

City of Richmond

Flood Protection Management Strategy 2019

Richmond

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Preface

The 2008–2031 Flood Protection Strategy (2008 Strategy) is a high-level guidance document for the management of flood risk in the City of Richmond. Since Council's endorsement of the 2008 Strategy, Staff have implemented flood protection updates in policy, partnered with the Provincial and Federal government to secure funding, completed Dike Master Plans, and constructed drainage and dike upgrades in priority locations.

The proposed Implementation Program objectives from the 2008 Strategy have been substantially achieved as shown below:

A list of planning actions from the 2008 Flood Protection Strategy and their statuses are noted in Table 1.

Table 1: 2008–2031 Flood Protection Strategy Implementation Program – Planning Actions

Actions	Results
Examine and pursue senior government cost sharing to implement the FPMS (Engineering; Public Works; Finance).	Successfully secured over $30 million in senior government grants for implementation of the FPMS. ***Completed***
Collaborate among City Engineering, Building Approvals, Policy Planning [PPD], Development Applications, Facilities Divisions to develop a phased plan for overall land grade increases (Engineering; Planning).	Adopted Bylaw No. 8204 to establish Flood Construction Levels (FCLs) for flood protection. Waterfront developments are encouraged to build superdikes. ***Completed***
Pursue and plan for appropriate grade changes in City area plans (e.g. City Centre Area Plan update) (PPD).	The City Centre plans are captured in the 2041 Official Community Plan (OCP).
Consult at timely intervals with experts (e.g., MoE, Canadian Hydrographic Service, FBC) and monitor the latest long-range ocean/climate change forecasts and science for their implications (Engineering).	The most applicable and current references have been used to complete the Flood Protection Management Strategy 2019. ***Completed***
Improve the City's ability to obtain data and undertake direct measurements (e.g., monitoring local sea level changes through City operated gauging stations (Engineering; Public Works).	Staff use a combination of river level, internal drainage water level, and rain gauges to control and monitor flood risk in the City. ***Completed***
Establish a protocol for obtaining dike rights of way for Mitchell Island (Engineering).	Dike rights of way are negotiated through the rezoning and development application process. ***Completed***



The City of Richmond has pursued and been awarded over $30 million in grant funding from senior government to implement the 2008 Strategy. Using this funding the City has completed Dike Master Plans, rehabilitated pump stations, and increased the City's overall resilience to flooding.



City crews continually maintain and upgrade the City's diking infrastructure. The Dike Master Plans Phases 1 to 5, anticipated for completion in 2019, specify upgrade requirements for Richmond's dikes according to current climate change science.

Actions	Results
Work with Department of Fisheries and Oceans (DFO) on a plan for widening the perimeter dikes—inside and outside existing dikes, addressing related mitigation and compensation requirements (Engineering).	Staff work with the DFO on all diking projects that may impact habitat or are in close proximity to water; draft Dike Master Plans have been shared with the DFO with no further comments at this point. ***Completed***
Work with external agencies (such as the Agricultural Land Commission) to develop a protocol that will allow for these changes in use through rezoning, development permits, etc. (PPD).	Diking rights of way, land raising, and other diking requirements are currently established through the development and rezoning permit process that engages agencies. ***Completed***
Prepare plans and policies (e.g., OCP, area plans) to support increased density adjacent to dikes but require grade increases and contributions to dike improvements. Retain dike rights of ways and access (PPD, Real Estate).	The 2041 OCP, Bylaw No. 8204, and Dike Master Plans guide floodplain management and dike upgrades; contributions to dike improvements are established through the development or rezoning process. ***Completed***
Ensure that emergency facilities and refuge areas are located in areas not subject to flooding (Engineering; Emergency & Environmental Programs; PPD, Dev Apps).	Emergency facilities are strategically located and built to the required Flood Construction Levels per Richmond Bylaw No. 8204. ***Completed***
Review implementation plans for refuge areas, emergency routes, and create public awareness (Engineering; Emergency & Environmental Programs)	As most of Richmond is a designated flood plain, emergency routes generally lead to raised refuge areas such as Area A in Bylaw No. 8204.
Review this Strategy approximately every five (5) years to ensure that new information is reflected (All).	Review of the 2008–2031 Flood Protection Strategy has been completed. ***Completed***
Develop on-going public evacuation and communication programs (Engineering; Emergency & Environmental Programs).	Richmond BC Alert, an emergency notification system, launched in 2015 is an ongoing campaign for communication and public involvement.
Direct staff to update the City's Flood Response Plan as part of the overall Emergency Response Plan (updated on basis of new modeling and technical information) (Engineering; Emergency & Environmental Programs).	The Flood Management Plan was updated in 2010. The Emergency Management Plan is scheduled for review in 2019. ***Completed***
Remove and relocate or replace toe ditches adjacent to dikes (Engineering).	Plans are in place through Dike Master Plans to remove or relocate toe ditches; strategies will be project specific. ***Completed***

Actions	Results
Encourage the City of New Westminster to harmonize their flood protection levels with Richmond's strategy (Engineering).	Engineering departments are working together to unify flood protection objectives; established partnership agreement for Boundary Road pump station. ***Completed***
Work with VIAA (YVR) to clarify jurisdiction, maintenance standards and improvement programs for the Sea Island dikes (Engineering).	YVR is involved as a stakeholder for Dike Master Plan Phase 5 planning. ***Completed***

All bylaw-related actions have been completed and are shown in Table 2.

Table 2: 2008–2031 Flood Protection Strategy Implementation Program – Bylaws Actions

Actions	Results
Rescind Floodplain Management Implementation Strategy Policy 7000 (PPD).	Policy 7000 has been replaced by Bylaw No. 8204, as recommended by the City's 2006–2031 Flood Protection Management Strategy. ***Completed***
Prepare a Floodplain Bylaw including the new FCLs and the requirement for covenants/ indemnity (Estimated cost–$7,500 for legal input) (Engineering; PPD; Law).	Adopted Bylaw No. 8204 to establish building setback, FCLs and exemption areas. ***Completed***
Adopt other mechanisms and techniques (All).	Development to follow BC Dike Design Guidelines; Zoning Bylaw No. 8500 for developer and builder reference. ***Completed***
Ensure issues of flood protection, grade levels, as well as refuge areas are considered in the development of local area plans (planning; engineering; Emergency & Environmental Programs).	Staff have integrated processes that use software (Amanda) or document review (department concurrences) to provide input on development. ***Completed***



Flood Plain Designation and Protection Bylaw No. 8204 was adopted by Council in 2008 to guide development setback, Flood Construction Levels (FCL), and exemption areas.

All diking actions and their current status from the 2008–2031 Flood Protection Strategy are listed in Table 3.

Table 3: 2008–2031 Flood Protection Strategy Implementation Program – Diking Actions

Actions	Results
Establish protocol for obtaining dike rights of way for Mitchell Island (Engineering, Law).	Dike rights of way are established through the rezoning and development permit process. ***Completed***
Seek direction from Province on new acceptable probability criteria that will address sea level rise and climate related extremes for the next 100 years • (Current city standard is 1:200 for sea level event, and the 1894 discharge of the Fraser River plus freeboard as per provincial standards, versus 1:1250 conditionally recommended by UMA). • (Potential additional sea level/ subsidence study cost estimate—$5,000) (Engineering).	The City of Richmond is currently in the process of adopting revised BC Dike Design guidelines for 1:500 tidal and river flood events with 0.6m freeboard plus 1m sea level rise and 0.2m subsidence to the year 2100. ***Completed***
Review dike maintenance programs at ongoing 3 to 5 year intervals (Engineering; Public Works).	Staff review the dike maintenance program on an annual basis. ***Completed***
Support sustainable funding for a federal (VFPA) river dredging program to maintain river profile (Engineering).	The Port of Vancouver is responsible for continuing the dredging program for the South Arm of the Fraser River. ***Completed***
Establish in City budget annual amount for land for access rights to waterfront and dike areas (All).	The City is constantly looking for opportunities to establish waterfront access with funding from Capital budgets. ***Completed***
Establish and maintain inventory of rights of way and access agreements to diking system (Engineering).	Rights of way and agreements are tracked in Amanda and Engineering's GIS. ***Completed***
Update existing procedural policy of comprehensive dike maintenance (Engineering, Public Works).	The City has a comprehensive dike maintenance program. The program is continually updated with best practices and research. ***Completed***
Prepare and implement a comprehensive perimeter dike improvement program (researching, strengthening and widening dikes to reduce the level of risk) (Engineering).	Richmond's perimeter diking program is established through the Dike Master Plans; upgrades are ongoing. ***Ongoing 80% Complete***

Actions	Results
Establish a program for phasing/ prioritizing perimeter dike improvement (e.g., seismically weak areas first, the mid-island barrier, overall perimeter dike improvements) (Engineering).	Priorities are established through the Dike Master Plans (Phases 1–5) which are anticipated for completion in 2019. ***Ongoing 80% Complete***

The actions and current statuses for the Mid-Island Dike are shown in Table 4 below. The Mid-Island Dike concept was studied (Delcan, 2009) and determined to provide a lower cost-benefit ratio when compared to upgrading the perimeter dike to a 10,000-year return period flood protection level. With this understanding, the Mid-Island Dike concept will be addressed after the perimeter dike has been fully upgraded or as opportunities to cost-share become available.

