City of Richmond

Report to Committee

To:	General Purposes Committee	**Date:**	June 29, 2006
From:	Terry Crowe, Manager, Policy Planning & Robert Gonzalez, P.Eng., Director, Engineering	**File:**	
Re:	**Richmond 2006-2031 Flood Protection Management Strategy**		

Staff Recommendation

That, as per the report from the Manager, Policy Planning and the Director, Engineering, entitled: "Richmond 2006-2031 Flood Protection Management Strategy" (**Attachment 8**), dated June 29, 2006:

1. Council receive the proposed "Richmond 2006 - 2031 Flood Protection Management Strategy";

2. The "Richmond 2006 - 2031 Flood Protection Management Strategy" be referred to the appropriate Provincial Ministries (Environment, Transportation) and stakeholders (e.g., City of New Westminster, Fraser River Port Authority, Fraser Basin Council), for comments and approvals;

3. Staff pursue cost sharing for the Strategy Implementation Program with senior governments and stakeholders;

4. Staff begin more detailed discussions with the BC Ministry of Transportation to clarify the scope of work required to construct the proposed mid-island barrier along the Highway 99 / Knight Street Corridor;

5. Flood covenants, including indemnity clauses, be required for all discretionary development applications (e.g., subdivision, rezoning, development permits);

6. Staff prepare an Interim Floodplain Bylaw and report back to Council in October 2006; and

7. Funding of $10,000, from the 2006 General Contingency Account, be approved for legal services, to prepare an Interim Floodplain Bylaw.

Terry Crowe
Manager, Policy Planning

Robert Gonzalez, P. Eng.
Director, Engineering

Att. 10

FOR ORIGINATING DIVISION USE ONLY			
ROUTED TO:	CONCURRENCE		CONCURRENCE OF GENERAL MANAGER
Law	Y ☑	N ☐	
Finance	Y ☑	N ☐	
Transportation	Y ☑	N ☐	
Building Approvals	Y ☑	N ☐	
Development Applications	Y ☑	N ☐	
Emergency and Environmental Programs	Y ☑	N ☐	
REVIEWED BY TAG	YES ☑	NO ☐	REVIEWED BY CAO YES ☑ NO ☐

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Staff Report

Origin

Richmond's current 1989 Floodplain Management Implementation Policy is provided in **Attachment 1.**

The reasons to update the existing Policy are to better address:
- the 1996 City-GVRD MOU in which the City agreed to prepare improved implementation plans for City flood and seismic protection. By preparing the proposed Strategy, the City has taken a major step towards accommodating increasing and planned City growth and development in its upcoming 2031 OCP update and in the 2031 LRSP update, both of which are currently underway;
- agricultural concerns (e.g., to not have a mid island dike along No 8 Road);
- financial concerns (e.g., a lack of senior government cost sharing);
- recent Provincial legislation changes and their City implications;
- the recent science regarding City flood hazards (e.g., ocean and sea flood hazards); and
- improved environmental information (e.g., sea level raise, pending studies)

These challenges are summarized in **Attachment 2**.

For these reasons, in 2002, Council directed that a comprehensive City Strategy be prepared, to better manage flood protection.

Background

1. General

Preliminary findings from the research-modeling phase of this project were previously reported to General Purposes Committee on April 5, 2004.

This report presents the process, final results, Strategy, Implementation Program and recommendations.

2. The Process

To prepare the Strategy, professional research was conducted which involved:
- a City inter-departmental team (e.g., Policy Planning, Engineering, Transportation Planning, Development Applications, Building Approvals, Environmental Programs, Law);
- experienced consultants (i.e., UMA Consulting);
- agricultural community input (Richmond Farmers Institute, BC Ministry of Agriculture and Lands, BC Agricultural Land Commission);
- senior government consultation (BC Ministry of Environment, BC Ministry of Transportation); stakeholder consultation (e.g., Fraser River Port Authority (FRPA), Port North Fraser (PNF) North City of Westminster).

The Strategy incorporates the UMA Consulting's recommendations, which were developed with City staff and external experts.

3. Research Highlights

The research:

- Addressed Council's concerns;
- Reviewed the City's flood protection actions from 1989 to 2006;
- Clarified the flood hazards;
- Analyzed existing flood event return periods;
- Reviewed 1989, 2003 and 2006 senior government and City seismic standards for existing and new dikes, and flood protection structures;
- Analyzed possible dike breach events and responses,
- Assumed a flood event return period (1:1250 years), for research and modeling purposes,
- Estimated the probability of a perimeter dike breach;
- Identified and reviewed three mid-island dike options (i.e., along No. 8 Rd, No. 7 Rd and the Highway 99/Knight Street corridor);
- Modeled four possible perimeter dike breaches, without a mid-island dike and with several possible locations for a mid-island dike;
- Estimated for the perimeter and mid island dike options, cost-benefits and potential damages from a flood;
- Identified a preferred long term flood protection management strategy including a mid island barrier along the Highway 99/Knight Street corridor;
- Utilized he latest flood protection science and information, and
- Reviewed senior government legislation and possible funding.

The research is discussed more fully in the following Attachments:

Attachment 3	25 Significant Flood Protection Actions Since 1989
Attachment 4	Research Highlights
Attachment 5	Summary of Provincial and City, Dike Elevation, Flood Return Period and Dike Design Standards, 2006-2031 Flood Protection Management Strategy, City Of Richmond
Attachment 6	Fraser Basin Council – Preliminary Briefing Notes Fraser River Hydraulic Modeling\Study

4. The Richmond 2006-2031 Flood Protection Management Strategy

(1) Synopsis Of The Strategy

A Synopsis of the Richmond 2006-2031 Flood Protection Management Strategy is provided in **Attachment 7**.

Richmond has been both proactive and innovative in its actions to monitor and maintain appropriate dike and drainage systems for the City.

The work done to date has meant that no significant flood event has ever affected Richmond since the installation of its perimeter dike system, which currently protects more than $31.3 billion dollars worth of land and improvements (based upon 2006 assessment values).

(2) Strategy Purpose

The Richmond 2006-2031 Flood Protection Management Strategy, which includes an Implementation Program, is presented in **Attachment 8**.

The Strategy proposes an up-to-date, innovative and co-ordinated set of actions, which comprehensively address Richmond's flood challenges, in a partnership manner.

The purpose of the Flood Protection Management Strategy is to make the City safer by providing an improved framework for addressing its flood protection and management.

(3) Study Area
The primary focus of the Strategy is Lulu Island and the need to explore alternatives to a previously discussed mid-island dike along No 8 Road. Some recommendations affect Sea Island and Mitchell Island.

(4) Strategy Priorities and Discussion (**Attachment 9)**
The Strategy emphasizes:
- Strengthening and improving the perimeter dikes;
- Reviewing and making recommendations on the adequacy of the perimeter dike standards;
- Pursuing a mid-island barrier along the Highway 99 / Knight Street Corridor;
- Requiring covenants to advise property owners of flooding potential and to indemnify the City;
- Preparing an Interim Floodplain Bylaw in 2006;
- Reviewing pending Federal, Provincial and regional flood related studies;
- Conducting additional sea level rise, land subsidence, flood modeling and legal research;
- Preparing floodplain mapping and a Full Floodplain Bylaw;
- Increasing the overall land grades, in a strategic manner, in the urban portions of the City; and
- Strengthening the City's emergency preparedness and response planning (e.g., updating the City's Flood Response Plan, creating public awareness, etc.).

The Strategy complements the recently approved East Richmond Agricultural Water Supply Study.

5. **Strategy Implementation Program - Key Actions**
   - (See **Attachment 8** - Strategy Implementation Program (pp. 29-34)

To implement the Strategy it is recommended that:

1. Council receive the proposed 2006 - 2031 Flood Protection Management Strategy.
   Intent: To acknowledge the merits of the Strategy and Implementation Program.

2. The Flood Protection Management Strategy be referred to the appropriate Provincial Ministries (Environment, Transportation) and stakeholders (e.g., City of New Westminster, Fraser River Port Authority, Fraser North Port), for comments and approvals.
   Intent: To seek comments and approvals regarding the Strategy and its implementation.

3. Staff pursue cost sharing for the Strategy Implementation Program with senior governments and stakeholders.
   Intent: To seek senior government and stakeholder cost sharing.

   Note: The Strategy and its Implementation Program are contingent upon technical feasibility, and senior government and stakeholder cost sharing.

Accordingly, to provide co-ordination and certainty, once staff have received and evaluated senior government and stakeholder technical and cost sharing feedback, they will advise Council regarding the:

- timing of the City's approval of the Strategy, and
- City Implementations Program funding options and recommendations.

Staff anticipate initially reporting to Council regarding these matters in the Sept. 2006.
Intent:

- *To approve the Strategy; and*
- *To fund the Strategy Implementation in 2007.*

4. Staff begin more detailed discussions with the BC Ministry of Transportation (MOT) to clarify the scope of work required to construct the proposed mid-island barrier along the Highway 99 / Knight Street Corridor.
   Intent: To clarify MOT's requirements regarding:
   - *the MOT suggested Multiple Account Evaluation analysis, and*
   - *activities to construct the mid island barrier.*

5. Flood Covenants, including indemnity clauses, be required for all discretionary development applications (e.g., subdivision, rezoning, development permits);
   Intent: To enable the City to require covenants on all applications for which it has discretion (e.g., subdivision, rezoning, development permits). The covenants will serve both to notify owners of the flood potential and to indemnify the City should an event occur. The requirement for covenants is recommended for immediate implementation. No grandfathering is necessary, as no changes are being made to flood construction levels at this time.

   Statutory covenants for all subdivision, rezoning, development permits and building permits will require an Interim or Full Floodplain Bylaw to be prepared.

6. Staff prepare an Interim Floodplain Bylaw and report back to Council in October 2006.
   Intent:
   The Interim Floodplain Bylaw will apply to development for all areas of Richmond, including the "Urban Exempt Area", to increase minimum Flood Construction Levels (FCLs) and improve flood protection. This involves complex analysis. Interim FCLs will be established based upon consideration of the 1989 Hay and Company Report, UMA Engineering's research, the Fraser Basin Council's (Northwest Hydraulic Consulting) modeling work and Provincial input.

