 52 to 83 m^3/s in a 10-year, 5-day winter rainfall event.

- Pumping capacity increased by 50%.

- There has been a reduction in fish mortality when the pumps are run.

Challenges:

- Operational parameters for the pumps have not been agreed to by all stakeholders. There was concern about accepting limitations on when the screw pump could be operated. Some stakeholders do not agree that a fish-friendly pump cannot be run in the winter.

- The original pump station design included a float-actuated gate on one flood box to allow fish passage. This proved to be ineffective and was replaced with an automated, motorized sluice gate.

- Residents do not always understand the time required for flood waters to travel to the pump station given the low gradient of the Salmon River. Although there may be flooding of upstream properties, the water level at the pump is as low as it can safely be without burning out the pump.

Opportunities and Tips:

- An additional bay was installed at the pump station to allow another fish-friendly pump to be installed in the future when the old submersible pumps are retired.

- The Township of Langley, Fisheries and Oceans Canada, private property owners and the Belmont Golf Course all contributed funding.

4.3.5 Fish-Friendly Pump Station For Flood Protection

Who: District of Kent

What: Duncan-Bateson Pump Station – A fish-friendly pump and upgrades to the existing flood pumps and pump house were constructed at the confluence of the Duncan-Bateson Slough and Harrison River. The project was completed with opening ceremonies and commissioning held on August 28, 2009..

Why: The project was intended to reduce flooding by increasing pump capacity while improving fish passage. The original pump was built after the 1948 flood. It was under capacity and did not allow for fish passage.

How: Three pumps were installed, including two large flood pumps with screening and a small fish-friendly pump in front of the main pumps.

Other Elements:

- During freshet when the pumps are not operating, fish passage to the Harrison River is cut off by the closed flood gates. Emigrating fish must wait at the pump station until either the gates are opened or the pumps are turned on.

- The small fish pump engages two minutes prior to and two minutes after the large flood pumps are engaged to allow fish passage into the Harrison River.

- There was a five-fold increase in pumping capacity (from 18,000 to 90,000 litres/minute).
- Increased flood protection in the Harrison Mills area and approximately 2000 acres of Harrison Mills agricultural and residential areas are being drained through this pump.
- A study of fish survival is currently underway.

Challenges:

- Flygt pumps were selected on the advice of engineers. Unlike Archimedes screw pumps, which move large volumes of water slowly and allow fish to migrate through the water column, the Flygt pump is a small separate pump that
- attempts to safely transport fish by bypassing the main flood pumps. However, the Flygt pumps involve new technology, and some "bugs" are still being worked out.
- Debris maintenance is required to keep the pump screens clear.
- The project cost $1.4 million.

Opportunities and Tips:

- Fisheries and Oceans Canada, as well as BC Ministry of Environment provided advice and had responsibilities as regulatory agencies.
- Financial support was provided through the BC Flood Protection Program.
- Previously, it was believed there was no fish migration within the watercourses drained by the Duncan/Bateson pump; however, the project indicated there are coho salmon within the watercourse.

4.3.6 Operational Mitigation Procedures to Prevent Pump-related Fish Mortalities

Who: District of Mission

What: "Block and seine" mitigation procedures have been implemented on Chester and Lane Creeks to help multiple fish species (coho, chum, cutthroat trout and steelhead) bypass high capacity pumps and reduce mortality rates as the fish attempt to migrate downstream from the creeks into the Fraser River.

Why: The procedures were implemented to salvage fish, reduce fish mortality and improve fish passage to the Fraser River. Pump operations coincide with the emigration of coho juveniles, cutthroat and steelhead trout. Historically, this has resulted in high fish mortality.

How: A soft net is used to block fish migrating downstream towards the Fraser River. The area directly upstream of the net is then seined. All fish salvaged are placed in holding buckets and transported unharmed downstream of the pump station. They are counted before being released.

Other Elements:

These operations include permits to lethally remove invasive fish species such as large mouth bass.

A technical consultant has undertaken the operations and monitoring.

Between 1997 and 2004, more than 8,600 coho salmon and almost 1,800 cutthroat trout have been salvaged in Chester Creek, along with many other salmonids.

Challenges:

- Upgrading to an Archimedes screw pump was likely too costly for the District of Mission.
- In 2009, there was a noticeable absence of species and reduced numbers of fish.

Opportunities and Tips:

- The program has proven to be an effective way for fish to bypass pumps when their migration coincides with pump operation.
- The program also provides important biological information on fish migration patterns, and presence of species at risk and invasive species.
- In 2000, cost estimates were developed for various options. Replacement of pumps with Archimedes screw pumps was estimated at $2.2 million. Blocking fish would put too much stress on the fish. The recommended option of "block and seine" was estimated to cost between $10,000 and $15,000 annually, but actual costs have averaged $7,100 per year.

4.3.7 Vegetation Maintenance in Streams and Drainage Ditches

Who: City of Chilliwack, City of Abbotsford and District of Kent

What: Vegetation growth within streams and drainage ditches is controlled manually at several locations rather than through the use of heavy equipment.

Why: Vegetation maintenance was required to ensure proper drainage, and environmental protection was required due to the presence of fish and wildlife, including species at risk such as the Salish sucker and the Oregon spotted frog.