Table 4: 2008–2031 Flood Protection Strategy Implementation Program – Proposed Mid-Island Dike Actions

Actions	Results
Work with the BC MoT and others on a program to study, plan and cost share in the building of the Highway 99/Knight Street mid-island barrier (may require a Multiple Account Evaluation of interior barrier options—study cost estimate—$100,000) (Engineering).	The completed 2009 Mid-Island Dike study (Delcan) showed that raising the perimeter dikes would result in higher overall benefit for the cost; the current focus is to raise all perimeter dikes to a minimum of 4.7m above mean sea level. ***Completed***
Once Mid-Island Barrier technical details are finalized: • established a phased implementation program; and • seek senior government cost sharing.	The Mid-Island Dike concept will be re-evaluated once the perimeter dike has been raised. ***Ongoing***
Pursue development of the mid-island barrier along the Highway 99/Knight Street Corridor (Construction cost estimate—$16 million) (Engineering).	The Mid-Island Dike concept will be re-evaluated once the perimeter dike has been raised. ***Ongoing***

While the 2008–2031 Richmond Flood Protection Strategy continues to provide a sound basis for the City's flood risk management program, an update is warranted to fully encompass new learnings, analysis, and re-emphasize the City's commitment to achieving world-class flood protection.

Part 1: The Flood Protection Management Strategy

1.1 Purpose of Strategy

The purpose of the Flood Protection Management Strategy 2019 (Strategy) is to guide the ongoing development of world-class flood protection for Richmond that will:

- keep Richmond a safe place to live, work, and play;
- compliment the Corporate Strategic Vision of making Richmond the most appealing, liveable, and well-managed community in Canada; and
- establish an integrated, sustainable Strategy which better:
  - enhances the City's ability to reduce flood risk, prevent flooding, increase flood protection, minimize flood damage, improve flood-proofing and responses to floods;
  - co-ordinates and manages dike integrity, land use, infrastructure, emergency response and sustainability;
  - defines partnerships, roles, responsibilities and cost sharing; and
  - address climate change implications specific to Richmond.

This report provides an update to the 2008–2031 Flood Protection Strategy which recommends periodic review to address current climate change science and flood mitigation guidelines.

1.2 Extent of Application

This Strategy applies to those areas within Richmond's municipal boundaries where the City has the legislative mandate and primary responsibility to address flood protection.

In locations where the City does not have the jurisdictional authority, such as the Port of Vancouver lands in Richmond, lands held or controlled by either the Federal or Provincial Governments (e.g., most of Sea Island), the City's Strategy encourages interagency cooperation to address mutual flood protection interests and benefits based on the Strategy principles and site circumstances.

Unless noted otherwise, all elevations in this report refer to the Canadian Geodetic Vertical Datum of 1928 (CGVD28). Should the newer CGVD2013 vertical datum be adopted, updating of the elevation references will be required at that time.

1.3 Principles

The Flood Protection Management Strategy is based on the following principles:

Principle	Emphasis
Safety	Richmond is an island city located between the Fraser River and the Strait of Georgia. The City's residents, businesses and infrastructure are to be safeguarded from flood hazards with a range of methods including an appropriate: • level of flood protection; • emergency response preparedness; and • flood recovery plans and programs.
Proactive Prevention	The City will proactively continue its efforts to: • research, plan, design, and implement a world-class flood protection program.
Risk Avoidance	The City will continue to minimize the risks and potential damage associated with flooding.
Sustainability	Flood prevention approaches are to be: • socially, economically, environmentally sustainable; and • able to achieve the City's long term planning, growth and development objectives.
Coordinated Partnerships	The City will coordinate its Strategy in partnership with senior governments, regional agencies, other municipalities, NGOs, emergency service agencies and the private sector.
Research	The City will continue its flood protection research with others to: • take advantage of the latest science, best practices, innovative solutions, and cost sharing; and • improve its understanding of flood risks and management.
Integrated Flood Planning	The City will prepare and update a range of flood protection documents including this Flood Protection Management Strategy 2019, Dike Master Plans, a Floodplain Bylaw, flood infrastructure plans, flood preparedness plans, emergency response plans, flood recovery plans and other plans, as necessary.
Adaptation	The Strategy is the City's primary response to adapt to the projected impacts of Climate Change on flood risks. Mitigation of Climate Change is addressed through the City's Community Energy and Emissions Plan (CEEP) and other strategies.

Principle	Emphasis
Standards	The City will establish and follow a variety of flood protection standards including: *Provincial Standards:* • Updated guidelines recommend planning for 1m of sea level rise to year 2100 and for 2m of sea level rise by 2200. • Provincial Dike Design Standards. • The Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use (2011) and Provincial Flood Hazard Area Land Use Management Guidelines (amended 2018). • Other, as necessary. *City Standards:* • Flood Construction Levels (FCL) standards for buildings and structures. • Flood proofing standards. • Alternate requirements for authorized exemptions to basic standards. • Other, as necessary.
Flood Protection System	The City will provide an integrated physical flood protection system which includes: • a Perimeter Dike as the primary system of defence; • long-term raising of land levels above the floodplain, strategically and economically, through policy and by specifying FCLs for new construction; • infrastructure (e.g. drainage system and pumping stations), • floodproofing buildings and structures; • maintenance programs—cleaning of infrastructure and upkeep of dikes; • stormwater retention/detention—best practices and implementation; • dredging (a Port of Vancouver responsibility); and • other, as necessary.
Incremental Solutions	The City will implement the Strategy incrementally, as cost effective solutions are identified.
Cost Effectiveness	The City: • will implement the Strategy in a cost effective manner, appropriate to existing and planned growth and development; and • recognizes that such costs are part of growth and development.
Cost Sharing	The City will actively solicit partnerships with other levels of government, NGOs and the private sector, to share the benefits and costs of implementing the Strategy. Senior government funding is the historic primary source of funding for flood protection in the Province and is critical for successful implementation going forward.

1.4 Legislative Framework, Roles and Responsibilities

City of Richmond's Role

The City is the primary actor and service provider for flood protection.

1. The City is responsible for local flood protection and management including the ongoing operation and maintenance of the dike infrastructure;

- Planning for perimeter dike upgrades is nearing completion with Dike Master Plans Phases 3, 4, and 5 which are expected to be finalized in 2019.
- The Dike Master Plans guide City designs for perimeter dike upgrades to the year 2100 with considerations for climate change induced sea level rise, land subsidence, and area plans.
- City of Richmond Engineering & Public Works staff monitor and maintain the City's dikes on a continual basis. Upgrades to the City's dikes are completed as Capital projects which are approved by Council in an annual process.

2. The City has a state legislated duty, through the *Emergency Program Act*, to respond first to emergency situations within its jurisdiction and to have an emergency plan in place;

- The City's Emergency Management Office (EMO) works together with senior governments and regional authorities to establish emergency management and recovery plans.
- The City's Engineering & Public Works Division, in coordination with the EMO, have prepared the 2010 Flood Response Plan.
- Threat specific plans are integrated by EMO into an overall management strategy.
- The Emergency Management Plan is scheduled for review in 2019.

3. The City has the authority, through the *Local Government Act*, to designate a floodplain and to set construction requirements for development, subject to Provincial policies and standards (e.g., the Provincial Flood Hazard Area Land Use Management Guidelines);

- Floodplain Designation and Protection Bylaw No. 8204 was adopted in 2008 and guides building setback, Flood Constructions Levels, exemption areas and alternative conditions.

4. The City reviews Discretionary Development Applications (i.e., Rezonings, Development Permits). The City has the authority to set conditions and to require the registration of restrictive covenants for development on land which may be subject to flooding for all discretionary development applications; and

5. The City reviews Non-Discretionary Applications (e.g., building permit approvals). The City has the authority, through the *Local Government Act*, to set conditions and to require registration of restrictive covenants for non-discretionary applications, when exemptions to the provisions of the floodplain bylaw are given.

Provincial Role

In 2004, the provincial role with regard to flood protection and management was significantly altered with legislative changes made to a number of statutes—notably to the *Land Title Act*, *Local Government Act*, the *Flood Hazard Statutes Amendment Act, 2003* and the *Miscellaneous Statutes Amendment Act (No. 2), 2004*.

1. Under the *Dike Maintenance Act*, responsibility and general supervision relative to construction and maintenance of dikes lies with the office of the Inspector of Dikes.

- The Provincial Inspector of Dikes can require reports, inspect records, audit diking authorities, make regulations and prescribe trusts.
- Approval from the Provincial Inspector of Dikes is required for:
  - the construction of a new dikes and flood barriers (*Dike Maintenance Act* Approvals: MoE 2007);
  - changes or alterations to the cross section or crest elevation of a dike;
  - the installation of culverts, pipes, flood-boxes, utility lines, pump stations, or any structure through, on or over a dike;
  - the construction of any works on or over a dike right of way, including structures, excavations and placement of fill or other materials;
  - the alteration of the foreshore or stream channel where the works could increase flood levels or impact the integrity of a dike such as dredging; and
  - construction of erosion protection works bridges and other in-stream works.

2. BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRO)

- FLNRO, through the Office of the Inspector of Dikes, provides guidelines for development in flood hazard areas, guidance and technical information

3. Subdivision Approval

- Provincial approval for subdivision is no longer required, unless the lots are in proximity to a Provincial highway.
- In those cases, the BC Ministry of Transportation and Infrastructure (MoTI) Approving Officers can now consider flooding and erosion potential.