   The Interim Floodplain Bylaw will also reflect the Province's Land Use Management Guidelines in its standards and will consider:
   - *establishing minimum habitable floor levels for residential developments with exemptions for entry ways, carports, etc.,*
   - *exemptions for certain types of uses (e.g., certain types of industrial activities),*
   - *setbacks from dike structures and water courses,*
   - *requirements for raising grades during redevelopment,*
   - *requirements for electrical and furnace systems,*

- *site specific exemptions and grandfathering clauses for development and building permit applications in stream; and*
- *any necessary modifications to existing City bylaws (e.g., OCP, Zoning, Subdivision) and policies.*

7. $10,000, from the 2006 General Contingency Account, for legal services to prepare an Interim Floodplain Bylaw.
Intent: To enable the City to obtain legal advice in preparing the Interim Floodplain Bylaw.

8. Review Pending Studies
The BC Ministry of Environment and the Fraser Basin Council; and the National Research Canada are currently completing flood management related studies (e.g., A Fraser River Hydraulic Modeling Study). When completed (e.g., Fall 2006), City staff will review these studies and advise Council regarding the necessity of changing the City's current:
- flood event return period reference standards, and
- perimeter dike level design standards (i.e., 1894 flood of record plus freeboard, Sea: 1:200 year plus freeboard),

Intent: To determine the adequacy of the City's current flood event return period and dike standards.

9. Further Research
Further research is identified in **Attachment 8** (pages 29 –34). The highlights of this work will include:
- Engineering studies regarding:
  - the design of the proposed Highway 99 / Knight Street Mid-Island Barrier;
  - additional computer modeling of dike breaches (focus will be on the area west of the barrier);
  - floodplain mapping to establish new FCLs;
  - sea level rise and land subsidence;
- Preparing a full Floodplain Bylaw, to replace the Interim Floodplain Bylaw, and
- Constructing the proposed mid-island barrier.

6. **Strategy Cost Implications**
- (See **Attachment 8** - The Strategy Implementation Program - pp. 29-34), and
- (See **Attachment 10** - Summary of Strategy Implementation Program Costs)

- General
The City cannot implement the Strategy alone and requires cost sharing assistance.

- Funding Sources
Possible Strategy funding sources include the federal and Provincial governments, stakeholders, the City (e.g., the City's Drainage and Dike Utility/Authority) and the private sector (e.g., through the City's DCC Program).

- General Senior Government Funding Sources
At this time, there is no assured source of senior government cost sharing assistance. The consultant has provided suggestions regarding possible external cost sharing sources such as the:
  - Canada-BC Infrastructure Program,

- Municipal Rural Infrastructure Program, and
- Exploring alternative funding arrangements with the Provincial and Federal governments.

Staff are aware that discussions are occurring between the Federal and Provincial governments on the possibility of re-instituting the Infrastructure Planning Grant Program. Each of these senior government-funding options will be pursued.

- Provincial Government Funding Considerations
  BC Ministry of Environment (MOE) staff have made a clear link between any flood protection strategy that the City adopts and their consideration or influence over the allocation of future senior government funding assistance. At this time, however, it is unclear as to what contributions the Province would consider making to:
  - first address any apparent shortcomings in the current Provincial flood protection and dike standards, and
  - second, what contributions it might make to supporting preventative measures beyond these standards.

  Staff will continue to explore this possibilities.

- City Drainage and Dike Utility and Authority
  In addition, the City's Drainage and Dike Utility will also be used to assist in financing the Strategy's implementation, primarily related to maintenance and upgrades.

- City DCC Funding
  To demonstrate the City's commitment to implement the Strategy, staff propose to review the City's DCC Bylaw, with the objective of introducing development charges (e.g., for redevelopment rezonings) to assist in paying for those portions of the Strategy improvements (e.g., the mid-island barrier and the perimeter dikes) that are attributable to growth.

  Through DCCs, new growth and development over the long term will be asked to contribute their share toward improving the level of protection afforded by the City's dike structures.

7. Status of the City's Flood Protection Management Documents

Upon receiving the proposed Richmond 2006-2031 Flood Protection Management Strategy, Council will manage flood protection by:

- Using the proposed Richmond 2006-2031 Flood Protection Management Strategy as a guide, and continuing to apply:
- The City's 1989 Flood Plain Management Implementation Policy;
- The City's 1999 Official Community Plan;
- The City's Zoning Bylaw;
- The City's Building Bylaw;
- Other City polices and bylaws.

Once the Richmond 2006-2031 Flood Protection Management Strategy is approved, Council will manage flood protection by the Richmond 2006-2031 Flood Protection Management Strategy and make any necessary modifications to the City's existing documents:

8. City-GVRD MOU

After the City receives and assesses senior government and stakeholder feedback regarding the 2006 – 2031 Flood Protection Management Strategy, staff will advise Council regarding how to respond to the GVRD, concerning the 1996 City-GVRD MOU. This matter is addressed in a separate report.

Financial Impact

Funding of $10,000, from the 2006 General Contingency Account, be approved for legal services, to prepare an Interim Floodplain Bylaw.

Conclusion

As the City's 1989 Floodplain Management Implementation Policy no longer meets the needs of the community, staff propose a 2006 – 2031 Flood Protection Management Strategy which includes an Implementation Program.

Terry Crowe, Manager, Policy Planning

David Brownlee, Planner 2

TTC:DCB

ATTACHMENTS

Attachment 1	❑	1989 Floodplain Management Implementation Policy
Attachment 2	❑	Why Prepare An Updated Flood Protection Management Strategy?
Attachment 3	❑	Research Highlights
Attachment 4	❑	25 Significant City Flood Protection Actions Since 1989
Attachment 5	❑	Summary of Provincial and City, Dike Elevation, Flood Return Period and Dike Design Standards, 2006-2031 Flood Protection Management Strategy, City Of Richmond.
Attachment 6	❑	Fraser Basin Council - Preliminary Briefing Notes Fraser River Hydraulic Modeling Study
Attachment 7	❑	Synopsis of the proposed 2006-2031 Flood Protection Management Strategy
Attachment 8	❑	Proposed 2006-2031 Flood Protection Management Strategy
Attachment 9	❑	Strategy Priorities and Discussion
Attachment 10	❑	Summary of Strategy Implementation Program Costs

City of Richmond Policy Manual

Page 1 of 2	Adopted by Council: Sept. 11/89	POLICY 7000
File Ref: 6410-05	FLOODPLAIN MANAGEMENT IMPLEMENTATION STRATEGY	

POLICY 7000:

It is Council policy that:

1. Flood construction levels are to be as follows:

   (a) new dyke works to be constructed at the No. 8 Road alignment, under the Knight Street Bridge and Highway 99 near Massey Tunnel are to be at a 3.8 m GSC level. The City will apply to the Provincial Government for Federal/Provincial funding for a cost sharing arrangement;

   (b) the minimum habitable or commercial building floor elevation is to be 3.5 m GSC east of No. 8 Road;

   (c) the minimum habitable or commercial building floor elevation is to be 3 m GSC between No. 8 Road and the Knight Street/Highway 99 corridor;

   (d) the minimum habitable or commercial building floor elevation is to be 2.6 m GSC in the non-exempt lands on Lulu Island west of the Knight Street/Highway 99 corridor, with provision for transition to existing land use adjacent to the non-exempt lands;

   (e) municipal standards only for minimum habitable or commercial building elevations in exempt areas;

2. A commitment to complete and adopt a Floodplain Management Plan utilizing the Hay and Company Report as the technical basis, is reconfirmed.

3. Subdivision plans outside the exempt area will continue to be referred to the Ministry of Environment for approval, pursuant to Section 82 of the Land Title Act until such time as a Floodplain Management Plan is adopted.

4. The construction of a No. 8 Road dyke and other minor dykes identified in Hay and Company Report on dyke construction will be identified as high priority (e.g. will be included in the 1990 ten year Capital Works Plan); and financing and construction will be coordinated with the Ministry of Transportation and Highways in light of recent transportation studies.

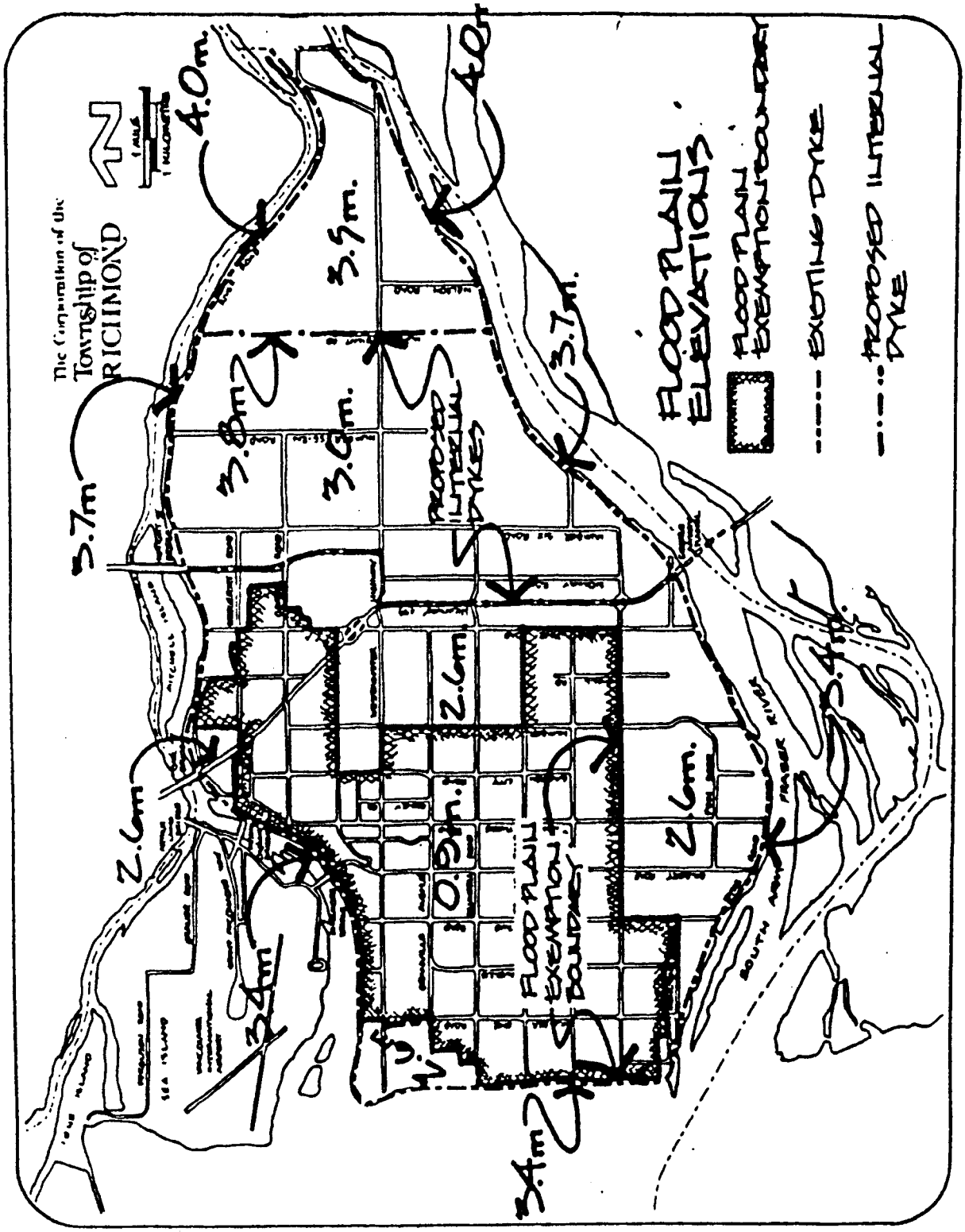
5. The terms of the Dyke Operation and Maintenance Manual shall be satisfied.