How: Fisheries and Oceans Canada and the BC Ministry of Environment provided advice. A technical consultant (Nova Pacific Environmental) initiated this work by submitting a proposal to the City of Chilliwack. A budget was approved, procedures and protocols were developed, and the work proceeded to the implementation and monitoring phases.

Other Elements:

- Regular maintenance is ongoing.
- Following initial success in Chilliwack, similar work was undertaken in Abbotsford and Kent.

Managing waterways includes tackling invasive plants. Hand maintenance is more environmentally-sensitive than using heavy equipment.

Challenges:

- This approach was previously untested.
- Residents in Kent wanted additional stream and ditch maintenance that would have included sediment removal.
- In some areas, the water is too deep to conduct maintenance by hand.

Opportunities and Tips:

- The work achieved an environmental benefit. Hand maintenance results in less environmental disturbance within the watercourse.
- The work is completed within the annual budget for drainage maintenance.
- Although this approach is labour intensive, hand maintenance may be less costly than using heavy equipment and operators.

4.3.8 Hatzic Valley Management Plan

Who: Dewdney Area Improvement District

What: Proposed flood protection and habitat improvement measures include installation of new fish-friendly pumps, and sediment removal to improve water conveyance to the pumps and fish access to spawning grounds.

Why: The project is intended to reduce flood risk and improve fish habitat. Agricultural production in the Hatzic valley has been adversely impacted by stream sedimentation and related flooding. Proposed projects could address flooding and improve fish habitat. Landslides at Patterson Creek (1930s and 1950s) resulted in siltation of the creek, which feeds into Hatzic Lake. Logging in more recent decades has exacerbated the problem of runoff and sediment transport.

How: Fish access to spawning grounds would be improved by installing a fish ladder at the flood gate and a fish-friendly pump. This would improve winter access and would reduce pump-related fish mortality. Sediment removal would improve water conveyance to the pump stations.

Other Elements:

- The Fraser Salmon and Watersheds Program has contributed $40,000 to the design and planning of the project. The Dewdney Area Improvement District has provided $110,000. Over several years, $200,000 has been spent on this project.
- It was recommended that floodgates be kept open during winter months. This was done last winter and seems to have been successful.

Challenges:

- No major works have been implemented to date.

- Many regulatory agencies are involved, and the planning process can be slow.
- The key remaining challenge is to secure funding for implementation. The estimated cost for implementation is $7 million over three years.

Opportunities and Tips:

- A good working relationship was established with the Inspector of Dikes.
- There have been no major challenges in working with environmental agencies.
- Although Board members had diverse and often conflicting viewpoints, they are now all in agreement and are working towards a comprehensive plan to reduce flood risks and keep the lake at a level that recreational users can enjoy. However, potential habitat impacts are unclear at this time.
- Planning, engineering and technical studies have all been completed.

4.4 Emergency Management

4.4.1 Emergency Dike Construction and Environmental Enhancement

Who: City of Richmond

What: A major dike upgrade was implemented along 1 km of the South Dike between No. 7 and No. 8 Roads, and included new standards in habitat protection and restoration, which were implemented within a 10-week period.

Why: The work was undertaken in preparation of the increased flood risk associated with the 2007 Fraser River freshet. The project had multiple objectives, including increasing flood and erosion protection and enhancing habitat and other environmental functions.

Note: This case study is profiled under this section on "Emergency Management" because the work was undertaken as part of urgent flood mitigation works. However, this approach would also apply to a longer planning and implementation cycle.

How: The project involved partnership, financial support from senior governments, the use of creative and integrated approaches, and a focus on the care and well-being of workers.

Key Elements:

- Curved and partial inland alignment – Typical dike alignment design follows the shoreline edge with minimum consideration given to existing vegetation. A multi-objective approach was adopted, which recognized the value of the existing foreshore vegetation and natural shoreline functioning. Accordingly, portions of the dike were aligned inland so that large areas of vegetation could be retained and natural foreshore function could be protected.

Dike bank protection construction in Richmond

Native sediments placement on riprap

- "Net-plus" approach – Although some major stands of shoreline vegetation existed, the area had been significantly impacted over time. Substantial amounts of riparian vegetation had been lost, fill had been deposited along the shoreline, and invasive plant species had proliferated. The dike upgrade project provided an opportunity for integrating and achieving ecological gains. The main restoration works involved creation of intertidal benches between the foreshore vegetation and inland riprap bank protection. The intertidal benches were easily constructed within the works already required for building the inland dike. The reinstatement of the low flow intertidal areas provides an ideal environment for fish to "rest" while they navigate the river.

Arrangement of logs at dike toe

Plantings for fish habitat

- Numerous native BC plants were planted and logs and woody debris were added to further enhance fish habitat and the natural estuarine environment. This also contributed to an aesthetically pleasing final product.

- Consideration of sea level rise – The City of Richmond adopted a proactive approach and set dike heights based on current provincial guidelines plus sea level rise over a 100-year period as projected by the Intergovernmental Panel on Climate Change.

- Financial support from senior governments – The provincial and federal governments provided a significant contribution of $1.371 million in grant funding. These funds were available due to the elevated Fraser River flood risk in the spring of 2007.

Challenges:

- Challenges included the need for additional materials and financial resources, and a very tight timeline due to the urgent nature of the work.