4. Approval of Municipal Floodplain Bylaws

- Provincial approval of municipal floodplain bylaws is no longer required.

5. FLNRO Establishing Flood Protection Standards

- The Office of the Inspector of Dikes establishes standards for municipal dike design, construction, operation and maintenance plans.
- The Office of the Inspector of Dikes reviews and approves these.

- The Province has adopted a new flood profile standard for the Fraser River which is defined by the 2008 study profile completed by Northwest Hydraulic Consultants. The Fraser River flood profile exceeds the coastal flood level for areas of Richmond east (upstream) of Nelson Road.
  - This new standard establishes flood design standards, for freshet, summer, winter and tidal flood threats, to safely convey the largest historical flood of record which occurred in 1894.
  - For Richmond, the new profile varies from approximately 2.8m GSC near Steveston to 3.3m GSC near Queensborough. This does not consider sea level rise or wave effects.
- Sea Level Rise Threats
  - The most recent study completed by the Province suggests a median projection of 1m of sea level rise by year 2100 and 2m of sea level rise by year 2200.
  - The Intergovernmental Panel on Climate Change (IPCC) reports on climate change (IPCC, 2018) estimate a lower increase in global mean sea level rise when compared to Provincial studies.
  - Additional research is needed to refine these values given the variability in current climate change science. As sea level rise is realized and more data is available the projections can be adjusted.
- For Subsidence Flood Threats
  - The most recent studies indicate that subsidence in Richmond is approximately 2mm/year.
  - These values will continue to be monitored and will inform flood protection planning.

6. Research

- The Province conducts research with others (e.g., contributions to the Fraser River Hydraulic Modelling study, assessment of current seismic guidelines).
- Ongoing Provincial research is encouraged.

7. Funding

- The Province was the primary source of funding for flood protection prior to the transition of diking authority to municipalities.
- In October 2007, the Province announced new flood protection funding for BC of $10 million per year for 10 years.
- In 2012, the City was awarded $3.6 million for pump station upgrades.
- In 2016, the City was awarded $16.6 million for pump station and dike upgrades.
- In 2017, the City was awarded $400,000 for flood protection planning.
- Ongoing Provincial funding is encouraged.

8. BC Provincial Emergency Program (PEP) Emergency Preparedness and Recovery

- The Province operates a BC Provincial Emergency Program (PEP) which coordinates aspects such as:
  - emergency preparedness training and funding;
  - disaster response including military assistance; and
  - recovery funding and assistance.
- PEP will respond to emergency calls from local governments and emergency personnel. Ongoing PEP assistance is encouraged.

9. Provincial (FLNRO) Approval of the City's Strategy

- Provincial Jurisdiction: The Province has jurisdiction to approve those items that are directly related to the dike system (i.e., any proposed modifications or additions).
- No Provincial Jurisdiction: For the City's Strategy, the Province is likely to provide only comments or advice.

10. Foreshore & Water

- Existing off-shore structures (navigation jetties) are controlled by senior governments. Contemplated offshore structures and nature-based concepts for wave attenuation (e.g. Sturgeon Banks) will also require land tenure and approvals from senior government.

11. Summary

- The City is committed to co-operating with the Provincial government.

Federal Government

The federal role has primarily been related to issues of national significance or to situations where the capacity or authority of a provincial government to deal with the situation is exceeded. Federal legislation such as the Emergencies Act enables the Federal Government to act in such situations. Much of the responsibility for flood protection has been turned over to the provinces and subsequently the municipality, with the Federal Government providing assistance through enabling funding and research.

1. The focus of Public Safety Canada (PSC) includes:

- Critical Infrastructure Protection;
- Emergency Preparedness; and
- Disaster Mitigation.

Programs under these topics are still evolving particularly with regard to critical infrastructure protection.

2. Establishing Flood Protection Standards

- The Federal Government does not currently establish flood standards; however, CMHC funding for urban development, or post disaster recovery funding may be limited in designated floodplain areas, unless adequate floodproofing measures have been taken.

- The City intends to establish adequate flood protection measure through this Strategy and a range of implementation measures.

3. Research

- The Federal Government provides research assistance (e.g., climate change).
- Ongoing Federal research is encouraged.

4. Funding

- The Federal Government may assist in funding studies, capital dike improvements, preparedness and recovery programs. Periodically, the Federal Government co-funds with the Provincial Government programs for flood protection, for example:
  - the Federal Government provided funds toward the 2006 Lower Fraser Hydraulic Modeling study which was completed by the Fraser Basin Council (FBC);
  - in 2007, $33 million for flood mitigation initiatives to address concerns related to anticipated spring freshet water levels;
  - in 2009 and 2010, $6.3 million was awarded to Richmond through the Federal and Provincially funded Flood Protection Program;
  - in 2013, $2 million was awarded to Richmond through the Federal and Provincially funded BC Building Canada Fund;
  - in 2016, $1.7 million was awarded to Richmond through the Federal and Provincially funded National Disaster Mitigation Fund; and
  - in 2017 the City of Richmond was awarded $1.1 million for flood protection planning through the National Disaster Mitigation Program.
- Ongoing Federal funding is encouraged.

5. Dredging & Foreshore

- The Port of Vancouver completes annual dredging of the South Arm of the Fraser River.
- There is considerable federal land along the perimeter dikes on Lulu Island and Sea Island. The City works together with the Fisheries and Oceans Canada, as well as other Federal stakeholders, on a project-specific basis to identify any concerns or opportunities while completing flood protection upgrades.

6. Summary

- The City is committed to co-operating with the Federal Government and encourages ongoing Federal flood protection programs and funding assistance.

Regional Role

There is no direct role for Metro Vancouver or other Lower Mainland jurisdictions with regard to the City's development and implementation of the Flood Protection Management Strategy, with the exception of coordination with New Westminster on infrastructure in the Hamilton-Queensborough area.

Fraser Basin Council (FBC)

Although it lacks a mandate or authority to oversee flood protection works or emergency services, the Fraser Basin Council has been working with federal, provincial, local government agencies and organizations to highlight flood risks through the Joint Program Committee (JPC) for Integrated Flood Hazard Management. This program has coordinated recent flood plain mapping exercises in the Lower Fraser and lead the recent study to update the Fraser Flood Profile.

In 2014, FBC initiated the Lower Mainland Flood Management Strategy to promote collaborative, regional flood management on the lower Fraser River and the coast between partners spanning all levels of government, including the City, other local governments, and non-governmental organizations.

FBC is the facilitator and administrator working on behalf of the partners to develop the strategy through three phases:

- Phase 1 "Building a better understanding";
- Phase 2 "Developing a regional action plan"; and
- Phase 3 "Implementation".

Phase 1, completed in 2016, focused on flood hazards, vulnerabilities, and existing structural and non-structural flood protection measures. Phase 1 produced the following components:

- analysis of future flood scenarios;
- regional assessment of flood vulnerabilities;
- Lower Mainland dike assessment; and
- review of flood management policies and practices.

Phase 2, initiated in 2017, is expected to include the following components:

- assessment of regional flood mitigation options; and
- assessment of decision-making models and cost sharing options.

The final strategy, anticipated in 2019, is expected to include specific commitments for partners and a cost-sharing approach to support implementation.

The City has been an active participant and funding partner in the Fraser Basin Council's JPC and is committed to the management of growth both within an overall regional context and in terms of its Official Community Plan (OCP).

Richmond intends to continue participating in the Fraser Basin Council and with other stakeholders to better address flood prevention and protection.

1.5 Strategic Framework

As a community within the floodplain, the City acknowledges that an element of flood risk will always exist for those areas that are not raised above the floodplain.

This Strategy provides an integrated flood protection framework which emphasizes:

- preventing flooding, and
- minimizing the impacts of a flood event, should such an event occur.

The integrated Flood Protection Management Strategy elements identified below addresses dike safety, land use management and emergency management.

1. Sustainable Approaches

- As the City of Richmond is committed to improving sustainability, where practical and cost effective, sustainable approaches will be undertaken when implementing the Flood Protection Management Strategy 2019. Flood prevention approaches are to be socially, economically, environmentally sound and sustainable, and able to achieve Richmond City Council's long term planning, growth and development objectives.

2. Flood Protection System

- The City's integrated flood protection system includes:
  - a Perimeter Dike;
  - raising land levels strategically and economically;
  - requiring Flood Construction Levels (FCLs) for new construction;
  - floodproofing buildings and structures;
  - infrastructure (drainage system and pumping stations);
  - maintenance programs—cleaning of infrastructure; and
  - other, as necessary.

3. Dike Integrity and Management

- Richmond's Flood Protection Management Strategy 2019 recognizes both storm surge and river flood threats.
- Richmond's perimeter dike is the primary flood protection system.

New Dike Crest Elevation Standard

The City is committed to meeting or exceeding the Province's coastal still-water flood level of 2.9m. In combination with 1m of sea level rise, a 0.2m land subsidence allowance, and 0.6m freeboard, this yields a design dike crest elevation of 4.7m.

This standard is designed to accommodate the largest historical flood of record which occurred in 1894, sea level rise, and land subsidence to the year 2100.