6. The establishment and administration of flood proofing and protection regulations for development in the floodplain, shall be undertaken.

7. Flood proofing in Urban Exempt Areas will be encouraged.

Note: Accompanying Floodplain Elevations plan.

(Urban Development Division)


The Corporation of the Township of RICHMOND
FLOOD PLAIN ELEVATIONS
FLOOD PLAIN EXEMPTION BOUNDARY
EXISTING DYKE
PROPOSED INTERNAL DYKE
4.0m
3.5m
3.7m
3.8m
3.6m
2.6m
3.4m
PROPOSED INTERNAL DYKES
FLOOD PLAIN EXEMPTION BOUNDARY

WHY PREPARE AN UPDATED FLOOD PROTECTION MANAGEMENT STRATEGY?

1. Types of Flood Hazards
   The causes of flooding include:

Type of Dike Failure	Cause
Overtopping/Breach	High Sea Levels ▪ High sea tides due primarily to lunar, solar, earth interactions ▪ Sea surge due to wind, storms and tsunami. (The 2005 study by Professors John Clague and Ian Hutchinson (SFU) indicates that tsunami threat for Richmond is very small) ▪ Elevated sea levels due to global warming (3.5 mm/year assumed over the next century) High River Levels ▪ Freshet due to spring snow melt runoff upstream in Fraser River ▪ Excessive precipitation for the Fraser River and/or the Richmond storm drainage system to handle ▪ Siltation / sediment deposition in the River, gradually reducing or altering the River flow and capacity ▪ A lack of dredging resulting in reduced flow capacity Lower Dike Crest ▪ Sinking of ground due to natural causes (e.g., soils, drainage, rain)
Piping	▪ Holes in the dikes due to seepage lines, plant roots, burrowing animals, structural settlement, etc., that result in back scour and erosion of the dike
Dike Design & Construction	▪ Poor dike design/construction and the use of improper materials
Liquefaction	▪ The liquefaction of soils under the dikes or general dike failure as a consequence of an earthquake or dike breach
Human Damage	▪ Vandalism, terrorism, mistakes, lack of understanding

2. Main Flood Protection Concerns
   The main reasons to prepare an updated Flood Protection Management Strategy are to better address:
   - the 1996 City-GVRD MOU and increasing City growth and development,
   - the types of flood hazards,
   - agricultural concerns,
   - financial concerns,
   - provincial legislation changes and city implications,
   - improved environmental information (e.g., sea level raise, Fraser River Hydraulic Modeling Research)

   These challenges are summarized below.

3. 1996 City-GVRD MOU
   In 1996, the City agreed in City-GVRD MOU to prepare improved implementation plans for City flood and seismic protection. The MOU states that the City and Province are to agree on the plans. By preparing the proposed Strategy [plan], the City has taken a major step towards accommodating increasing and planned City growth and development in its upcoming 2031 OCP update and in the 2031 LRSP update, both of which are currently underway.

4. Agricultural Concerns
   A major impetus to prepare this Strategy came from the farming community. The 1989 Hay Report on flood protection identified a need for a "mid-island dike" along No 8 Road. The agricultural community has always objected to this mid-island dike because of its negative affects on the farming (e.g., negative drainage, land removed from farm production, more difficult farm access). For this reason, the farm community assisted in preparing the Strategy.

5. Financial Concerns

In 1995, Council directed that:

- the City would not do any further engineering work on the mid-island dike, until the source (e.g., Provincial) of funding was determined, and
- global warming be considered in flood protection management.

To date, this financial assistance has not been secured.

6. Provincial Legislation Changes and City Implications

(1) General

After the Study began, the Province changed the provincial flood hazard legislation. In 2004, the Province changed the roles and responsibilities for both the BC Ministry of Environment (formerly the Ministry of Water Land and Air Protection) and local government by enacting the Provincial Flood Hazard Statutes Amendment Act and the Miscellaneous Statues Amendment Act in 2004. These legislative changes have resulted in uncertainty as to what approval, if any, the BC Ministry of Environment has with regard to any new local government flood protection strategies and bylaw regulations.

(2) BC Ministry of Environment (MOE) and Local Government Roles

(a) BC Ministry of Environment (MOE) staff have indicated that local government now has considerable autonomy to make its own flood protection regulations, provided that municipalities consider Provincial guidelines.

(b) The Ministry has retained approving authority regarding issues directly related to the dikes under the BC Dike Maintenance Act.

(c) At this time, the Provincial flood approval role is uncertain. The Province is currently seeking a legal opinion to clarify exactly what approving role it will have. It is not known when this matter will be fully clarified.

(d) Rather than wait, City staff have brought the Strategy forward and recommend that, until otherwise clarified, the City continue to seek Provincial approval of the Strategy, Implementation Program and future bylaws and actions, in order to continue receiving the Province's expertise and advice, and to maximize any available funding.

(e) In the meantime, while MOE may not offer any formal approval on the overall Flood Protection Management Strategy, or any flood plain bylaw prepared by the City, MOE will formally review and endorse, or reject, aspects of these documents that pertain to the City's dikes. In general, the Provincial emphasis will be to ensure the technical soundness of any actions related to, or affecting, the dikes.

(f) MOE staff have suggested that, pursuant to the Disaster Financial Assistance regulation of the BC Emergency Program Act, MOE would have difficulty supporting flood recovery financing for structures which were not "properly" flood protected and were built since the changes to the legislation in 2004.

(g) The proposed Strategy and continued Provincial involvement in its approval and implementation will maximize Richmond's opportunities for senior government funding.

(h) Staff will advise Council of MOE clarifications, as they arise.

(3) Indemnity

As noted in the Strategy, the Province no longer supports general exemptions to the flood construction elevation requirements (i.e., such as the City's Urban Exempt Area). On this point alone, issues of liability may arise for Richmond since the City is not currently requesting covenants or indemnity for many new developments which are being constructed at levels below the flood construction elevations now recognized by the Province.

Currently, Richmond only requires flood covenants and indemnity requirements for the following applications:

- *Outside the Urban Exempt Area*
  - Rezoning, subdivision or development permit applications; and,
  - For any building permit with a habitable floor elevation below the City's Building Bylaw elevation of 0.9 m.

- *Inside the Urban Exempt Area*
  - Only for building permits with a habitable floor elevation below the City's Building Bylaw elevation of 0.9 m.

  For Building Permit applications not involving a rezoning or development permit, unless a covenant has already been established under subdivision, the City's current practice is to accept construction at 0.9 m with no covenant or indemnity requirements.

  Until a Floodplain Bylaw is put into effect, the City can partially address the liability issues by requiring Flood Covenants, including indemnity clauses, for all rezoning, subdivision and development permit applications (i.e., applications that involve discretionary approval). These covenants will serve notice that there is a potential flood danger to the lands, and indemnify and save Richmond harmless from any loss or damage to the lands, building, structures, etc. caused by flooding or erosion.

  Once a Floodplain Bylaw has been put into effect, the City will have the statutory ability to require covenants and indemnity on all its development related applications.

Summary
The details of the above Provincial legislative changes were not known when the study began, and the study work program and resources were adjusted to address these changes once known.

7. Environmental Information

(1) Sea Level Rise Estimates

For the flood modeling used to prepare the Strategy, a sea level rise of 0.35 m over the next 100 years was assumed. This figure was based upon discussions between the consultant and experts with the Federal Government's research centres and was considered the best information available at the time.

Preliminary results from two recent, as yet, unreleased reports suggest that these estimates may be conservative, as follows:

a) Northwest Hydraulic Consultants' (NHC) work developing the preliminary design profile for the lower Fraser River Hydraulic Model (a project initiated by the Fraser Basin Council and MOE) indicates that, while a global sea level rise in the order of 0.4 m is anticipated, when taken into consideration with the overall subsidence of the Fraser delta of approximately 0.2 to 0.3 m over the next 100 years, the combined effect is expected to be in the order of 0.6m.
b) Similarly, National Research Canada researchers, in their report entitled "Impacts of Sea Level Rise on Roberts Bank", have examined the scientific information on global warming, local tectonic and subsidence effects. They have indicated that there is now a "very high confidence" that the rate of sea level rise will accelerate over time, and that there is "high confidence" of a 0.6 m rise by 2100.

On-going monitoring will be undertaken to determine if the assumed 0.35 m per 100 years needs to be adjusted.

(2) Fraser River Hydraulic Modeling Research

An important objective of the lower Fraser River Hydraulic Modeling work being undertaken by the NHC is to determine if existing dikes in the lower Fraser are meeting the 1894 event design standard. A preliminary results briefing paper released by the Fraser Basin Council on May 30, 2006, includes the following notation:

While further modeling and investigative work will help to refine the modeled (Fraser River) water levels and increase our understanding of why the current River profile is higher than the 1969 (River) profile, the updated dike design level is expected to be higher than the existing dikes throughout much of the lower Fraser River.

Staff believe that any MOE changes to the standards that apply to Richmond will be of a more minor nature, but bear monitoring.

The research is showing that the 1969 River design profile used to establish the Provincial dike standards for a number of areas in the lower mainland was too low and will need to be increased. Notably, the preliminary results do not as yet incorporate any sensitivity analysis to address the recent sea level rise numbers identified above.

Concerns stemming from the implications of global warming and climate change have resulted in a spate of studies being undertaken, such as those mentioned above. The results from each of these studies are improving our understanding of the challenges that lay ahead. Virtually all of these studies, however, point to the need for further study and analysis to confirm and refine the results. These lingering uncertainties make the creation of an updated, comprehensive Strategy both more difficult and more necessary. Staff will continue to monitor this matter and report findings, as necessary.