- Large quantities of contaminated soil were discovered approximately midway through the construction work. Various types of unknown waste material appeared to have been dumped and buried along the river's edge. A specialist was retained to categorize the contaminated soils, which were subsequently stockpiled separately on site for removal after the dike erosion protection work was completed. Numerous hydrocarbon-based contaminants were identified. The contaminated material has all been removed.

Opportunities and Tips:

- A "Net-Plus" approach was undertaken, which resulted in an enhanced foreshore.

- The discovery of underlying soil contamination created an opportunity for the municipality to address this problem.

- Regulatory approvals – While tendering was in progress, approvals were sought from the Ministry of Environment (Dike Authority), Fraser River Estuary Management Program and Fisheries and Oceans Canada. Through several site meetings and written correspondence, City staff secured all necessary external agency approvals. A number of conditions needed to be met, including the requirement for conducting the work solely during low tide conditions.

- Monitoring and inspection – All on-site construction work was monitored and inspected by a full-time professional geotechnical engineer who had experience in dike construction. An experienced professional in environmental shoreline management conducted environmental monitoring to meet the requirements of regulatory approvals, and to ensure that construction activities achieved the City's dike structural and ecological objectives. Environmental monitoring also supported on-site field design refinements to respond to construction needs and optimize environmental benefits.

In 2009 the District of Kent completed upgrades at the pump station at the confluence of the Duncan-Bateson Slough and Harrison River. The project included the installation of two new high-capacity pumps with screening and a smaller fish-friendly pump positioned in front of the main pumps. The original pump — built after the Fraser Valley flood of 1948 — no longer offered sufficient pumping capacity and did not allow fish passage.

5. Summary and Conclusions

This report outlines a broad range of management activities and corresponding roles and responsibilities involved in implementing an integrated approach to flood hazard management that protects communities and public safety. The report highlights a variety of adverse environmental impacts, which have resulted from traditional approaches to flood management, particularly the use of flood protection infrastructure. However, leadership and innovation is being demonstrated by many local authorities, regulatory agencies and community-based stewards as they pursue numerous options to improve the environmental performance of flood hazard management practices and policies.

The following are some examples of these innovations:

- environmental assessments and monitoring to improve understanding about the species, habitats and other environmental features and functions that interact with, or are impacted by, flood management strategies;

- broad planning processes to better understand flood risks, related environmental issues and other community interests to inform a comprehensive analysis of recommended management options;

- land use change to direct the development of buildings and infrastructure away from rivers and floodways and to restore river corridors to more natural landscapes that are less vulnerable to flood damages;

- setback dikes, which are located inland away from riverbanks and riparian habitats;

- fish-friendly pump and flood gate designs, which enable safe migration of fish between off-channel habitat in the floodplain and habitat within the mainstem of the river;

- alternative approaches to channel maintenance such as the use of sediment ponds to limit the footprint of sediment removal operations, and manual maintenance of vegetation within and along streams and drainage ditches; and

- incorporating habitat restoration features, such as riparian vegetation, intertidal benches, off-channel habitat and stormwater detention ponds, into the design of flood protection and drainage systems.

This report includes only a small sample of what is being done in the field. It is not intended to be a comprehensive review, but rather a cross-section of diverse examples, representing a range of flood management practices. There are more than 1,000 kilometres of diking systems in BC. In the Lower Mainland alone, there are 600 kilometers of dikes, 100 pumps and 400 flood gates. Numerous tributaries have been severed from their destination rivers and many wetlands and other aquatic habitat features have been drained, filled, or otherwise degraded. Considerable progress has been made by some communities in recent years to improve the environmental performance of flood hazard management policies and practices. However, across the Lower Mainland and throughout BC, we have a long way to go to more fully implement the available and emerging suite of environmentally sound policies and practices, helping to sustain a diversity of fish and wildlife species, habitats, and ecosystems.

As profiled within this report, many local authorities have implemented environmental improvements in flood management. Most of these involved partnerships and collaboration with other agencies and organizations, as well as different sectors and interests from within the community. For the most part, technical designs are available. It is a matter of adapting and adequately funding the solutions that emerge, bringing people together and building common understanding, trust and collaborative working relations. This will increase the likelihood of success in identifying the options that are best suited to local circumstances, are technically feasible, are supported by public and political will, and are within the financial resources available.

Much research has been done on the environmental impacts of flood protection and drainage infrastructure, particularly in relation to impediments to fish migration. However, this work has often been undertaken by stewardship groups and environmental agencies without the full participation of those responsible for flood protection and drainage. Unfortunately, the problems observed today are in part a result of this divide between flood management and environmental protection. If historically, flood managers had fully engaged with environmental stewards when floodplain management policies and flood protection practices were being developed, we might have avoided some of the adverse impacts we now observe.

The time is right to build bridges between these two worlds and create a vision where environmental stewardship coincides with flood hazard management. We need to connect those whose primary objective is environmental stewardship with those whose primary objective is protecting communities from flood hazards. Only through this type of knowledge sharing and collaboration will we find robust, locally appropriate solutions that are broadly supported by the community at large.