The City will continue to work with the Provincial, Federal and regional agencies to secure funding for research and construction to meet or exceed the provincial dike standards.

Perimeter Dike Improvement Program

In conjunction with Provincial Diking Authorities, the City is currently upgrading priority sections of the perimeter dike. Completion of the Dike Master Plans will further guide efforts to upgrade the City's primary system of defence against flood hazards.

4. Managing Sea Level Rise Risks

- Sea level rise is monitored and the City will adjust flood protection strategies and implementation timelines to address climate change induced flood hazards as defined by the IPCC and subsequent regional analysis. Currently the City's design for perimeter dike upgrades includes an allowance for 1m of sea level rise to the 2100 and 2m of sea level rise to the year 2200 (baseline at year 2000).
- The City will participate in research studies, in partnership with others, to ensure that climate change induced sea level rise is monitored and proactive adjustments are made to the Strategy.

5. Monitoring Subsidence

- While geological subsidence is very slow and minor relative to sea level rise, it should be monitored and addressed.
- Current levels of subsidence are monitored and the City has made allowances to accommodate additional flood risks due to subsidence.
- The City will participate in research studies, in partnership with others, to ensure that there is proactive planning for land subsidence.

6. Flood Construction Levels (FCL):

- Floodplain Designation and Protection Bylaw No. 8204 establishes the floodplain boundaries, construction setback requirements, Flood Construction Levels, and exemption areas for the City of Richmond.
- Bylaw No. 8204, in consideration of Provincial guidelines, defines certain classes of use and geographic areas within which construction elevations will not be required to meet the established flood levels.
- Examples of exemptions (e.g., to raising the land, to building to FCLs, may include:
  - agricultural buildings and structures (except residential dwellings and accessory buildings); and
  - the Steveston Village Heritage Area where the introduction of grade changes for new construction would detrimentally affect the important heritage character of the area.

7. Raising Land Levels

- As an overall long term objective, the City will seek to raise the average grade of land within all areas of the City.
- To achieve this, the City at its discretion, will strategically and incrementally encourage or require ground levels to be raised, for example where:
  - development opportunities exist (e.g., through rezoning and property redevelopment);

- site size is sufficiently large to enable it to be achieved effectively;
- negative impacts can be reasonably mitigated; and
- land raising is being proposed to meet other objectives such as agricultural viability.

West Cambie example: This approach was taken for the West Cambie area, where the whole Alexandria quarter section was raised during redevelopment.

8. Interface Areas

Between areas of different required raised land height and FCL construction level requirements, the City may establish land and FCL transition requirements and techniques to manage grade changes with minimal problems.

In these situations, the City will determine specific raised land and FCL requirements, on a site by site basis.

9. Ongoing Analysis

The City will monitor the latest flood protection and climate change science (e.g. sea level rise, subsidence, river, ocean conditions), best practices, the effectiveness of its flood protection system and the Strategy. Improvements will be made as necessary.

10. Annual Flood Protection System Improvements

Each year the City will improve its Flood Protection System. This will be achieved by preparing an Implementation Program for Council's consideration as a part of this Strategy. Funding will be through the designated diking utility and grant opportunities.

Individual projects will be submitted through the annual Capital Program for Council's consideration.

11. Emergency Management

- City Emergency Management Office (EMO): The City has established an Emergency Management Office [EMO] which works with Richmond's protective service agencies and City departments to prepare response plans and programs that establish and implement mitigation, preparedness, response and recovery measures for emergency events.
- City Emergency Plan: Under the EMO's guidance, the City has established an Emergency Plan that provides overall direction to guide the City's actions to prepare for, respond to and recover from major disasters. This Plan identifies the key hazards, such as flooding, which threaten the community, priority actions to be taken by threat, roles and responsibilities of staff and key response agencies responsible for managing the City's response and recovery from disasters.
- Flood Response Operational Plan: The City Flood Response Operational Plan outlines the City's strategies for preparedness, response, and recovery surrounding the seasonal spring freshet and any flood events that may result from this annual event.

- City Flood Response Plan: Through the direction of the EMO, a series of threat specific plans have been, or are in the process of being prepared. With direct reference to flood protection management, a City Flood Response Plan has been prepared and operationalized through the City's Public Works Roads and Construction Department and a City Flood Evacuation Plan is currently being drafted.
- Key Emergency Management Elements: Some of the key emergency management elements imbedded within the Implementation Program include:
  - the co-ordination of community planning and emergency facilities to ensure that City refuge/public gathering areas during disasters are located in areas which do not flood;
  - the preparation and on-going updating of City public evacuation and communication programs;
  - reviewing and implementing plans for refuge areas, emergency routes, and creating public awareness;
  - establishing a protocol for dike restoration (e.g., City procedural response plan); and
  - updating the City's existing procedural policy of comprehensive dike maintenance.

12. Funding

- Each year, to implement this Strategy, the City intends to:
  - budget to implement this Strategy, subject to corporate priorities and funding,
  - seek senior government funding.

13. Senior Government and Partner Funding

- The success of the Strategy requires senior government and partner funding.
- The City will seek senior government and partner funding for a wide range of flood prevention and protection research, monitoring, studies, planning and improvements.

14. City Diking and Drainage Utility

- In 2006, the City established a City Diking and Drainage utility for the purpose of funding dike and drainage improvements. The City intends to continue and grow this utility.

15. Annual City Dike Improvement Capital Funding

- The City establishes an annual City capital budget to ensure that each year funds are available to undertake flood protection studies and work. The City intends to continue this funding mechanism.

16. Implementation (see Part 2)

- The City will implement the Strategy by establishing an Implementation Program.
- The Strategy will guide all City Flood Protection actions and is to be referenced in all relevant City proposals and senior government funding requests.

Part 2: The Implementation Program

The 2008–2031 Flood Protection Strategy was intended to be a living document—one which evolved over time as new science, information, concepts, techniques, programs and cost sharing opportunities arose. The updated Flood Protection Management Strategy 2019 provides this information and recommendations for future work related to flood protection.

The City also recognizes that the Strategy requires:

- jurisdictional, economic and cost sharing partnerships;
- the involvement and direction, of senior governments, specifically regarding dike standards; and
- on-going actions to enhance the City's knowledge and ability to prevent flooding.

The Flood Protection Management Strategy 2019 will be reviewed and updated, as required.

The Flood Protection Management Strategy 2019 will be implemented through an Implementation Program.

The Implementation Program Chart below identifies:

- some of the key tasks;
- the approximate completion dates;
- status of projects;
- cost estimates (where available); and
- City Division responsibilities.

Implementation will occur, subject to City corporate priorities and funding.

Detailed implementation will be determined by Council annually.

The City's Engineering and Public Works Division will lead the Strategy and Implementation Program in a proactive and collaborative manner with other City division sections including Policy Planning, Finance, Building Approvals, Development Applications and the Emergency Management Office.

Implementation Program – Next Steps

Category	Action
Program Management	Ensure that the flood risk reduction program is supported by leading edge technical investigations. Short-term priorities should include a wave runup analysis, and definition of the potential flowslide zone around the island perimeter.
Lulu Island Perimeter Dike	Finalize Phases 3, 4, and 5 of the Dike Master Plans to complete the conceptual framework for upgrading the City's perimeter dike.
	Review the Phase 1 Dike Master Plan to determine whether the proposed Steveston Island offshore dike / sea gate continues to be cost effective in view of the seismic design standard, and to update/ complete the construction cost estimate.
	Update the Phase 2 Dike Master Plan to include construction cost estimates.
	Establish a target timeframe for completion of dike upgrading as per the current Dike Master Plans, along with a system to report progress on this important objective.
	Adopt a world class standard for the next round of Lulu Island Dike Master Plans (10,000-year return period flood, current sea level rise projection for 100-year horizon, consideration of sea level rise for 200-year horizon, conservative wave runup allowance). Support such determination with a risk-based approach.
	Develop and adopt a seismic dike design standard that considers the specific situation in Richmond, and is also acceptable to the Province.
Floodplain Designation and Protection Bylaw	Update the flood construction levels of the bylaw to reflect the most recent Fraser River flood profile and current coastal flood level (including sea level rise). This would ideally involve updated dike breach inundation modeling.
	Update the other provisions of the bylaw as noted in this report. Endeavour to reduce the number of situations in which exemptions and relaxations are provided.

Category	Action
Secondary Dikes on Lulu Island	Consider potential other effective secondary dikes on Lulu Island that would reduce the extent of flooding from a dike breach and/or help to achieve the desired level of seismic performance.
	Proceed with the Boundary Road secondary dike as per the Phase 3 and Phase 4 Dike Master Plans, with the intent to provide redundancy in flood protection, and also fulfil seismic performance objectives.
	Proceed with the mid island secondary dike on an opportunistic basis, either in conjunction with Highway 99 upgrading, or with large-scale land raising.
Internal Drainage on Lulu Island	Review and update design criteria for drainage pump stations and floodboxes (key issues include increasing flood level, increased duration of pumping, increasing internal runoff, and fish passage). Also consider whether some or all stations should be able to provide post-disaster service (key issues include seismic performance, standby power, and emergency access).
	Update the master drainage plan to accommodate the soon to be completed Dike Master Plans (in particular, moving drainage channels away from the perimeter dike) and Local Area Plans and Sub-Area Plans (with respect to land raising).
Dike Operation and Maintenance	Establish a consolidated dike operation and maintenance manual, organized by dike master planning reach (including Sea Island, Mitchell Island and Richmond Island) to provide a thorough record of dike design drawings, inspection reports, maintenance work, and miscellaneous activity along the dike.
Management of Lulu Island Perimeter Dike Corridor	Designate a wide (perhaps several hundred metres) strip of land along the perimeter dike corridor as a development permit area for flood protection purposes. The purpose would be to ensure that all activity in this area gives priority to long-term flood protection objectives.
	Integrate the above-noted development permit area provision for flood protection purposes with other City programs such as the Waterfront Strategy and the Ecological Network Management Strategy.
Sea Island	In the Burkeville residential area, consider flood protection concepts as noted above for Lulu Island (land raising, updated flood construction levels, and internal drainage are particularly applicable).