8. Summary

The above concerns generate a need to prepare an updated Strategy, as the current City 1989 Policy does not meet the community's needs.

Prepared by the City Of Richmond

RESEARCH HIGHLIGHTS

1. Introduction

The research:

- Addressed Council's initial concerns;
- Summarized the City's flood protection actions from 1989 to 2006;
- Clarified the flood hazards,
- Analyzed existing flood event return periods,
- Reviewed 1989, 2003 and 2006 senior government and City seismic standards for existing and new dikes, and flood protection structures
- Analyzed possible dike breach events and responses,
- Assumed a flood event return period (1:1250 years), for research and modeling purposes,
- Estimated the probability of a perimeter dike breach;
- Identified and reviewed several mid-island dike options (i.e., along No. 8 Rd, No. 7 Rd and the Highway 99/Knight Street corridor);
- Modelled several perimeter dike breaches, without a mid-island dike and with a several possible locations for a mid-island dike;
- Estimated perimeter and mid island dike option cost-benefits, potential damages from a flood and probability potential damages from a flood
- Identified a preferred long term flood protection management strategy including a mid island barrier along the Highway 99/Knight Street corridor.

2. Breach Events and Response

Both the 1989 Hay report and the Strategy discuss the probability differences between a breach from the west (ocean) half of Lulu Island or the east (river) half of the island. Fundamentally, each breach is different:

- *Ocean Breach*
  A breach from the ocean side, which is closer to the urban developed area, will typically be tidal – allowing time for response to repair the damage during slack tide.
- *Fraser River Breach*
  A Fraser River breach from the east (e.g., in the north east of Lulu Island), particularly during freshette, may not offer the same opportunity to respond until the freshette levels drop – which could take days or weeks.

This is the primary reason for considering the installation of a mid-island barrier.

3. Existing Flood Event Return Periods

Currently:

- As noted in the Strategy, the current City "design flood event" is:
  - The 1:200 year flood level for a sea level event; and,
  - The 1894 discharge of the Fraser River.
- City dikes are designed to meet these two flood event levels plus add an additional amount to account for wave run up and a freeboard (a safety factor to allow for uncertainties in design and construction). These additions typically add another 0.6 m to the height of the dikes.
- A summary table of current return event standards is provided in **Attachment 5**.

4. Assumed Flood Event Return Periods For Research and Modeling Purposes

For modeling purposes, an assumption had to be made regarding what flood event return period should be tested. UMA recommended a 1:1,250 year flood event return period, which was used:

- To test for an possible event greater than City's existing river and sea flood protection and design standards, as:
  - The frequency analysis has shown that the 1894 river flood of record appears to have a return period that is most likely between 136 years and 685 years,

- The current City's 1:200 year design sea flood event plus freeboard standard may not address long term sea level rise,
- It may be possible that a flood event greater than the City's existing river and sea flood design event standards could occur,

- To ensure that the substantial increases in Richmond's population, development, investment, which will continue, are best protected,
- To proactively maximize "Safety" and "Prevention", which are major City priorities,
- To increase the confidence in the City's flood protection assumptions and planning,
- The 1:1250 flood event would provide useful insights to better prevent and manage flooding.

It is noted that other places use the 1:1,250 year (or greater) flood return period event assumptions now in their modeling and in practice (e.g., Netherlands).

Note that the City's existing river and sea design flood event standards will continue but that the City will review its standards by evaluating the pending Fraser Basin Council / MOE studies, direction regarding possible increases to the Fraser River design flood level standards and any recommendations regarding additional levels of protection to improve safety.

If a 1:1,250 flood protection design event standard:
- Is proven to be needed, the Strategy prepares the City for it;
- Is not needed, but an alternate standard is, this Strategy provides the City with a context to assess it implications with more confidence and certainty.

5. Seismic Dike and Flood Protection Standards

(1) Provincial Standards – For New Buildings and "Post Disaster" Structures:

- The Province is responsible for adopting seismic design standards for buildings in the BC Provincial Building Code based on the National Building Code of Canada.
- The current National and Provincial Building Codes only govern "buildings".
- The Codes do not cover seismic requirements for dikes or flood protection structures, except water and sewage pump stations that are specifically addressed in the current Codes.
- Currently, the BC Building Code, 1998 (BCBC 98) seismic standard addresses:
  - For All New Buildings: The BCBC 98 earthquake standard for all new buildings is based on a probability of 10% in 50 years (1:475 year) earthquake return period and additional seismic design requirements,
  - For New Post Disaster Buildings The BCBC 98 requirements for post disaster buildings (buildings that are essential to the provision of services in the event of a disaster, such as hospitals, water and sewage pumping stations) is based on the same probability (10% in 50 years), but more stricter seismic design requirements,
- In December 2006, it is expected that the Province will approve a BC Building Code 2006 (BCBC 06) based on the published National Building Code 2005 which will address:
  - For All New Buildings: The BCBC 06 earthquake standard for all new buildings is based on a lower probability of 2% in 50 years (approximately 1:2500 year) earthquake return period, and different seismic design requirements vs. BCBC 98,
  - For All New Post Disaster Buildings: The BCBC 06 requirements for post disaster buildings is based on the same probability (2% in 50 years), but more stricter seismic design requirements.
  - For Emergency Response Facilities: The BCBC 06 will include emergency response facilities, public water treatment and storage facilities also sewage treatment facilities in addition to the buildings specified as post disaster in BCBC 98.

2) City

- In 2003, to be proactive, the City adopted, a seismic standard at probability of 1:475 year earthquake return period, for new and upgrades to existing flood protection structures (e.g. pumping stations), which is in line with the BCBC 98.

- In January 2006, to be proactive, the City adopted, a seismic standard at probability of 1:475 year earthquake return period, for new and upgrades to existing dikes, which is in line with BCBC 98.

- In late 2006, after the 2006 BC Building Code is approved, the City will review its seismic standards for new and upgrades to existing flood protection structures and dikes. It is essential for the City to consider post disaster seismic design requirements in addition to the probability factors (that are applicable to any building governed by the provincial codes) in the new policy.

Prepared by the City Of Richmond

25 SIGNIFICANT RICHMOND FLOOD PROTECTION ACTIONS SINCE 1989

1. **Planning Related Actions**
   (1) Implementation of the Flood Plain Management Implementation Policy (1989)

   (2) Official Community Plan Amendments (1990) - Includes objectives and policies to:
   - Maintain and upgrade the perimeter dike systems on Lulu and Sea Islands;
   - Construct the internal dike system identified in the Hay and Company report;
   - Work with the BC Ministry of Environment in resolving improved flood protection measures for the historic settlement areas.

   (3) Memorandum of Understanding with the GVRD (1996)
   In part, a commitment to developing an implementation plan for flood and seismic protection which acceptable to the City and Province.

   (4) Preliminary Flood Response Plan Prepared (1999)

   (5) Public Education Emergency Preparedness Workshops (1999 and Ongoing)

   (6) Information Brochure on Flooding and Richmond (2000)

   (7) Support to the Fraser Basin Council's Subcommittee on Floodplain Hazard Management 2002-2004
   In part to examine alternative approaches to residential development in historic settlement areas that would address flood protection concerns.

   (8) Study Completed: Tsunami Hazard at the Fraser River Delta (2005)
   Provided information that, based upon sediment samples dating back 4000 years, the apparent threat to Richmond from tsunamis is very small.

2. **Project Related Actions**
   (1) Drainage Utility (2002)
   - Implemented a Drainage Utility (2002). Believed to be unique in the lower mainland.
   - This provides a dedicated annual source of dollars toward drainage improvements.
   - In 2006 the funding level was $2.49M, the majority of which is being used in the 2006 capital program.

   (2) Generator Installations
   - Completed Generator Installations at Peace Arch pump Station and Triangle Pump Station (2005)

   (3) 7-year Drainage Assessment Program (2002-2008)
   - Five years into a 7-year Drainage Assessment Program with the goal of completing an overall drainage master plan.

   (4) Electrical Connection Upgrades (2005)
   - Began Electrical Connection Upgrades at various drainage pump stations in 2005.

   (5) Drainage Upgrades (2005 / 2006)
   - Completed Drainage Upgrades (pipe installation, slough dredging, pump station modifications and ditch maintenance) in the entire Horseshoe catchment area in 2005/2006.
   - Pump station screen upgrades and an irrigation gate installation are pending for the same area in 2006.

   (6) A Dike Utility (2006)
   - Implemented A Dike Utility (possibly unique in the lower mainland if not Canada) in January 2006.
   - This provides a dedicated annual source of dollars (±$600k annually) for dike improvements.

   (7) Dike Upgrades (2001 – 2006 – ongoing)
   - Dike upgrades were also completed near Terra Nova in 2001/2002.
   - Completed approximately 150 metres of dike upgrades at the south end of Gilbert Road in February 2006.

(8) Seismic Dike Upgrade (2006)
- Awarded an options/methodology Seismic Dike Upgrade Assignment for the dike between No. 4 and 5 Roads.
- This assignment is expected to be complete by July 2006 with actual upgrade work to follow shortly thereafter subject to Council approval, overall cost and cost sharing.

(9) Drainage Upgrade Studies (2006)
- Completed Drainage Upgrade Studies in the Aztec/Montego catchment and Lucas Road catchment areas in 2006.
- Funding is in place to commence the required drainage upgrades, starting the later part of 2006.

(10) Box Culvert Upgrade (2006)
- Pending for June 2006 the City will be completing a box culvert upgrade on Steveston Highway between No. 5 Road and the Highway interchange.

(11) 2006 West Cambie Area Plan Flood Proofing (2006 and beyond)
- In the proposed West Cambie Area Plan update, the entire flood construction elevation is proposed to be raised to 2.6m geodetic, for the entire Alexandra quarter section.

3. On-Going Programs

(1) Drainage Pump Stations
- An ongoing upgrade / replacement program (generally annually) for the City's 39 drainage pump stations.
- The most recent upgrades (last 5 years) have been Hollybridge, Blundell West and No. 1 Road South.
- Upgrades for the Francis West Drainage Pump Station is scheduled to be completed this year.

(2) Annual Dike Upgrade / Maintenance Budget
- The City has an ongoing operational dike upgrade / maintenance budget of approximately $320,000 annually.

(3) Dike Upgrades
- Numerous dike upgrades have been undertaken in coordination with development.
- The most recent include London Road at No. 2 Road and Riverport (i.e. Steveston Highway near Entertainment Boulevard).
- The Richmond Oval project also includes a planned dike upgrade to 4 metres (GSC).