Through creative problem solving, innovative design and best management practices, environmental objectives may be achieved while maintaining a high standard of flood protection and public safety. However, environmentally sound management practices for habitat mitigation or compensation may be associated with increased costs, or may require additional research or technical support. This can be particularly challenging for local governments with limited capital budgets. Therefore, there is a need to develop and promote the use of environmentally sound designs and practices that are both technically and economically viable.

There is a need for existing infrastructure funding programs to assist with environmentally sound approaches to flood protection. There is also a need for new funding opportunities through habitat stewardship or green infrastructure programs, which would help offset any incremental costs associated with environmental protection. A variety of existing financial instruments have been used by different organizations to help fund the best practices that are profiled within this report. Some examples include:

- Infrastructure grants and cost-sharing;
- Environmental stewardship grants and cost-sharing;
- Development cost charges;
- Diking and drainage utility fees; and
- Annual operations and maintenance budgets.

In addition, there may be a broader suite of innovative funding approaches. For example, different financial incentives or disincentives could be developed to encourage, enable and facilitate the implementation of best practices. There may be opportunities to refine existing policies to create a favourable financial environment. Habitat compensation projects could be directed to improving fish access to high quality, under-utilized off-channel habitat. This might be more effective, cost-effective and technically viable than traditional approaches to habitat compensation, which has often relied upon construction of new habitat features. Land trusts might be one mechanism to facilitate the return of prime habitat features along river corridors to a more natural state. There is a need to explore these and other financial instruments to better enable the alignment of environmental protection within flood hazard management practices and policies.

This report presents a compilation of existing guides, reports, studies and projects. It is intended as a resource guide for practitioners to support continued discussion and collaboration so that environmentally-sound approaches to flood hazard management will be developed, adapted and implemented long into the future.

6. Appendices

6.1 Relevant Legislation and Regulatory Requirements

The following overview of key legislation and regulatory requirements were obtained from the *Guidelines for Management of Flood Protection Works in BC*:

Federal Fisheries Act

Fisheries and Oceans Canada (DFO) is responsible, under the *Fisheries Act* (R.S.C., 1985, c.F-14), to protect fish and fish habitat in all Canadian marine and freshwater areas. Pacific salmon that utilize both waters are a federally-managed resource. All works or undertakings (e.g., vegetation removal, rip rap placement etc.) are subject to the habitat protection provisions and prohibition on deleterious substance deposit of the *Fisheries Act*. To ensure compliance with the Act, submission of project plans to DFO for assessment is strongly recommended. The Act does not "permit" works but can charge and prosecute in cases where habitat is damaged or deleterious substances deposited

The following overview of key legislation and regulatory requirements were obtained from the *Environmental Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment*:

BC Dike Maintenance Act

The principal legislation in BC pertinent to operation and maintenance of flood protection works is the *Dike Maintenance Act*. The Act establishes a public official known as the Inspector of Dikes (IOD) who has "general supervision of all dikes and the operation of all diking authorities relative to the construction and maintenance of dikes".

Section 2(4) of the Act provides that works in and about flood protection dikes shall be subject to written approval by the Inspector of Dikes. "This includes:

- Anything that may lower or decrease the size and/or integrity of the cross-section of a dike.
- Installations of flood boxes, culverts, pipes or any structure in a dike.
- Construction of works over or on a dike right of way.
- Alterations to the foreshore adjacent to a dike."

The Act empowers the Inspector of Dikes to make Orders under the Act, and take measures in the interests of public safety if there is a failure to comply.

The Act also provides for offenses where "a person ...

a) Injures or interferes with a dike or its operation;

b) Hinders a diking authority, the inspector or a person acting on behalf of either of them from protecting property from flooding:

c) Contravenes the act or an order of the inspector or minister."

BC Fish Protection Act

The BC *Fish Protection Act* is intended to both enable, and require provincial decision-makers to address the needs of fish and fish habitat in the adjudication of applications for water licenses, amendments, or approvals. Section 5(1) of the Act states “in making a decision on an application ..., the comptroller or regional water manager may (a) consider impact on fish and fish habitat, and (b) include conditions respecting fish and fish habitat in the license, approval, or amendment.”

Section 6(2) states “The Lieutenant Governor in Council may, by regulation, designate a stream as a sensitive stream under this section if the Lieutenant Governor in Council considers that the designation will contribute to the protection of a population of fish whose sustainability is at risk because of inadequate flow of water within the stream or degradation of fish habitat.” Section 6(4) states that a license, approval or an amendment to a license or approval, in relation to a sensitive stream, may only be issued by the comptroller or regional water manager if any adverse impact on the sustainability of the protected fish population is likely to be insignificant, or if mitigation, and/or compensation will render the impact insignificant.

The *Fish Protection Act* also strengthens the provincial *Water Act* through a consequential amendment, which prohibits the introduction of debris into a stream, stream channel or area adjacent to a stream if, as a result, harm or damage is caused to the stream or stream channel, or fish or fish habitat. Debris is defined as “(a) clay, silt, sand, rock or similar material, or (b) any material, natural or otherwise, from construction or demolition.”

BC Water Act

Ownership of the water and most stream beds is vested in the provincial Crown in British Columbia. Changes in and about streams have been managed and regulated through legislation for many years in order to protect and maintain certain values, resources, and legal rights associated the streams.