Category	Action
Mitchell Island	Proceed with a program of road raising, with future development areas raised to the flood construction level (as is recommended in the Phase 5 Dike Master Plan).
Habitat Compensation	Recognizing that dike upgrading will impact the fisheries resource, and that on-site mitigation of impacts is not always effective and/or practical, develop a broad-scale habitat compensation program to address the cumulative impacts of dike upgrading in all areas of the City (possibly as a dike master plan phase).

Implementation Program – Continuing Strategies

Category	Action
Program Management	Continue to have a senior staff position designated as the leader of the City's flood risk management program.
	Enhance monitoring of river/sea level, wind and wave effects, dike fill, internal water level and dike crest elevation.
	Review the level of funding for the Drainage and Diking Utility to ensure an appropriate rate of construction of structural flood protection works.
River Engineering Considerations	Work with the Port of Vancouver, and possibly other local governments in the Fraser River estuary, to ensure that key river monitoring activities are undertaken. This includes bathymetric survey, dredging management, and river engineering assessment.
Lulu Island Perimeter Dike	Continue to upgrade the Lulu Island perimeter dike as the top flood protection priority.
	Promote and enable widespread land raising on Lulu Island through Local Area Plans and Sub-Area Plans.
	Investigate regional soil disposal and dredging material as cost-effective sources of fill.
	Ensure that major underground utilities that cross Lulu Island are designed to accommodate significant future landfill that would be associated with widespread land raising.
	Encourage the City of New Westminster to adopt a similar standard and approach for upgrading of its portion of the Lulu Island Perimeter dike.
Internal Drainage on Lulu Island	As pump stations are upgraded, ensure that location is consistent with the long-term dike alignment.
	Pursue an effective approach to rehabilitation of box culverts within the internal drainage system.

Category	Action
Sea Island	Continue to cooperate with the Vancouver Airport Authority to upgrade the Sea Island perimeter dike, and on other flood protection issues.
Richmond Island	Continue with flood protection as a responsibility of the single land owner on the island (as is recommended in the Phase 5 Dike Master Plan).
Emergency Management	Continue with an integrated emergency management planning approach both internally and with recognition of other agencies and partners the City will rely on during significant events.
	Continue to work with transportation authorities with the objective of making bridges and the tunnels able to function as post-disaster structures as key components of an emergency evacuation plan.
	Continue to enhance capabilities for emergency planning, flood response and flood recovery.
Periodic Program Review	Continue to review the Flood Protection Management Strategy annually and consider formal updates on a 5-year cycle.

Appendix 1: Analysis

Introduction

This section was prepared by the City of Richmond with assistance from Kerr Wood Leidal Associates Ltd. and sub-consultants who provided expert advice on environmental, geotechnical, and other fields related to flood protection.

Purpose

The purpose of the Flood Protection Management Strategy 2019 is to enhance the City's ability to prevent flooding and minimize the risk and effects of flood damage by monitoring climate change, implementing proactive policies and partnerships, and upgrading critical flood protection infrastructure.

Context

The City of Richmond is comprised of islands and is located in the floodplain of the Fraser River.

The three most developed islands are:

- Lulu Island on which lies the developing urban portion (60%) of the City (West Richmond) and a considerable amount of valuable agricultural land (40%) in the provincial Agricultural Land Reserve;
- Sea Island on which lies the Vancouver International Airport (YVR) and the community of Burkeville; and
- Mitchell Island which consists of industrial related activities.

Richmond is bounded by the Fraser River and the Strait of Georgia, and is subject to flood risks from the Fraser River and the sea. The City is also subject to other flood-related hazards, including dike breach, seismic effects, internal drainage, and river instability. The City recognizes that with the human investment in both urban development and agriculture, the need for the protection of residents, farming and infrastructure is paramount.

Until 2004, when the Province terminated its floodplain management program, flood protection requirements and construction levels were regulated by the Province. These have now become largely the responsibility of the City as the local Diking Authority.

The principal method of protecting life and property on Lulu Island from flooding has been a structural one, primarily diking.

Richmond and New Westminster rely on each other for flood protection on Lulu Island as they share responsibility for the Lulu Island perimeter dike. The Lulu Island perimeter dike is approximately 56km in total length, of which approximately 49km (88%) is under the City's jurisdiction. Richmond relies on New Westminster for flood protection at the critical

upstream end of Lulu Island (Queensborough). New Westminster relies on Richmond for flood protection in a broader sense, given that the greater proportion of the perimeter dike is within Richmond.

Richmond and the Vancouver Airport Authority rely on each other for flood protection on Sea Island as they also share responsibility for the perimeter dike. The Sea Island perimeter dike is approximately 15km in length, of which approximately 1.1km (7%) is under the City's jurisdiction.

2008–2031 Flood Protection Strategy

At a high level, the 2008–2031 Flood Protection Strategy:

- documented climate change and sea level rise as emerging issues that the City would need to address;
- recognized the Lulu Island perimeter dike as the cornerstone of the City's flood defences;
- initiated a dike master planning process for dike upgrading;
- identified the need for further consideration of seismic risk;
- identified the need for an updated floodplain bylaw to regulate development;
- provided for widespread land raising to be considered in the planning process; and
- recommended the review secondary inland dikes.

Key Factors Influencing the Strategy

Climate Change

Climate change induced sea level rise, higher intensity storms, and increase in freshet flows are primary considerations in the Flood Protection Management Strategy 2019 due to their significance in increasing flood risk. Models that project future climate suggest that the rate of sea level rise will accelerate as the climate warms. The effects of long-term subsidence also need to be considered due to its impact on relative sea level rise. Review of these projected conditions will guide infrastructure upgrades and land use considerations.

Provincial Guidelines & Regional Considerations

The Province has significantly updated their sea level rise and dike design guidelines (e.g., Flood Hazard Area Land Use Management Guidelines) since the 2008–2031 Flood Protection Strategy was endorsed. These changes, including regional initiatives and guidance documents, such as those presented by the Fraser Basin Council, contribute to Richmond's updated design standards for flood protection.

New Information

The availability of improved information on climate change, variation in land use over the years, and the need to examine both structural and non-structural issues related to floodplain management, further demonstrates the need to review the 2008 Strategy.

Project Context

Flood Risks

Flood Hazards – Summary

The City faces the following primary flood hazards:

- A dike breach that may occur as a result of water overtopping the dikes;
- The liquefaction of soils under the dikes as a consequence of an earthquake or dike breach;
- Piping through a dike caused by water under pressure, eroding soil particles to cause a tunnel through the dike; and
- Human damage to a dike.

The Strategy addresses these flood hazards in a comprehensive manner, in particular, those that:

- originate from high tidal ocean levels; and
- are caused by high freshet discharges in the Fraser River.

It is unlikely that both extreme high ocean levels and extreme high river discharges will occur at the same time.

Most of the land surface of Lulu Island that has not been raised by fill placement lie between an elevation of 0.5m to 2.5m geodetic, with the average land level in Richmond between elevation 1.0m and 1.5m.

Contributing Factors

For floodwater to enter the interior of Lulu Island from the river or the sea, it must either overflow the perimeter dikes, or these dikes must be breached in some manner. Given the current design and generally good condition of the existing dikes, an overflow would likely only result from:

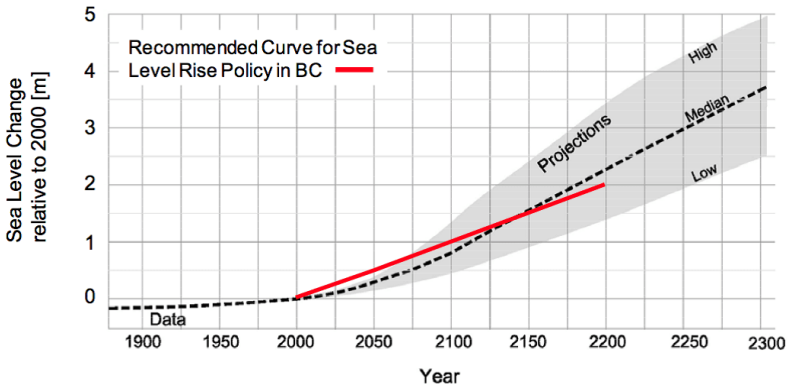
- an extreme high water condition in the river or tidal sea;
- from a lowering of the dike crest; or
- an increase in the level of the Fraser River exceeding the dike crest, by extreme freshet discharges in the Fraser River.