(4) Raising Dikes
- Richmond has taken a proactive policy of raising dikes when the opportunities are presented.
- This is a proactive measure taken to reflect the possibility of sea level rise due to global warming.
- The projects noted in the bullet above reflect this proactive measure.

(5) Gauging Stations
- Four gauging stations have been constructed by the City - each with the SCADA system for monitoring Fraser River water levels.

(6) Perimeter Dike System
- The City has an ongoing program to survey one fifth of the perimeter dike system each year to verify both its elevations and cross sections as part of its on-going maintenance program.

Prepared by the City of Richmond

Summary of Provincial and City
Dike Elevation, Flood Return Period and Dike Design Standards
2006-2031 Flood Protection Management Strategy, City Of Richmond

Ocean Side				
Standard	**Elevation**	**Return Period (years)**	**(Current) Dike Design Standard**	**Possible (TBD) 1:1250 Dike Design Standard**
Provincial	Water: 2.68 m Dike: 3.35 m	1:200	Water: 2.68 m Dike: 3.35 m	Not in place
City	Water: 2.68 m Dike: 3.35 m	1:200	Water: 2.68 m Dike: 3.35 m	Water: 2.68 m (still water) Dike: 4.1 m
River Side				
Standard	**Elevation**	**Return Period (years)**	**(Current) Dike Design Standard ***	**Possible (TBD) 1:1250 Dike Design Standard**
Provincial	Water: 1894 flood of record Dike: (see column: Dike Design Standard - current)	136 – 685 years	Dike: 3.8 m (Hamilton area) 4.08 m (South Arm) 3.35 m (balance)	Not in place
City	Water: 1894 flood of record Dike: (see column: Dike Design Standard - current)	136 – 685 years	Dike: 3.84 m and 3.35 m (dependent on location)	Dike: 4.74 m and 4.03 m

General Comments

1. * Current dike design standards are calculated on basis of 1894 flood design levels plus 0.6 m freeboard.
2. Actual river water level numbers vary with hydraulic grade line along river.

Ocean Comments

- For the ocean side data, the 2.68 m water level as the 'still water level'. This is the water level assuming no waves, and is a correct way of expressing this number.
- This explains why the design for the dike allows for wave run up. This is true for both the current 1:200 event design and the possible 1:1250 design.

River Comments

- For the river side data, the City and Provincial standards should coincide, as original levels were established by the Province.
- The design level is based on the 1894 flood of record and should not be referred to as a 1:200 year event, as the actual probability / frequency has not been accurately established (hence the large range shown in the table).
- The indicated dike levels vary with the location being measured.
- This reflects the hydraulic grade of the river which slopes down towards the ocean.
- The dike levels are 0.6 m above the flood levels (1894) of the river.
- UMA did not include river water elevation numbers, but these are thus 0.6 m below the current dike design levels.
- As mentioned in earlier correspondence and discussions, all numbers for dike design levels should be reviewed or reaffirmed upon the completion of the Northwest Hydraulics study.

Prepared by UMA Consulting

ATTACHMENT 5

Fraser Basin Council

Issue Brief: Preliminary Lower Fraser River Hydraulic Model Results

Date: May 30, 2006

I. ISSUE:

- Preliminary results from the new lower Fraser River hydraulic model indicate that diking systems from New Westminster to Chilliwack are below the most recent estimates for updated design levels.
- In most cases dikes constructed and maintained to meet the original 1894 flood profile (including freeboard) should protect against flows close to the 1948 peak flow at Mission (the second largest flood on record).
- However, the preliminary results indicate that several diking systems could be overtopped if the 1894 flood of record were to re-occur.

II. BACKGROUND – The Lower Fraser River Hydraulic Model:

- The Fraser Basin Council is a nongovernmental, not-for-profit organization working in collaboration with others to resolve long-standing sustainability issues in the Fraser Basin.
- The Fraser Basin Council along with provincial, federal, local governments and other partners are being pro-active in completing this study, as flood protection and dike safety is a critical sustainability issue in the region.
- More than 20 Fraser Valley communities, including First Nations, are protected by over 300 km of Fraser River diking between Agassiz and Delta (including the sea dikes). Almost 250 km of these dikes were reconstructed by the federal/provincial Fraser River Flood Control Program between 1968 and 1994.
- The dike design levels (estimated flood water level plus 0.6m freeboard) for the reconstruction were established in 1969 by the federal Inland Waters Directorate. This profile was based on high water marks from the 1948 and 1894 floods, plus limited computer modeling. The 1894 flood is the largest flood in the last 112 years.
- In 2003, the Fraser Basin Council and the BC Ministry of Environment initiated a multi-year project to develop a hydraulic model of the lower river (focusing on the reach from Sumas Mountain to Richmond) to:
  - Update the dike design profile and assess the adequacy of existing diking systems;
  - Better understand the effects of sedimentation and dredging on the dike design profile;
  - Provide a flood level forecasting tool during spring freshet floods; and,
  - Assist with land use planning decisions and floodproofing practices.
- The project has been supported by financial and in-kind contributions from the BC Ministry of the Environment, Canadian Coast Guard, Fraser River Port Authority and several municipalities, including Surrey, Richmond, Delta, Abbotsford, Township of Langley, Maple Ridge and Pitt Meadows.
- Comprehensive bathymetric and topographic surveys were completed in 2004/05 and the hydraulic modeling work began in the fall of 2005, utilizing the peak flow estimate for the Fraser River at Hope for the 1894 flood. The peak flow at Hope is estimated to be 17,000 cubic metres

per second, but there is much uncertainty with this value as well as the peak flow downstream of Hope.

III. PRELIMINARY RESULTS:

- The preliminary flood profile closely agrees with the 1969 profile downstream of New Westminster (if sea level rise is not considered), but diverges significantly upstream. The new profile is 0.68 m higher at Pitt Meadows and 1.48 m higher at Mission than the profile originally estimated in 1969.
- The lower Fraser River and related flood hazard studies are highly complex. The engineers in 1969 simply did not have access to the sophisticated data gathering and analytical tools that are available today and could not explicitly deal with some of the river's complexities. Despite recent improvements in analytical tools, the current studies and preliminary results also remain subject to sources of uncertainty.
- The river modeling process has followed standard engineering practice, including calibration and verification utilizing data from different flood events. In addition, confidence in the modeling has been supported by the development of a completely independent model (different software and river survey data), which produced similar results.
- The work to date has improved the understanding of the factors that influence flood levels. For example the confinement of the channel by diking, and subsequent reduction in floodplain storage (comparing river conditions today with 1894 conditions), appear to have a major influence. Tidal levels and changes in riverbed levels appear to affect the profile only marginally, particularly in the upstream areas where there is the greatest difference in the design flood profile. Design flow estimates at various points in the model as well as riverbed roughness are other factors that are being analyzed in terms of their influence on flood levels.
- The current freshet design flood is not directly comparable to the actual historic 1894 flood which had substantial overbank spills, detention storage on the floodplain and unknown tributary inflows downstream of Hope. These confinement effects from the dikes were apparently not fully accounted for in the 1969 studies.
- The preliminary flood profile results represent the study team's current best estimate of the profile given the boundary conditions specified by the project, the available data and careful model calibration. However, significant further work is required to reduce the uncertainties and to verify or further modify the results.
- While further modeling and investigative work will help to refine the modeled water levels and increase our understanding of why the current profile is higher than the 1969 profile, the updated dike design level is expected to be higher than the existing dikes throughout much of the lower Fraser River.
- Even small increases (more than a few 10^{th}s of a metre) in the design profile have significant public safety, dike upgrading and floodplain development implications.
- Preliminary results indicate that increased dredging of the shipping channels in the lower river would not reduce flood levels to 1969 design levels, particularly in upstream areas.

IV. CONCLUSIONS:

- Updating the dike design profile is a critical dike safety and flood protection project.
- The Fraser Basin Council will continue to work with the project partners and the consultants to review and refine the preliminary results to ensure their validity. Some immediate priorities to address information gaps and uncertainties include:
    - Estimate the effect of floodwater detention within the floodplain in reducing the peak discharge downstream of Hope during the 1894 flood event;
    - Setup the model to reproduce the 1948 flood and estimate actual roughness conditions during this extreme flood event; and,
    - Assess the effect of dike confinement on water levels downstream of Sumas Mountain by comparing the estimated water levels that would occur with dikes versus without dikes.
- Significant further work is required before a new design flood profile would be adopted for dike design and related flood protection measures. Additional technical studies and analyses that may be required to help resolve this issue could include:
    - An investigation into the hydrology of the Fraser River Basin flood flows given current watershed conditions and considerations for climate change
    - Determination of an appropriate design flood flow based upon risk analysis and expected flood damages.
    - Cost estimates for dike rehabilitation and review of other potential mitigation measures, including upstream storage;
    - Funding and governance arrangements for a major capital works program to rehabilitate the dikes.

For more information about this issue, please contact

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SYNOPSIS OF THE STRATEGY

The highlights of the 2006-2031 FLOOD PROTECTION MANAGEMENT STRATEGY include:

1. A new Flood Protection Management Strategy Concept: (**Attachment 8** - page 27)
   "To enable Richmond to be a safe place to live, work and play, in an environment that minimizes the hazards associated with flooding".
2. New Flood Protection Management Strategy Principles (page 27)
   - ❑ Safety
   - ❑ Prevention
   - ❑ Sustainability
   - ❑ Cost effectiveness
   - ❑ Partnerships & Cost sharing
   - ❑ Co-ordination
3. Physical Flood Protection Elements
   The Strategy flood protection elements emphasize:
   - ❑ Improvements to the perimeter dikes
   - ❑ A new mid-island barrier, along Highway 99 and Knight Street
   - ❑ Improve minimum habitable building construction levels:
     - Outside the Urban Exempt Area
     - Inside the Urban Exempt Area
   - ❑ Flood proofing buildings
   - ❑ Raise land grades – particularly for larger development sites (e.g., the Alexandra area in West Cambie)
   - ❑ Dredging: Support continued dredging of the Fraser River (e.g., by the Fraser River Port Authority and the Port North Fraser Authority).