Section 9(1) of the *Water Act* states “The comptroller, a regional water manager or an engineer may grant an approval in writing authorizing on the conditions he or she considers advisable (a) a person to make changes in and about a stream, (b) a minister of the Crown, either in right of Canada or of British Columbia, to make changes in and about a stream, or (c) a municipality to exercise its powers under Divisions (3) and (4) of Part 16 of the *Municipal Act*.”

Section 9(2) further states that “A minister or other person or a municipality may only make changes in and about a stream in accordance with an approval under this section or in accordance with the regulations or a license or order under this Act.”

Changes in and about a stream are defined as (a) any modification to the nature of a stream including the land, vegetation, natural environment or flow of water within a stream, or (b) any activity or construction within the stream channel that has or may have an impact on a stream.

The Regulation enables a person to carry out a number of routine works without obtaining an approval, provided that the general conditions and notification requirements are carried out. For example, the repair and maintenance of existing dikes may be carried out under the Regulation, as long as the Habitat Officer is notified and the changes are made in accordance with any terms and conditions specified by the Habitat Officer to protect habitat.

6.2 Summary of Resources

6.2.1 General Websites of Interest

BC Ministry of Environment – Water Stewardship – Public Safety (Floods, Dikes, Dams and Droughts)

www.env.gov.bc.ca/wsd/public_safety/index.html

This site includes substantial information resources, including:

- a list of flood protection structures (by owner/administrator and by watercourse);
- maps of flood protection structures and floodplains;
- information on *Dike Maintenance Act* approvals;
- guidelines for vegetation management on flood protection works that apply to protecting public safety and the environment; and
- links to other web sources.

Fraser Basin Council – Integrated Flood Hazard Management Program

www.fraserbasin.bc.ca/programs/flood.html

This site includes general information, including:

- background information on flood risk on the Fraser River;
- background information and reports on flood management;
- information on the role of the Fraser Basin Council;
- Frequently Asked Questions; and
- links to other web sources.

6.2.2. Flood Hazard Information and Planning Resources

BC River Forecast Centre

www.env.gov.bc.ca/rfc/

Staff of the River Forecast Centre (RFC) collect and interpret snow, meteorological and streamflow data to provide warnings and forecasts of stream and lake runoff conditions around the province. Most of the meteorological and streamflow data are collected by other agencies, but the RFC is the lead agency in British Columbia for:

- flood advisories and warnings
- water supply and drought advisories
- collection, quality control, analysis and archiving of snow data

Guidance for Selection of Qualified Professionals and Preparation of Flood Hazard Assessment Reports

www.env.gov.bc.ca/wsd/public_safety/flood/landuse_mgmt.html

This document provides guidance on selecting qualified professionals and preparing flood hazard assessment reports.

Author: BC Ministry of Environment, Lands and Parks. 2004.
Source: BC Ministry of Environment

Floodplain Mapping Guidelines and Specifications

This document was developed as a framework for floodplain mapping projects. It was prepared for the Fraser Basin Council by engineering and mapping consultants, and provides guidance on developing new floodplain maps and a generic framework that can be used by a wide range of proponents who are interested in developing floodplain maps throughout BC and beyond.

Author: Water Management Consultants
Source: Fraser Basin Council. Steve Litke, Senior Program Manager.
slitke@fraserbasin.bc.ca.

Adaptation Guidelines for Flood Hazards and Risk Assessments

New professional practice guidelines are being developed for flood hazard and risk assessments that incorporate the impacts of climate change. This initiative is being undertaken by the Association of Professional Engineers and Geoscientists of BC for the BC Ministry of Environment. This resource is currently in development.

Author: Association of Professional Engineers and Geoscientists of BC (2011)
Source: Ministry of Environment (TBD)

6.2.3 Floodplain Management Resources

BC Ministry of Environment Website

For information about floodplain management and updated legislation, please refer to www.env.gov.bc.ca/wsd/public_safety/flood/brochur3.html.

Flood Hazard Area Land Use Management Guidelines

www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/guidelines.pdf

Management guidelines for flood hazard area land use have been prepared to help local governments, land use managers and approving officers develop and implement land use management plans and make subdivision approval decisions for flood hazard areas. The goals of the guidelines are to reduce or prevent injury, human trauma and loss of life, and to minimize property damage during flooding events. The guidelines are based on the policies and procedures established and refined over the life of the provincial flood hazard management program, and in the absence of more site-specific studies or information, they are the recommended provincial minimum requirements for land use management in flood hazard areas.

Author: BC Ministry of Water, Land and Air Protection. 2004.
Source: BC Ministry of Environment website:

Climate Change Adaptation Guidelines for Sea Dike Design and Coastal Flood Construction Levels in BC

New guidelines for sea dikes and coastal development are being developed and adopted by the Province. The guidelines are essential for protecting coastal communities from flooding due to sea level rise related to climate change. The new guidelines will be used to update sections of the existing Ministry of Environment *Flood Hazard Area Land Use Management Guidelines* (2004) and *Dike Design and Construction Guide: Best Management Practices for British Columbia* (2003)**.** This initiative is being undertaken for the BC Ministry of Environment. This resource is currently in development.