When water overflows an earth dike, it may erode the embankment and breach the dike. The possibility of a breach developing from an overflow depends on the magnitude, nature and duration of the flow and the design and surface materials of the dike.

Climate Change – Sea Level Rise

Sea level rise projections currently referenced by the Province is shown on Figure 1. The recommended linear projection will allow municipalities to overbuild their dikes in advance of the median projection. The City of Richmond has adopted 1m of sea level rise by 2100 and 2m of sea level rise by the year 2200 (relative to the year 2000) in current perimeter dike designs.

Figure 1: Sea Level Rise Projections (BC, Delcan, 2009)



Climate Change – Temperatures and Snow Melt

Climate change will increase average temperatures across BC. While precipitation will increase slightly, the fraction falling as snow will decrease. By mid-century, models suggest this will result in substantial declines in snow accumulation at lower and mid elevations across the watershed (Islam et al., 2017).

While average snowpacks and high-flow conditions are expected to decrease, climate change will also increase variability. Given the extensive uncertainties associated with climate change, a precautionary approach is appropriate.

Sedimentation, Dredging and Erosion

The Fraser River transports about 20 million metric tonnes of sand and silt to the sea each year, with about 80% of the annual delivery occurring during the spring freshet (Williams and Roberts, 1989). The material is transported as both bedload (along the river bottom) and suspended load (within the water column).

For the period between April 2006 and March 2007, the Fraser River Estuary Management Program (FREMP) reported the removal of 3.18 Mm3 for the navigation channel (FREMP, 2007). The need for removal of sediment by dredging needs to consider environmental impacts and ensure that river erosion is not increased in other areas.

As a result of dredging and flood protection projects by various authorities on the lower Fraser River, the river has been relatively stable in the past century. Trifurcation works are maintained at New Westminster to control the flow split between the North Arm, South Arm and Annacis Channel. The potential remains for the river alignment to abruptly change in the future, most likely during a large flood. This could result in increased bank erosion where the redirected flow hits a vulnerable river bank. Such potential is greatest on the South Arm due to a higher percentage of flow that is directed into it.

Wind Setup

Wind setup is a local increase in water depth near the shoreline caused by the shear force of an wind blowing over the water surface towards the land. The magnitude of wind setup depends on the available wind fetch and water depth, and will be greatest where there are extensive areas of shallower water. Sturgeon Bank is an example of an area that could contribute to wind setup along the western shoreline of the city.

Because of its local nature, a "typical" value for wind setup cannot be defined for Richmond. Where applicable, site-specific values must be determined and added to the still-water coastal flood level. A case study of the West Dike in the 2011 Sea Dike Guidelines (Ausenco Sandwell, 2011a) includes a local wind setup allowance of 0.3m to 0.4m.

Wave Effects

Wave effects can greatly exacerbate coastal flood hazards in unprotected areas. Historically, the western shorelines of Lulu Island and Sea Island have benefitted from the protection provided by Sturgeon Bank. This extensive complex of sand banks, mud flats and intertidal marshes follows the west side of the two islands from the Fraser River North Arm to the main South Arm. The shallow features help to dissipate wave energy during storms, causing the largest waves to break before reaching the foreshore.

Tsunamis

Tsunamis generated by major earthquakes at remote locations around the Pacific Rim are not a major hazard to Richmond. The City is protected by Vancouver Island, and a tsunami generated at a distant location would lose considerable energy passing through the Juan de Fuca Strait and Strait of Georgia.

Earthquakes

Potential impacts of an earthquake on the dike system include:

- settlement of the dike crest, which increases the likelihood of overtopping;
- deformation of the dike cross-section, which decreases geotechnical stability while increasing seepage and the potential for internal erosion; and/or
- liquefaction of the dike fill and/or underlying river bank, triggering in a "flowslide" where some or all of the liquefied material flows into the river or foreshore.

Liquefaction is considered the most severe of the above impacts, since a major flowslide could conceivably result in the complete loss of a dike section, resulting in flooding at the next high tide.

Regional Opportunities and Challenges

Federal

Federal jurisdiction relates to dredging of the Fraser River. Prior to 1998, the Coast Guard reported to Transport Canada and were responsible for dredging. In 1998 the Coast Guard began reporting to DFO, and through this, were given a revised mandate that does not include dredging (largely due to costs). As a result, dredging has become the responsibility of the Port Authorities.

According to a 2014 report on Fraser River dredging (City of Richmond, 2014), bigger vessels have resulted in a need to increase the navigable river depth from 8.7m in the 1960s to the current depth of 11.5m.

Provincial

In 2014 the Province established new guidelines for dike seismic design, replacing the standards from 1998. The current BC Seismic Design Guidelines for Dikes outline an approach that is considered difficult to meet without costly and impractical ground improvement works. Additionally, the guidelines are considered very conservative in some situations because they require performance under extremely rare scenarios. For example, the guidelines require dikes to maintain 0.3m freeboard in the event of a 10-year return period flood occurring following a 2,475-year return period earthquake which has a probability of 0.004% in a 1-year period. This is significantly rarer than the design event for the dike crest elevation (500-year return period event has a 0.2% annual exceedance probability). It is understood that the Province is currently reviewing the guidelines, and an updated version may be forthcoming by 2021. This is considered to be an emerging area of regulation where the end result is uncertain.

City of Richmond

Raising Land

City of Richmond Council adopted a Floodplain Management Implementation Policy 7000 on September 11, 1989. The strategy established:

- flood construction levels;
- procedures for development occurring within an exempt area (the principal urban portions of Richmond); and
- priority dike construction and improvements.

Bylaw No. 8204, recommended by the 2006–2031 Flood Protection Management Strategy and adopted in September 2008, has since replaced the Floodplain Management Implementation Policy 7000 and provides guidance on development setback, Flood Construction Levels, and exemption conditions.

The general exemption for Area A is notable in that it covers a high population, urban area of the City, as shown on Figure 2. Structures within Area A are generally exempted from the above-noted FCL requirements, and are instead required to have the lowest level (underside of a floor system, pad, etc.) set at minimum 0.3m above the highest elevation of the crown of any road adjacent to the parcel. The Richmond existing ground elevation map (Figure 3) shows that the majority of land within Area A lies at or below elevation 1m. Therefore, it is interpreted that the Area A exemption would result in building lowest level elevations of 1.3m or less. This would be more than 1.5m lower than the 2.9m FCL prescribed for the area without the exemption.

Review of the current large area exemptions could allow for more opportunities to raise land with development.