The highlights of the Strategy IMPLEMENTATION PROGRAM (Attachment 3, pages 29-34) include:

- ❑ Planning related actions
  - ► Co-operation:
    - Continue co-operating with senior governments and stakeholders (e.g., Fraser Basin Council (FBC), Fraser River Port Authority (FRPA), North Port Authority, National Research Canada, Universities)
  - ► Financing:
    - Pursue senior government and stakeholder cost sharing to implement the Strategy,
    - Using City powers (e.g., Drainage and Dike Utility Authority, DCCs) to finance flood protection infrastructure,
    - Encouraging sustainable funding for dredging the Fraser River.
  - ► Flood Event Return Period Standards:
    - Continue with the City's current Flood Event Return Period standards (i.e., River: 1894 flood of record, Sea: 1:200 year event)
    - Review current pending flood protection studies (e.g., by the BC Ministry of Environment and the Fraser Basin Council; National Research Canada),
    - Review the standards, as information becomes available
  - ► Perimeter Dike Level Design Standards:
    - Continue with the City's current perimeter dike level design standards (1894 flood of record plus freeboard, Sea: 1:200 year plus freeboard)
    - Review the standards, as studies become available (e.g., Fraser Basin Council's Fraser River Hydraulic Modeling Study).
  - ► Perimeter Dike Maintenance and Improvements
    - Continue and review standards, as studies become available.
  - ► Emergency Flood Response and Recovery
    - Continue to Improve Emergency Flood Response and Recovery Plans including the preparation of an updated Flood Response Plan as part of the overall Emergency Response Plan
- ❑ Bylaw related actions
  - Require flood protection covenants during redevelopment (e.g., to achieve minimum standards, to indemnify the City)
  - Establish an Interim Floodplain Bylaw
  - Improve flood proofing standards in the Urban Exempt Area (West Richmond)
  - Prepare floodplain mapping
  - Establish a Full Floodplain Bylaw
- ❑ Dike related actions
  - Perimeter Dike Standards – await pending studies, review standards and make recommendations to Council.

- Mid-Island Barrier: Pending technical studies and obtaining senior government and stakeholder funding, construct a mid-island barrier along the Highway 99/Knight Street Corridor, not along No. 7 or 8 Rds (assumes a 1:1250 year flood event standard).

SYNOPSIS OF THE STRATEGY cont'd

STRATEGY BENEFITS

The benefits of the 2006-2031 Flood Protection Management Strategy include:

- **General**
  - Addresses longstanding flood protection concerns (e.g., the mid-island barrier),
  - Applies the latest science and studies,
  - Better addresses current ocean, Fraser River and geotechnical flood dynamics and hazards (e.g., global warming, sea level rise, tides, the current Fraser River profile, subsidence, earthquake, land rise),
  - Establishes a comprehensive, long term Strategy,
  - Provides more legal and scientific clarity and certainty,
  - Improves flood protection,
  - Increases public safety.
- **For the City**
  - Enables the City to better meet its legal and planning flood protection responsibilities,
  - Enables the City to better manage flood protection,
  - Better protects public infrastructure,
  - Enables the City to better support sustainable dredging of the Fraser River,
  - Enables the City to respond to the 1996 City-GVRD MOU,
  - Enables the City to co-operate with senior governments with more certainty,
  - Continues close cooperation with senior government and stakeholders,
  - Establishes a better basis for a comprehensive, senior government and stakeholder cost sharing approach.
- **For Developers**
  - Provides more certainty.
- **For Senior Governments**
  - Clarifies Richmond's flood protection needs,
  - Provides an improved rationale and program basis for partnering and cost sharing.

City of Richmond

2006 - 2031 Flood Protection Management Strategy

June 29, 2006

Prepared by

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0947-028-01-01

UMA | AECOM

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1.0 INTRODUCTION

1.1 Purpose of Strategy

The purpose of the 2006 – 2031 Flood Protection Management Strategy is to enhance the City's ability to prevent flooding and minimize the risk and effects of flood damage, by increasing flood protection, flood proofing and responses to floods.

1.2 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:

- Sea Island on which lies the Vancouver International Airport (YVR) and the community of Burkeville,
- 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, and
- Mitchell Island which consists of industrial related activities.

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 recently, 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.

Study Area

The focus of this study is on Lulu Island, the most inhabited of Richmond's islands and the one where the City has primary responsibility for flood management protection.

Hay Report (1989)

A review of flood protection options was last prepared in 1989 resulting in recommendations that led to development and adoption of several Council policies. This included the establishment of Flood Construction Levels (FCL) and areas exempt from flood construction levels. The proposed flood construction levels were defined in a 1989 Hay & Company report and adopted by Council. However, not all of the flood management recommendations were

implemented (e.g., due to funding limitations, agricultural concerns); and Council made a decision to review the earlier strategy and policies with consideration to potential modifications.

The City undertook a review of the issues involved in development of a new strategy by establishing a Technical Advisory Committee working in conjunction with a consulting team.

A Flood Strategy Update...

- Enables a more comprehensive understanding of the flood hazard problem
- Considers a range of approaches for managing the problem
- Examines options for mitigating the problem and addressing flood issues if an emergency arises
- Acknowledges the City's legal flood management responsibilities
- Outlines a process for implementing new actions, policies and regulations to improve the City's flood management capabilities.

1.3 Key Factors Influencing the Strategy

Reconsideration of Proposed No. 8 Road Dike

A major impetus to preparing a new strategy was an element in the 1989 strategy which suggested the construction of a new interior dike at the No. 8 Road alignment supplemented with short dikes near the Highway 99 / Steveston exit and under the Knight Street Bridge approach ramp. These construction initiatives were deemed a high priority. However, this proposal was not implemented due to both high costs and concerns expressed by the agricultural community (loss of land and impacts on farm operations and drainage) that would result from the construction of the proposed No. 8 Road dike. These concerns contributed to the City's desire to review the current policy and provide direction for revisions, as necessary.

Provincial Legislation Changes

The *Flood Hazards Statutes Amendment Act, 2003* repealed section 82 of the Land Title Act which authorizes the Province to designate floodplain areas and to establish subdivision conditions in such areas. The Province, by adopting this Act, transferred responsibility for floodplain regulations to municipalities. The City can enact its own floodplain bylaws and development permit area requirements. The Province still retains regulator authority for the dikes under the Dike Maintenance Act.

Regional Considerations

In 1996, the City and the GVRD agreed that it would establish a flood hazard protection strategy as one step for the City to be considered for inclusion in the GVRD Livable Region

Strategic Plan (LRSP) Growth Concentration Area. By being in the LRSP Growth Concentration Area, the City would have a better ability to accommodate residential, commercial and industrial growth, and Light Rapid Transit (i.e., the Canada Line).

New Information

The availability of improved information, changes in land use over the years, and the need to examine both structural and non-structural issues related to floodplain management, further advanced the need to re-examine the Hay Report and current City policies.

2.0 STUDY PROCESS

A City Technical Advisory Committee was established to coordinate the work and liaise with the consulting team (UMA) throughout the project. This Committee included broad representation of City staff as well as external agencies:

- BC Ministry of Water, Land and Air Protection,
- the City of New Westminster, and
- Richmond Farmers Institute and others.

2.1 Development Stages of the Study

The work proceeded over a number of stages which are reflected in a series of technical reports including the following:

- **Technical Memorandum #1** (UMA, April 2003). This report provides an overview of the Hay & Co. report, summarizes information gained from technical agencies, reviews the contributing causes to flood events, and summarizes the issues and consequences of flood events. The report also describes the key concepts appropriate to flood strategies and identifies those aspects that would most likely provide the greatest benefit in updating Richmond's flood management strategy and policies.
- **Technical Memorandum #2** (UMA September 2003), focuses on flood control options and includes a synopsis of the modeling and computer animation work. The report summarizes alternative flood control options (e.g., a mid-island dike, the perimeter dike), provides a description of the dike breach computer models developed, and summarizes the results of the dike breach modeling.
- **Cost Benefit Analysis** (UMA October 2004) reviews the costs and benefits of the interior dike options and includes a review of the type of flood damage that might occur. It incorporates an estimation of damages resulting from several simulated scenarios; a review of dike breach probabilities; and summarizes the results of the cost benefit analysis.
- **Draft Strategy Report** in October 2004, and June 2005 (UMA) which summarizes the flood hazards, reviews the implications of the modeling results, considers mitigation options,

examines flood scenarios and the impact of different physical barriers, sets out strategic objectives and reviews the elements of an integrated strategy. The earlier draft reports culminated into this final document.

3.0 PROJECT CONTEXT

3.1 Threat of Flooding

The City of Richmond is situated on islands surrounded by arms of the Fraser River, and the Strait of Georgia to the west. The entire area is within the floodplain of the Fraser River, and prior to diking was subject to periodic inundation. With most of the population residing on Lulu Island, the safety of the City's citizens and protection of the built environment is dependent substantially on flood protection measures.

The water bodies surrounding Richmond are influenced by both Fraser River discharges and variations in the water level in Georgia Strait.

Flood threats considered here include the following natural and human actions:

Dike Failure – Summary Information Table

Type of Dike Failure	Cause
Overtopping/Breach	High Sea Levels ▪ High sea tides due primarily to lunar, solar, earth interactions ▪ Sea surge due to wind, storms and tsunami. (Recent reports indicate that a tsunami is now not a major threat) ▪ Elevated sea levels due to global warming (3.5 mm/year assumed over the next century) High River Levels ▪ Freshet due to spring snow melt runoff upstream in Fraser River ▪ Excessive precipitation for the Fraser River and/or the Richmond storm drainage system to handle ▪ Siltation/sediment deposition in the river, gradually reducing or altering the river flow and capacity ▪ A lack of dredging resulting in reduced flow capacity Lower Dike Crest ▪ Sinking of ground due to natural causes (e.g., soils, drainage, rain)
Piping	▪ Holes in the dikes due to seepage lines, plant roots, burrowing animals, structural settlement, etc., that result in back scour and erosion of the dike
Dike Design / Construction	▪ Poor dike design / construction and the use of improper materials
Liquefaction	▪ The liquefaction of soils under the dikes or general dike failure as a consequence of an earthquake or dike breach
Human Damage	▪ Vandalism, terrorism, mistakes, lack of understanding

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 0.5 m to 2.5 m Geodetic, with the average land level between elevation 1.0 m and 1.5 m, and
- for the Floodplain Exemption Boundary, which includes the more densely populated area in west Richmond, land that is lower than elevation 1.0 m.

3.2 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, and
- 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.

Emergency flood fighting measures can prevent an overflow from developing into a breach, especially when resources are readily available and action is taken quickly.