Author: Sandwell Engineering Inc. (June 2010)
Source: Ministry of Environment (TBD)

6.2.4 Flood and Erosion Protection Works Resources

BC has published several important guides and reports to assist local diking authorities in carrying out various management activities, including:

- Guidelines for the Management of Flood Protection Works in British Columbia (1999);
- Flood Protection Works Inspection Guide (2000);
- Environmental Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment (1999);
- Operation and Maintenance Manual for New Works Template (2001);
- Dike Operation and Maintenance Manual Template (2001);
- Dike Design and Construction Guide: Best Management Practices for British Columbia (2003); and
- Rip Rap Design and Construction Guide (2000).

See www.env.gov.bc.ca/wsd/public_safety/flood/structural.html for more information or to download any of these documents.

Environmental Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment

www.env.gov.bc.ca/wsd/public_safety/flood/structural.html

These guidelines were developed by the BC Ministry of Environment, Lands and Parks Water Management and Fish and Wildlife Management Branches and Fisheries and Oceans Canada. The guidelines present minimum standards under the *Dike Maintenance Act* for vegetation management on flood control structures to protect public safety, and identify opportunities to protect and/or enhance habitat to benefit the environment.

Author: BC Ministry of Environment, Lands and Parks and Department of Fisheries and Oceans Canada. 1999.
Source: BC Ministry of Environment

Climate Change Adaptation Guidelines for Sea Dike Design and Coastal Flood Construction Levels in BC

See Section 6.2.3

Miscellaneous Resources on Flood Pumps, Flood Gates/Boxes and Other Impediments to Fish Migration

Charland, J. 1998. *Tide Gate Modifications for Fish Passage and Water Quality Enhancement.* Tillamook Bay National Estuary Project, Garibaldi, Ore.

Department of Fisheries and Oceans. 1995. *Freshwater Intake End-of-Pipe Fish Screen Guideline.* Department of Fisheries and Oceans, Ottawa, Ont.

Katopodis, C. 1992. *Introduction to Fishway Design.* Department of Fisheries and Oceans, Ottawa, Ont.

LGL Limited, Musqueam Indian Band, Mountain Station Consultants Inc. and Kerr Wood Leidal Associates Ltd. 2009. *Prioritization of and Rehabilitation Considerations for Fish Migration Impediments in Lower Fraser River.* Prepared for Fraser Salmon and Watersheds Program.

Pacific Streamkeepers Federation. 2009. *Identification and Prioritization of Fish Migration Impediments in Fraser River Watersheds East of Brunette River.* See also www.pskf.ca/program/case/impediments/index.html.

Thomson, A.R. 2005. *Flood Box Management in Southwestern British Columbia*.

Prepared for the BC Ministry of Water, Land and Air Protection, Victoria, B.C.

Thomson, A.R. 1999. *Study of Flood Proofing Barriers in Lower Mainland Fish Bearing Streams .* Department of Fisheries and Oceans. Vancouver, B.C.

Waterman Industries Inc. (undated online brochure). *Self-Regulating Tidegate*. 19–23. www.watermanusa.com/DrainageGates.htm.

6.2.5 Emergency Management Resources

Provincial Emergency Program

The Provincial Emergency Program (PEP) offers a wide range of information resources to support emergency planning, preparedness, response and recovery. In particular, the PEP website provides numerous publications, resources, training materials, toolkits, other information and links to other relevant sources. See www.pep.bc.ca/index.html

Emergency Preparedness
www.pep.bc.ca/hazard_preparedness/Personal_Safety.html

Community Emergency Planning, Response and Recovery
www.pep.bc.ca/Community/community.html

Disaster Financial Assistance
www.pep.bc.ca/dfa_claims/dfa.html

6.3 Terms and Definitions

The following terms and definitions were derived from a variety of sources and are definitions specific to flood management. Unless otherwise referenced, most can be found in one of the following:

- Fraser Basin Council website: www.fraserbasin.bc.ca/programs/flood_terms.html
- *Environmental Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment; or,*
- *Flood Hazard Area Land Use Management Guidelines.*

Alluvial Fan: the alluvial deposit of a stream where the stream issues from a steep mountain valley or gorge upon a plain or at the junction of a tributary stream with the main stream.

Approving Officer: the appropriate person appointed under the *Land Title Act.*

Bank Protection: treatment of slopes of dikes and banks of streams, lakes and other water bodies by placement of riprap (an engineered layer of graded broken rock pieces) or other forms of protection to prevent erosion by surface runoff, stream flows and/or wave action.

Commercial Use: a use providing for the sale or rental of goods or services, for personal services, or for the servicing and repair of goods; and includes retail sales, wholesaling in conjunction with retail sales, commercial and government offices, personal services, commercial schools, household services and household repairs.

Debris Flow: the rapid downslope movement descending steep pre-existing drainage channels of water-saturated soil and debris by true flow processes.

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

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

Dike: a dike is “an embankment, wall, fill, piling, pump, gate, flood box, pipe, sluice, culvert, canal, ditch, drain, or any other thing that is constructed, assembled or installed to prevent the flooding of land (*Dike Maintenance Act*).

Dike Height: the vertical distance from the dike crest level to natural ground as measured at the landside toe of a dike.