Figure 2: Bylaw No. 8204 Schedule B – Flood Construction Levels

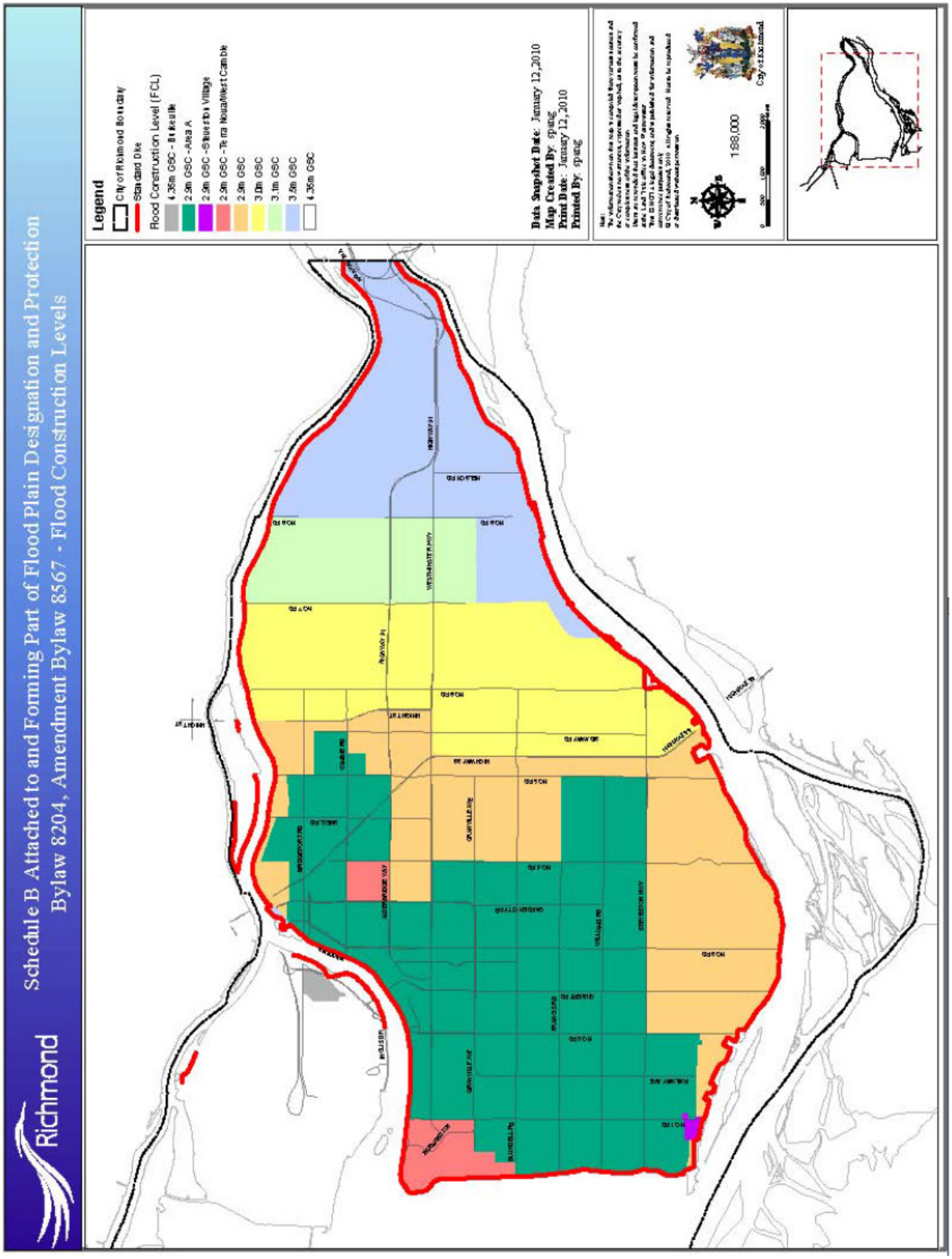
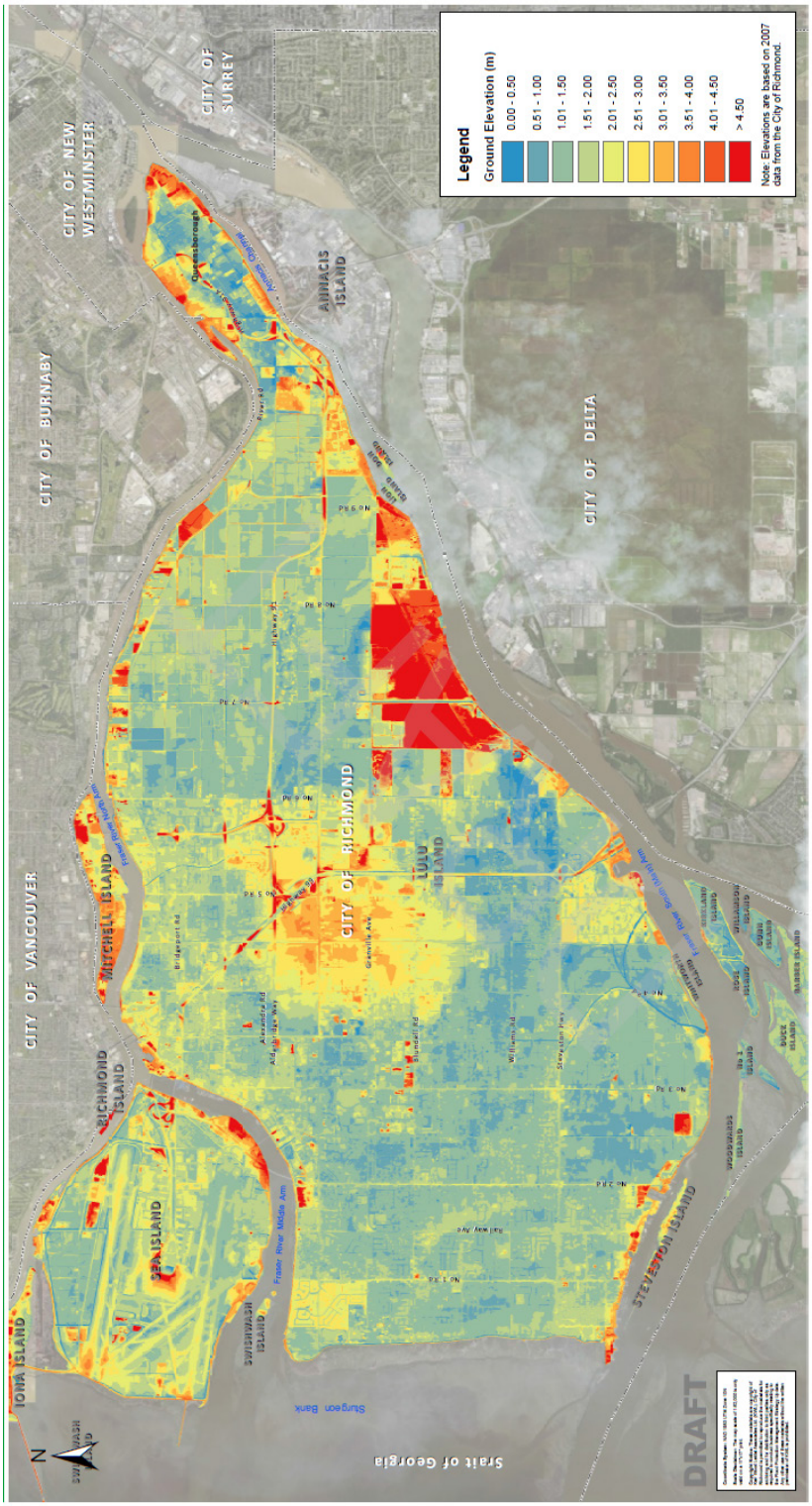


Figure 3: City of Richmond Elevation Map (2016)



Hazard-Based vs Risk-Based Level of Performance

A literature review was conducted to learn how other jurisdictions determine level of performance standards for structural and non-structural flood risk reduction measures.

Two major high-level approaches were identified:

1. Hazard-based level of performance

A legal/political decision is made to set the performance of measures to a specific flood hazard intensity (e.g. 200-year return period/0.5% annual exceedance probability). Often, the specific level is based on a historic event. This is the current system in British Columbia (200-year return period/1894 Fraser River flood). This approach often does not take into account the consequences and overall risk associated with failure of the flood risk reduction measures.

2. Risk-based level of performance

A technical analysis of flood risk (a product of flood probability and flood consequences) is used in conjunction with a legal/political decision on societally tolerable risk to determine the suite of structural and non-structural measures needed to reduce the flood risk to an acceptable level.

Two local jurisdictions are currently using the risk-based approach, these being the District of Squamish and the District of North Vancouver.

Legal Considerations

To take full advantage of the regulatory authority provided under the *Local Government Act*, Richmond has adopted Bylaw No. 8204 to guide developments in the City. In addition to allowing the municipality to regulate setbacks, flood construction levels and provisions for use, the Act provides the ability to require a statutory covenant and establish indemnity to the City and the Province for new construction in areas where flooding could occur.

Under the Community Charter where the Building Inspector thinks that a flood hazard exists a geotechnical report can be required but once requested, the Building Inspector must abide by the report without deviation and the building permits can only be issued with a covenant. While a Section 910 bylaw is seen as the preferred and more flexible option for regulating flood protection measures, uncertainty exists as to how the following section of the Compensation and Disaster Financial Assistance regulation of the Emergency Program Act will be interpreted in the aftermath of a significant flood event:

"If an area is designated under the Municipal Act as a floodplain and a public facility is built or installed in that area after the area has been so designated, no assistance will be provided to repair, rebuild or replace the public facility if it is damaged in a flood unless the structure was determined by the Minister of Environment, Lands and Parks or by Canada Mortgage and Housing Corporation to have been properly flood protected."

The regulation also places similar constraints upon new public facilities.

Financial Considerations

As part of any new strategic initiatives, dike improvements, maintenance, as well as construction, requires substantial capital investments. Richmond has an established dike utility which is used to address seismic/stability improvements to some of the weaker portions of the perimeter dike system. However the City will not have the resources to undertake such capital improvements on its own. Thus, there is a need to pursue partnerships, senior government assistance as well as to, broaden the use of City Development Cost Charges (DCCs) to include dike improvements, and other initiatives.

At a current level of utility funding of nearly $12M per year, and assuming that 75% of the funding is applied to dike upgrading, at least 60 years (and likely more) of dike upgrading work will be required to meet the performance level reflected in the current Dike Master Plans. Further work would be needed to implement any higher dike standard that may be desired.

Changes to sea level rise and other flood hazards may require review of the current funding allocations. If flood hazards increase at a faster rate than currently projected, the City may need to adjust funding priorities to mitigate the additional risk.

Flood Risk Mitigation Analysis

Flood Event Return Period

For the lower Fraser River, the river flood design profile has been derived based on the largest contemporary flood peak which occurred in 1894. This flood design profile and the extreme sea level recorded at Point Atkinson has been commonly used as the provincial standard for deriving design dike profiles for the Lower Fraser River and flood construction levels in the adjacent floodplains. The peak discharge at Hope for the 1894 event has been estimated at 17,000m3/s.

Historically, the design flood level has been the site-specific maximum of the 200-year return period coastal flood (0.5% annual exceedance probability) and the 1894 Fraser River freshet flood of record.

During the development of this Strategy, a decision was made to provide a higher standard of flood protection in Richmond by considering the 500-year return period flood event with sea level rise allowance, land subsidence and seismic events. This was based on the following:

- a flood event greater than the current design event could occur;
- to ensure that the substantial increases in Richmond's population, development, and investment, are best protected;
- to maximize "Safety" and "Prevention", which are major City priorities;
- to increase the confidence in the City's flood protection assumptions and planning; and
- to consider the combined effect of a significant seismic and flood event occurring within the same year.

For deriving the design sea level, the City has adopted the Province's coastal still-water flood level of 2.9m defined by the 2008 study completed by Northwest Hydraulic Consultants. In combination with the largest historical flood of record which occurred in 1894, 1m of sea level rise, a 0.2m land subsidence allowance, and 0.6m freeboard, this yields a design dike crest elevation of 4.7m for most of Richmond's perimeter dike.