Flood Hazards – Summary

The City faces the following principal flood hazards:

- A dike breach that may occur as a result of water overtopping 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
- Human damage to a dike

The other contributing factors that may influence the degree of flood hazard, include:

- The sea level is rising relative to the land level. Global warming causes sea levels to rise due to increased water temperatures and increased volumes of water from ice melt. The deltaic deposits underlying the City of Richmond are still settling, a process that has been occurring since the sand, silt and clay was deposited. The motion of the continental plates near the west coast is responsible for some vertical motion and the land surface is also rising slowly as a result of the retreat of the huge ice sheets of the last ice age. For the purpose of the flood strategy work it was assumed that an average relative sea level rise of 3.5 mm/year will occur over the next century.
- Sediment deposition and changes in peak flood discharges may result from global warming. A significant portion of the sediment load that is transported by the Fraser River surrounding Lulu Island is deposited in these channels, with maximum deposition rates coinciding with the freshet period. This continual build-up of sediment in the South Arm of the Fraser River is partly removed by frequent dredging, which is currently conducted by the Fraser River Port Authority (FRPA) to maintain a navigation channel for deep draft vessels that travel up the River as far as New Westminster.

4.0 ISSUES AND CHALLENGES

4.1 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 FRPA representatives, between 1.2 million to 5 million cubic metres of materials are dredged or removed each year. Dredging can aid in maintaining river channels and avoid flooding as sediments are continuously deposited especially during spring freshet.

4.2 Provincial

Traditionally, the provincial government regulated construction in the floodplain by requiring approvals for bylaws in flood hazard areas. The *Flood Hazards Statutes Amendment Act, 2003* repealed section 82 of the Land Title Act authorized the Province to designate floodplain areas and to establish subdivision conditions in such areas. This is no longer the case and exemptions previously granted by the Ministry are no longer under provincial authority. However, bylaws previously approved by the Ministry and in effect on the date the new section 910 of the *Local Government Act* came into force, have not been repealed. Currently, the City does not have a flood exemption bylaw but has such a policy.

The *Local Government Act* now provides local government with approving and regulatory authority through bylaw provisions, upon designation of the land as being a floodplain. Included is the authority to establish setbacks, flood construction levels and provisions to, for example, regulate specific uses within buildings through a bylaw. Provincial guidelines for construction and regulations in the floodplain must, however, be considered in exercising this City authority. The recent legislative changes have left a degree of uncertainty in terms of the role of the Province in sign-offs to plans, dike works and other related aspects. Clarification is likely to occur over a period of time, as specific issues are addressed.

4.3 Greater Vancouver Regional District (GVRD)

The *Local Government Act* makes provisions for Regional Districts to adopt a regional growth strategy. Where such a strategy has to be adopted, the affected municipalities are required to prepare a Regional Context Statement – intended to explain the relationship between the community's Official Community Plan and the regional growth strategy. The GVRD's version of the strategy is the Livable Region Strategic Plan (LRSP).

Currently there is no regional flood hazard management policy.

Through a 1996 Memorandum of Understanding (MOU) with the GVRD, Richmond withdrew its objection to the adoption of the original LRSP, in part, subject to agreement that the GVRD Board would support rapid transit to Richmond and that Richmond would seek agreement with the Province on a mutually acceptable implementation plan for flood and seismic protection, plus adopt land use policies and bylaws for achieving future population consistent with the LRSP.

While not its sole intent, the proposed Flood Protection Management Strategy and its Implementation Program will, in large measure, respond to the City's commitment to develop a plan to address the flood related issues identified in the 1996 MOU by outlining the many programs that Richmond has been – and is currently involved in – to improve flood protection for the City.

4.4 City of Richmond

City of Richmond Council adopted a Floodplain Management Implementation Policy 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.

The concept of Flood Construction Levels (FCL) relies on measures that raise the lowest habitable floor elevations of all buildings above the FCL to protect the integrity of the building during a "design flood event".

Richmond's Design Flood Event Standards

The current "design flood event" is the 1:200 year flood level for a sea level event, and the 1894 discharge of the Fraser River.

The FCL is typically set above the design flood level by a "freeboard" amount which varies from 0.3 m to 0.6 m.

The current flood construction levels for Richmond were defined on the assumption that an interior barrier on the Number 8 Road alignment would be constructed along with other minor dikes identified in the Hay Report. Based on that assumption the FCL was set as follows:

(a) 3.5 m Geodetic Survey of Canada (GSC) for habitable or commercial building floor elevations east of No. 8 Road.

(b) 3.0 m GSC for habitable or commercial building floor elevations between No. 8 Road and the Knight Street/Highway 99 Corridor.

(c) 2.6 m GSC for habitable or commercial building floor elevations in non-exempt lands on Lulu Island west of Knight Street/Highway 99 Corridor, with provision for transition to existing land use adjacent to non-exempt lands.

(d) in the exempt areas, the FCL is 0.9 m.

Only City standards apply for habitable or commercial floor elevations in flood regulation exempt areas. Current Flood Construction Levels are depicted in Figure 1.

The City has a number of protective measures in place such as dikes, 39 pumpstations, drainage ditches, and flood construction level requirements that have worked well for many years to prevent negative impacts associated with significant flooding upon the community. Conditions have, however, changed since 1989. Notably:

- Provincial legislation has placed a greater responsibility upon local government for flood protection, with no provincially approved urban exempt areas, and municipalities having sole authority to designate by municipal bylaws floodplain areas and flood proofing requirements;

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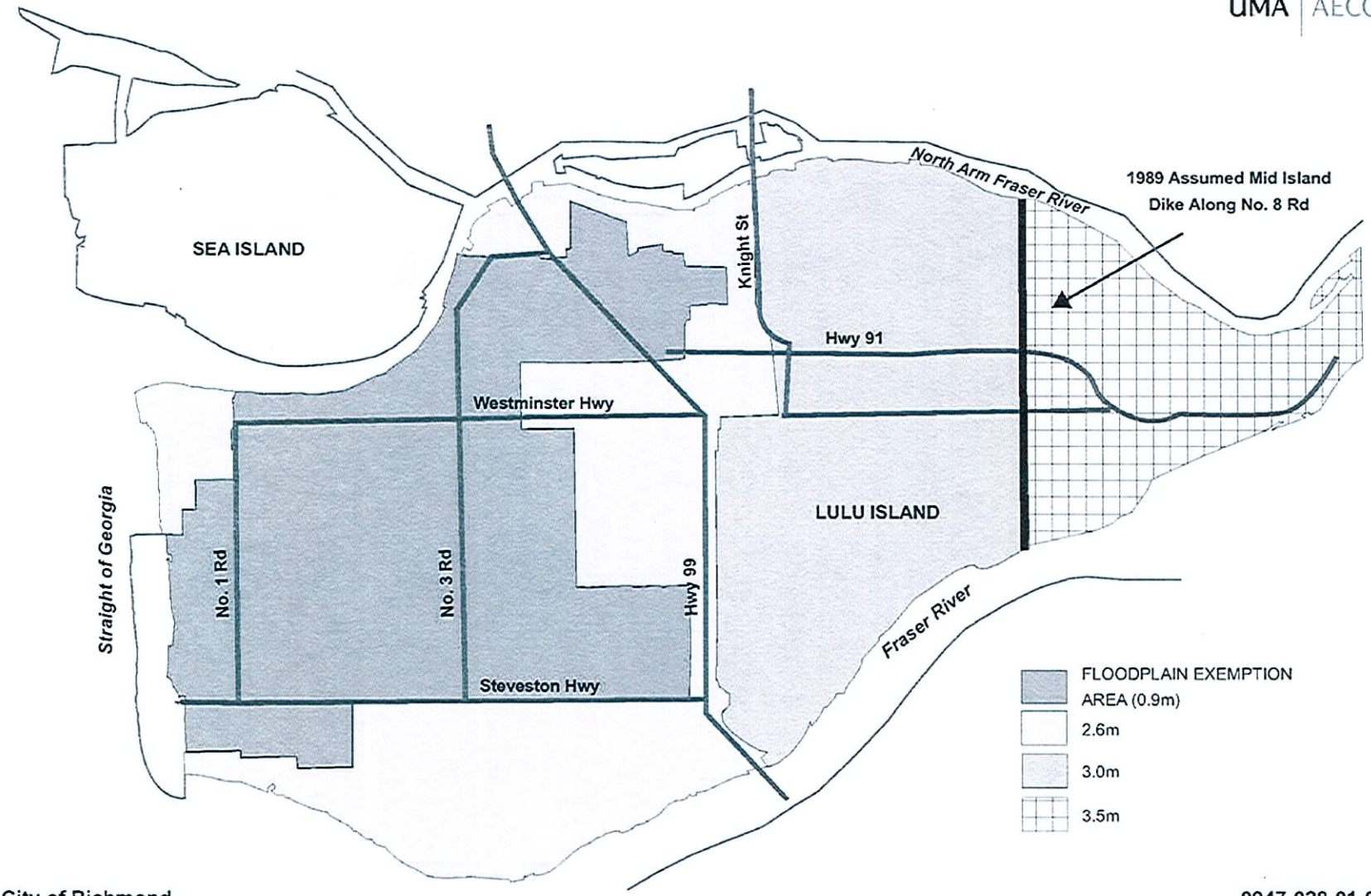


City of Richmond
Flood Management Strategy

0947-028-01-02
May 2006

Flood Construction Levels

Figure 1

- The level of investment and the number of people living in the community have grown significantly;
- There exists a much stronger understanding of flooding and the changes in the physical environment which affect this community;
- There is better science available on how to improve flood protective measures, and
- There is clear evidence of the long term social and financial impacts after significant flooding through events such as New Orleans, and other flood affected locations.

Such challenges give rise to opportunities to strengthen the preventative and responsive flood management approaches – such as proposed in this Strategy.

Legal Considerations

To take full advantage of the regulatory authority provided under the *Local Government Act*, Richmond will need to prepare a floodplain bylaw pursuant to Section 910 LGA. 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. The elements contained within such a bylaw will depend upon improved floodplain mapping, what plan is adopted by Council and appropriate documentation that will require preparation by legal counsel.

Without such a bylaw, some provisions do exist allowing covenants to be sought (e.g. through subdivision under Section 86 of the *Land Title Act*), however, only voluntary covenants can be sought for certain other situations (e.g. typical building permits for single family dwellings). 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.

4.5 Financial Concerns

As part of any new strategic initiatives, dike improvements, maintenance, as well as construction, requires substantial capital investments. Richmond has recently established a dike utility to begin 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.