Diking Authority: a "Diking Authority" is defined as:

- the commissioners of a district to which part 2 of the *Drainage, Ditch and Dike Act* applies;
- a person owning or controlling a dike other than a private dike;
- a public authority designated by the minister as having any responsibility for maintenance of a dike other than a private dike; and/or
- a regional district, a municipality, or an improvement district.

Disposition: disposition of Crown land by certificate of purchase, grant, lease, licence of occupation, right-of-way, or easement under the *Land Act*.

Excessive Vegetation: growth such as blackberry and salmonberry whose pervasive presence obscures visibility and inhibits access.

Flood: an influx or overflowing of water beyond its normal confines such as a riverbank, lakeshore, flood protection dike, etc. Floods are part of a river's natural life cycle and can be expected to occur with some predictability.

Flood Box: “a flood box is a culvert or set of culverts that provides hydraulic connectivity through dikes that separate internal drainage areas and the receiving waters. Flood boxes are located where small watercourses intersect a dike or where estuaries have been reclaimed and isolated from tidal influence by a dike. They are also found at most pumping stations on larger streams. A flap gate mounted at the discharge end of the culvert allows the gravity discharge of flow in a downstream direction only, thereby acting as a check valve by preventing back flow from the mainstem when the mainstem water level exceeds that behind the dike” (Thomson 2005).

Freshet: a seasonal rise in river discharge caused by heavy rain or melted snow.

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

Floodplain: means a lowland area, whether diked, floodproofed, or not which, by reasons of land elevation, is susceptible to flooding from an adjoining watercourse, ocean, lake or other body of water and for administration purposes is taken to be that area submerged by the designated Flood plus freeboard.

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

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

Floodway: the channel of the watercourse and those portions of the floodplains that are reasonably required to discharge the flood flow of a Designated Flood. A minimum required floodway shall be equal to the width of the channel within the natural boundary plus a minimum setback of 30 m from the natural boundary on each side of the channel or channels unless otherwise approved.

Freeboard: a vertical distance added to the Designated Flood Level. Used to establish the Flood Construction Level.

Habitable Area: any room or space within a building or structure that is or can be used for human occupancy, commercial sales, or storage of goods, possessions or equipment (including furnaces) which would be subject to damage if flooded.

Heavy Industry: includes such uses as manufacturing or processing of wood and paper products, metal, heavy electrical, non-metallic mineral products, petroleum and coal products, industrial chemicals and by-products, and allied products.

Historic Settlement Area: means an area which has been developed or is committed through early settlement to further development either through infilling or redevelopment.

Inspector of Dikes: an official of the Ministry of Water, Land and Air Protection as defined under the *Dike Maintenance Act*, RSBC 1996, chapter 95.

Institutional Use: a use providing for public functions and includes federal, provincial, regional and municipal offices, schools, churches, colleges, hospitals, community centres, libraries, museums, jails, courts of law and similar facilities; and specifically excludes public storage and works yards, and public utility uses.

Integrated Flood Management: an integrated approach to flood hazard management includes each of the following management activities as well as strong integration and coordination among all levels of government:

- management of flood protection works;
- floodproofing practices and land use planning decisions; and
- emergency preparedness, response, and recovery.

Large Growth: tree species, such as cottonwood, alder, birch, cherry, fir, spruce, cedar and maple, which potentially have a diameter exceeding about 0.3 m and/or height exceeding about 5–6 m.

Light or Service Industry: includes such uses as assembly, fabrication and light manufacturing, warehousing, wholesaling and food processing.

Manufactured Home: a structure manufactured as a unit, intended to be occupied in a place other than at its manufacture, and designed as a dwelling unit, and includes mobile homes, and specifically excludes Recreation Vehicles.

Minimum Ponding Elevation: a minimum construction level assigned to reduce possible flood damage due to ponding of local drainage during a severe local storm.

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

Non-conforming: any existing building located on flood prone land that does not meet floodproofing requirements set out in any pertinent bylaw, regulation or covenant.

Pad: a paved surface on which blocks, posts, runners or strip footings are placed for the purpose of supporting a manufactured home or unit.

Professional Engineer: a person who is registered or licensed under the provisions of the *Engineers and Geoscientists Act*, RSBC 1996, chapter 116.

Overbank: the area of land between the waterside toe of a setback dike and the top of the streambank.

Overwidth Dike: a dike having standard dike side-slopes (or flatter) and a minimum 9-m crest width measured from the landside crest edge. (Overwidth dikes are sometimes formed by roads or dikes constructed beside natural riverside levees.)

Natural Riverbank: the bank of the river, formed naturally and not part of the dike fill; located below the dike height on the river side.

Recreation Use: a use providing for indoor or outdoor recreation and includes parks, playgrounds, and sports facilities.

Riprap: an engineered layer of graded broken rock pieces placed for bank protection (Ministry of Environment, Lands and Parks. 2000).

Riparian Vegetation: the vegetation immediately in contact with a water body or sufficiently close to have direct influence on aquatic habitat values.

Riverside Dike: a dike located adjacent to a stream (i.e., directly on a streambank). Riverside dikes may be with or without bank protection.

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

Setback Dike: a dike that is set back from the ordinary high water mark of a river creating an overbank strip of natural ground between the dike fill and the riverbank.