The Fraser Basin Council is completing other studies which will increase our knowledge of flood event levels and regional flood protection management. The City will consider this information in its on-going monitoring.

Uncertainties

While the type of hazards can be defined, including the probability of certain water levels being realized, current knowledge is insufficient to determine the actual risk or probability of a dike breach or failure. Dikes are now designed to be higher than a certain water level, and it is assumed that the defense system will not fail until at least that level is reached.

Accurately assessing the probability of a dike breach is technically complex and requires a variety of detailed data.

Information is required about:

- load characteristics (e.g., flood levels, wave effects, earthquake models, climate change assumptions, etc.);
- potential failure modes (overtopping, piping, erosion, earthquake, etc.); and
- performance characteristics of the dike structure (e.g. foundation conditions, crest elevation, geometry, fill materials, compaction, site-specific seismic response soil data, etc.).

Data on dike performance characteristics are much more limited for many of the dikes in BC's Lower Mainland. Most of the local dikes were originally built (or re-built) around the turn of the century without comprehensive engineering design standards or records. A significant data collection and monitoring program would be required to support on-going analysis of the likelihood of dike breaches. Some of this information (e.g., accurate and detailed crest profile drawings) is considered critical for the effective operation of any high-consequence dike system; obtaining this information is a priority for the City. The City of Richmond continues to collect and analyze dike performance data in coordination with regional diking authorities.

The City has completed assessments of hydraulic (flood) loads and is currently looking into wave effects, seismic events, and performance characteristics of the City's dikes.

Combined Frequency Analysis

Earthquakes and floods can individually result in dike breaches through flowslide failures associated with earthquakes and overtopping, piping and other processes associated with floods.

Earthquake and flood hazards can also interact to intensify dike breach hazards.

While the potential for damage to the dike would be high, the likelihood of a major earthquake and a minor to major flood occurring at the exact same time is effectively zero. Consideration should therefore be placed in the scenario where seismic events damage the dikes and Richmond is exposed to an elevated flood risk until repairs are completed.

Table 5 presents the probability that a flood occurs within 1 year of a major earthquake for a range of earthquake and flood intensities. This effectively represents the situation where an earthquake occurs and it takes 1 year to complete repairs to the dike system. For example, for any given year there would be a 1 in 24,750 chance or 0.004% probability of a 2,475-year return period earthquake and 10-year return period flood occurring within the same year.

Table 5: Combined Probability of Earthquake and Flood Occurring in the Same Year

Earthquake Return Period (Years)	Flood Return Period (Years)		
	≥ 10	≥ 200	≥ 500
≥ 100	1:1,000	1:20,000	1:50,000
≥ 475	1:4,750	1:95,000	1:237,500
≥ 2,475	1:24,750	1:495,000	1:1,237,500

Site-specific geotechnical seismic performance analysis and water level frequency analysis is required to assess this hazard. In general, the probability of this combination of events for various earthquake and flood event combinations can be determined using the following steps:

1. Residual Crest Elevation

Estimate the post-earthquake crest elevation of the dike (for a non-flowslide event).

2. Minimum Overtopping Event

Estimate the minimum return period water level event that would cause reduced freeboard such that overtopping is likely (e.g., 0.3m or less).

3. Exposure Period

Estimate a reasonable duration of time that would be required following the earthquake to repair the dike, including raising the crest to the pre-earthquake/design level.

4. Probability

Calculate the probability that the minimum return period overtopping water level occurs within the exposure period.

Contemplated Approach in Richmond

Recognizing the unique situation in Richmond, an alternative approach and criteria have been developed as part of the strategy and current dike master planning activities. This represents some variance with the current BC Seismic Design Guidelines for Dikes.

The purpose of this alternative approach is to harmonize the level of performance between seismic and non-seismic (i.e., overtopping, piping, etc.) dike failure modes. This will allow the City to more efficiently identify, prioritize, and address the areas of highest risk regardless of the governing failure process.

The approach is conceptually simple, but requires confirmation of multiple scenarios. Should flowslide failure be anticipated under the 475-year return period earthquake, additional mitigation measures should be implemented. The alternative approach calculates the post-earthquake dike elevation for the specified area and identifies the flood return period which would result in unacceptable wave overtopping. Assuming a 1-year exposure period for dike repair (this value can be modified) the method then calculates the total overtopping risk by combining the probabilities for the earthquake and flood scenarios. This calculated probability is then compared with the performance criterion (e.g., the adopted flood risk return period) to determine if seismic performance is acceptable.

The most important aspect of seismic dike protection in the City is to identify potential flowslide areas, and to implement appropriate counter measures. As improvements in and around the dike are not likely to be effective in most flowslide situations, further investigation into large area land raising to mitigate flowslide failure may be warranted.

Options for Minimizing the Potential for Flooding

In addition to diking, there are a number of other approaches available to prevent and mitigate flooding. These include the following:

Raise Land Levels

The rationale for raising the level of the land is similar to that which led to the establishment of flood construction levels. It is an attempt to retroactively institute consistent flood construction levels related to design flood levels for all parts of Lulu Island, even those which are currently in the Floodplain Exemption Area.

Flood Construction Levels

It is appropriate to periodically update the FCL's that are specified in the bylaw. This may be based on four considerations:

- updated dike breach modelling in consideration of current sea level rise projections and estimated Fraser River flood level;
- the extent to which land raising may be practically performed in various parts of the City in accordance with existing grade constraints;
- the degree to which it is appropriate to require structural elevation of buildings (as opposed to landfill); and
- specific direction for portions of buildings that may be below the FCL.

Further to the last bullet, further restriction of building use and/or configuration below the FCL could be required where achieving the FCL by structural means is permitted. The need for further structural, waterproofing and flood protection measures for building areas below the FCL (underground parking areas and basements) could also be considered.

Flood Proofing

Flood proofing is achieved by raising habitable space on fill, or on a crawlspace or carport or garage that can survive flooding.

An alternative called wet "flood proofing" allows habitable space below the FCL, but relies on the use of flood resistant building materials and construction methods to mitigate the flood impact.

Management of Dike Corridor

Under the *Local Government Act*, a municipality may designate Development Permit Areas in its Official Community Plan for one or more of the following purposes: protection of the natural environment; protection of development from hazardous conditions; protection of farming; revitalization of an area in which a commercial use is permitted; and establishment of objectives for the form and character of intensive residential, commercial, industrial and multi-family development.

There may be merit in the City expanding the designation of development permit areas along the dike corridor, and developing additional guidelines to encourage land development to achieve the above-noted ideal scenario for the perimeter dike.

Potential benefits may include:

- bring the perimeter dike issue more broadly to the attention of the public and the development community;
- giving the City an additional tool to appropriately oversee/regulate all activities along the dike that may impact the dike;
- consider options for raising land inside the dike in conjunction with land development (i.e. establish a superdike); and
- promote the concept of widespread land raising inside the dike.

Land Use and Environmental Considerations

Growth

Most of the residential, commercial and administrative nodes of the city are situated within the 'floodplain exemption area' in West Richmond. Residential growth, as well as commercial expansion, has continued, but is confined largely to the western portions of the city (with the Hamilton area on the New Westminster boundary and Burkeville on Sea Island being notable exceptions). This additional development further emphasizes the need for continued monitoring and flood mitigation planning, since the added population and investment in the area has significantly increased the potential for damage from a flood event. Agriculture predominates in the eastern portions of Lulu Island, with

extensive cranberry fields towards No. 8 Road and Nelson Road. This has been a growing sector over the past few years, and now over 850 hectares of the agricultural crop land is devoted to cranberry production (the next largest crop is hay with about 430 hectares). Special drainage canals, ditches and dikes are required for the seasonal harvesting of cranberries.

Land Use Changes

Land use change has been dramatic since the initial adoption of the 1989 flood management strategy. Notable is the expansion of the residential development in the City Centre and industrial and business park base. Major new activities include the development of the Port of Vancouver lands which extend along the south arm of the Fraser River at the southern ends of No. 7 Road, No. 8 Road and Nelson Road. Large warehousing and distribution centres characterize this area. The area has been developed on an extensive volume of fill sand taken from the dredging operations conducted by the Port of Vancouver. This fill creates a substantial area of high elevation topography in Richmond with a land surface situated above even the worst case extreme flood levels. The Port of Vancouver (Richmond lands) will ultimately provide for about 1,000 hectares of industrial use in this location, and the elevation of the land here functions as a significant flood barrier.

Environment

The City considers the environment to be of significant importance and has successfully protected several natural areas such as foreshore areas, the Richmond Nature Park, the Northeast Bog Forest and the Terra Nova Natural Area. In 1991, the City amended its Official Community Plan to include an inventory of environmentally sensitive areas such as bogs, estuaries, and sloughs as valuable natural habitats. In 2005, parks and protected areas accounted for 9.7% (1248ha) of the municipality's land base.

The City's 2022 Parks and Open Space Strategy (2013), Ecological Network Management Strategy (2015), Waterfront Strategy (2009), and Trail Strategy (2010) are all considered as a part of Richmond's Flood Protection Mitigation Strategy.

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City of Richmond
6911 No. 3 Road, Richmond, BC V6Y 2C1
Telephone: 604-276-4000
www.richmond.ca