Standard Dikes: those dikes built to a minimum crest elevation equal to the Flood Construction Level and meeting standards of design and construction approved by the Ministry of Water, Land and Air Protection and maintained by an ongoing authority such as a local government body (BC Ministry of Water, Land and Air Protection 2004).

Training Works: any wall, dike or protective structure used to prevent a stream from leaving its channel at a given location. This includes any debris flow training structures including basins, trash racks, or other works.

Tsunami: a sea wave generated by tectonic or volcanic activity.

Vegetation Clumps: selective vegetation such as willow, red osier dogwood, and approved shrubs which are pruned and maintained to have an approximate branch spread of no greater than about 3 m in diameter and height no greater than about 5–6 m ensuring there is no obstruction to inspection visibility, displacement of riprap, nor potential for formation of holes.

Watercourse: any natural or man-made depression with well defined banks and a bed 0.6 m or more below the surrounding land serving to give direction to a current of water at least six months of the year or having a drainage area of 2 km^2 or more upstream of the point of consideration.

6.4 References

Barrett, S. 2006. *Mitigating the Impacts of Channel Maintenance in the Lower Fraser Valley: 2003–2004 Field Trial and Literature Review.* BC Ministry of Environment. Surrey, BC.

BC Ministry of Environmental Protection, 1988. *Ambient water quality objectives for boundary bay and its tributaries fraser-delta area*. Victoria, BC.

BC Ministry of Environment, Lands and Parks. 2000. *Riprap Design and Construction Guide.* Victoria, BC

BC Ministry of Environment, Lands and Parks (BC MELP) and Fisheries and Oceans Canada. 1999. *Environmental Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment.* Victoria, BC.

BC Ministry of Water, Land and Air Protection. 2004. *Flood Hazard Area Land Use Managemnet Guidelines.* Victoria, BC.

BC Ministry of Water, Land and Air Protection. 2002. *Water quality objectives attainment summary Boundary Bay tributaries.* Available on the internet at: http://www.env.gov.bc.ca/epd/regions/lower_mainland/water_quality/reports/bound_bay_tribs/index.htm

Fraser Basin Council and the Dike and Channel Maintenance and Habitat Subcommittee. 2001. *Comprehensive Management for Flood Protection Works.* Joint Program Committee for Integrated Flood Hazard Management. Vancouver, BC.

Giannico, G.R and J.A. Souder. *The effects of Tide Gates on Estuarine Habitats and Migratory Fish.* University of Oregon, WA. Research report funded by the Oregon Sea Grant, OR.

Ham, D. 2005. Morphodynamics and sediment transport in a wandering gravel-bed channel: Fraser River, British Columbia. PhD thesis, Department of Geography, University of British Columbia.

LGL Limited, Musqueam Indian Band, Mountain Station Consultants Inc. and Kerr Wood Leidal Associates Ltd. 2009. *Prioritization of and Rehabilitation Considerations for Fish Migration Impediments in Lower Fraser River.* Prepared for Fraser Salmon and Watersheds Program.

Lyle, T.S. 2001. *Non-structural Flood Management for the Lower Fraser Valley, British Columbia.* MSc thesis. Simon Fraser University, Burnaby, BC.

NOAA 2004. *Sediment Removal from Freshwater Salmonid Habitat.* Guidelines to NOAA Fisheries Staff for the Evaluation of Sediment Removal Actions from California Streams.

Northwest Hydraulic Consultants Ltd. 2009. Lower Cowichan / Koksilah River Integrated Flood Management Plan – Final Report. Prepared for Cowichan Valley Regional District

Perrin, C.J., J.L. Taylor, and T.B. Stables. 2003. Effects of dredging operations on the aquatic community in the lower Fraser River near Barnston Island. Report prepared by Limnotek Research and Development Inc. for Fraser River Port Authority.

Rosenau, M. and M. Angelo. 2000. *Sand and Gravel Management and Fish Habitat Protection in British Columbia Salmon and Steelhead Steams.* Pacific Fisheries Resource Conservation Council, Vancouver, BC.

Rosenau, M.L. and M. Angelo. 2005. *Conflicts between Agriculture and Salmon in the Eastern Fraser Valley.* Pacific Fisheries Resource Conservation Council, Vancouver, BC.

Rosenau, M.L. and M. Angelo. 2007. *Saving the Heart of the Fraser: Addressing Human Impacts to the Aquatic Ecosystem of the Fraser River, Hope to Mission, British Columbia.* Pacific Fisheries Resource Conservation Council, Vancouver, BC.

Schmetterling, D.A., C.G. Clancy, and T.M. Brandt. 2001. *Effects of Riprap Bank Reinforcement on Stream Salmonids in the Western United States.* Fisheries 26 (7): 6–13.

Souder, Jon A. 2006. *Coos Watershed Tide Gate Replacement Project-Effectiveness Monitoring - Project Completion Report*. Coos Watershed Association, Oregon.

Thomson, A.R. 1999. *Study of Flood Proofing Barriers in Lower Mainland Fish Bearing Streams.* Department of Fisheries and Oceans, Vancouver, BC.

Thomson, A.R. 2005. *Flood Box Management in Southwestern British Columbia.* BC Ministry of Water, Land and Air Protection. Surrey, BC.

Yakima County. 2007. 2007 Upper Yakima Comprehensive Flood Hazard Management Plan.

Fraser Basin Council