5.0 FLOOD MINIMIZATION ANALYSIS

5.1 Flood Event Return Period

An assessment was completed to simulate the potential impact of flooding due to a dike breach on Lulu Island. In developing the flood analysis consideration had to be given to the design river flood profile and sea levels that need to be planned at designated breach locations.

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 17,000 m^3/s.

During the development of this Richmond Flood Management Strategy, a decision was made to provide a higher standard of flood protection in Richmond by using the 1:1250 year return period Fraser River and Ocean storm surge levels for the modeling. 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
- The current City's design standard does not address long term sea level rise.

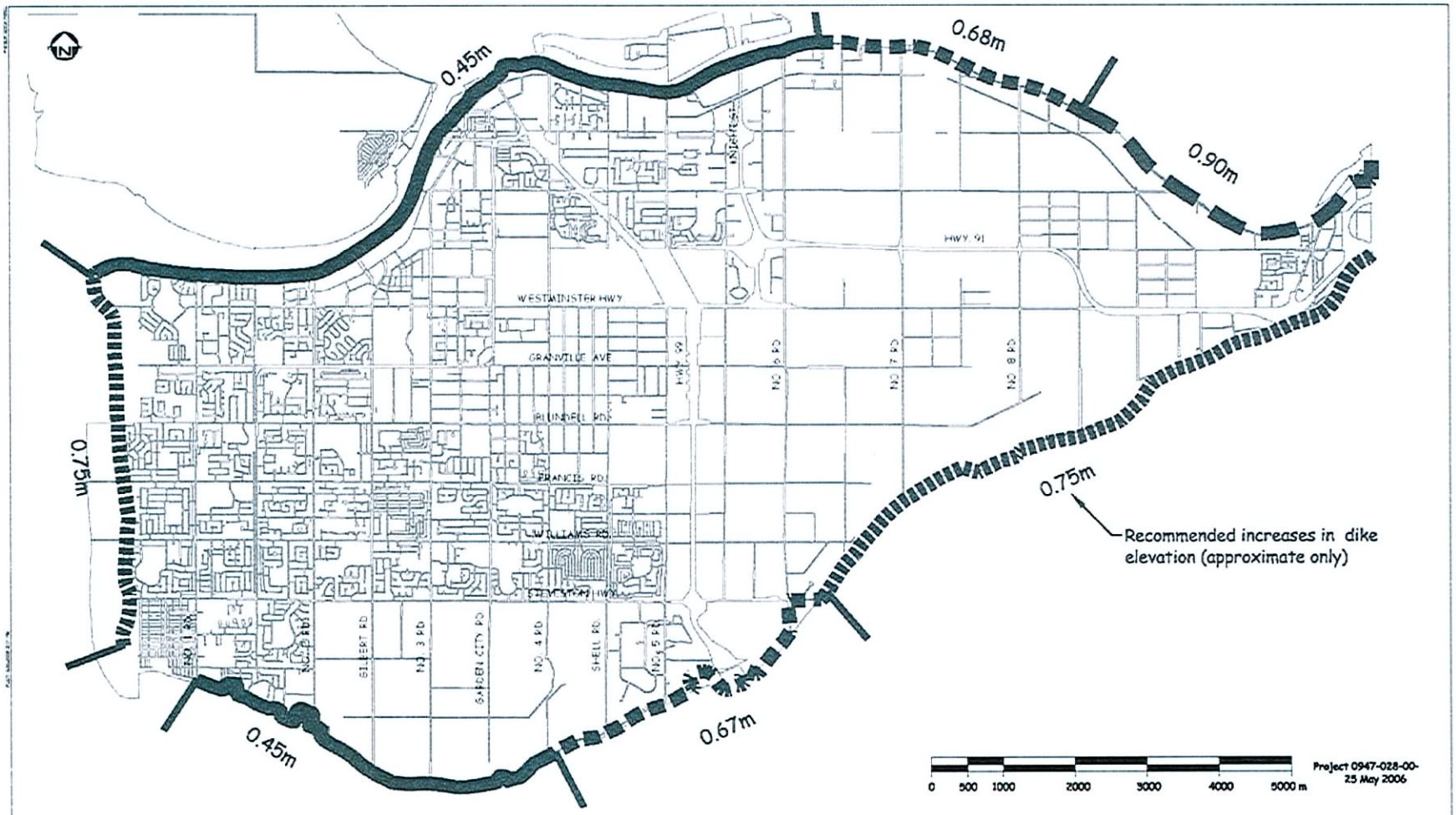
It is noted that other places now use the 1:1250 and greater event for their dike design (e.g., Netherlands)

Frequency analysis was performed for both the Fraser River freshet discharges and the ocean storm surge levels. For the river flood, the frequency analysis has shown that the 1894 flood of record appears to have a return period that is most likely between 136 years and 685 years. A reasonable working estimate of the 1894 flood return period suitable for dike design purposes is 200 years. Increasing the 1894 discharge by 25% to 21,250 m^3/s brings the Fraser River discharge to be as a 1:1250 year event. In order to simulate a Lulu Island dike breach event, the discharge in the Fraser River at Hope was set to 21,250 m^3/s, plus inflows from tributaries downstream of Hope. To model a 1:1250 year, event the discharges corresponding to the modelled hydrograph at Mission were increased by a factor of 1.25.

The impact of using the 1:1250 year return period event has on current dike heights in the municipality is illustrated by Figure 2. The 1.25 factor therefore exceeds the current Provincial and City standards and, if implemented regionally, would likely impact dike heights through to Mission.

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

For deriving the design sea level, a frequency analysis of the annual peak water levels recorded at Point Atkinson was conducted. The 1:1250 year return period still water level of 2.684 m which resulted from this analysis almost exactly matches the current design water level (2.68 m) for the dikes that are governed by the recorded extreme highest sea level. Accounting for long term sea level rise, a design 1:1250 sea level of 2.828 m was used for the modeling.


0.45m
0.68m
0.90m
0.75m
0.75m
Recommended increases in dike elevation (approximate only)
0.45m
0.67m
WESTMINSTER HWY
GRANVILLE AVE
BLUNDELL RD
FRANCIS RD
WILLIAMS RD
HWY 91
HWY 99
NO 3 RD
NO 4 RD
NO 5 RD
NO 6 RD
NO 7 RD
NO 8 RD
GILBERT RD
GARDEN CITY RD
SHELL RD
0 500 1000 2000 3000 4000 5000 m
Project 0947-028-00-
25 May 2006
City of Richmond
FLOOD MANAGEMENT STRAGEGY
PROPOSED DIKE HEIGHTS, 1:1250 EVENT
Figure 2
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5.2 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 defence system will not fail until at least that level is reached. The probability of a failure is difficult to determine without additional information, including the following:

- Detailed knowledge of critical properties of the soils that make up the entire perimeter dike system, including the soils that lie beneath the dikes.
- Detailed knowledge of the design and condition of all structures that are situated in the dikes, and the soils adjacent and beneath these structures.
- Data and techniques that would allow uncertainties related to the probability of dike breaches and flooding to be quantified.

Although it is expensive to gather the above information, once this data is made available, it should be possible to identify the areas of potential dike weakness and to assign probabilities of a dike breach to each structure and segment of dike. The City is currently engaged in seismic upgrade studies for selected areas of the perimeter dikes.

5.3 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:

5.4 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.

While it is difficult to implement in built-up areas (there would have to be a consistent fill elevation level over a fairly large area), this strategy provides one of the most secure, effective and long-lasting means of flood protection possible.

The result of raising the land area would be similar to what exists at the Fraser Port Authority lands today. Densely populated areas with many underground utilities could be raised in stages over a long period of time, reaching the ultimate elevation after a few centuries.

If only portions of areas are raised, then refuge areas are created. These refuge areas can serve as places for people to gather in an emergency such as a flood or major earthquake. They would be most functional if they contained critical facilities for emergency response, such as hospitals, fire halls and police stations. Other public buildings such as schools could also be considered

for future refuge areas, since they generally occupy relatively large lots and would be more amenable to a fill pad of a few metres in height.

5.5 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.

This approach which Richmond has had in place since 1989 increases public safety and reduces flood damage in the event that the diking system fails. Although used to only a limited degree, it is easily enforced on new construction and major reconstruction through building permits. It can also be applied to each individual building independently. This method is being implemented in parts of Lulu Island.

This concept does however face several major challenges. It is difficult to implement for existing structures, but can be feasible if implemented over a very long time.

5.6 Improving River Channel Conveyance

The lowering of river flood levels can be achieved with sustained, aggressive and continuous dredging of the river bed. It entails significantly enlarging the channels of the Fraser River that surround Lulu Island. If dredging is used to increase the flow capacity of the channels, then continual maintenance to maintain that flow capacity is also required, since the Fraser River continues to deposit sand into the enlarged channel, especially during freshet periods.

However, this concept can only address flood levels caused by high river discharges. It does not reduce the flood threat posed by extremely high tidal sea levels. It may also affect aquatic habitats in the Fraser Estuary.

6.0 LAND USE AND ENVIRONMENTAL ISSUES

6.1 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 a revaluation of the flood management strategy, 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.

6.2 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 Fraser Port 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 Fraser River Port Authority. 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 Fraser Port (Richmond lands) will ultimately provide for about 1000 hectares of industrial use in this location, and the elevation of the land here functions as a significant flood barrier.

6.3 Environment

Over the past decade, the City has placed significant importance on the environment 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% (1248 ha) of the municipality's land base.

6.4 Zoning Authority

The City, under the *Local Government Act* has the authority to zone land and controls its use and density. Zoning provides an important element in an overall flood management strategy. For example, it provides an opportunity to allow for the gradual widening of the perimeter dike, in agreed to locations, to minimize the probability of such events as piping. This approach is similar to what has occurred at the Fraser Port lands. This would involve the identification of areas where the City wishes to achieve a widened dike on private property. As part of a development agreement and subsequent zoning, owners can be encouraged to fill their lands to an appropriate standard, with rezoning offering an incentive to minimize or mitigate costs to the public and the owner. This strategy, driven by planning considerations, would be considered similar to the filling of land to raise the elevation and offers one of the best possible means of long term flood protection.

This policy, while of broad application, is likely most effective for northeast Lulu Island. A potential area for redevelopment is readily identifiable, using the rail tracks as the southern boundary, with No. 6 Road as the western boundary (up to an established industrial area), and the Hamilton residential district as the boundary to the east. Other areas can also be included, but the interior extent of the potential raised area would require better definition. Land within these areas may be considered for redevelopment from agricultural to industrial, thus providing some incentive to private property owners to fill land and at the same time, fulfilling an industrial strategy to create more water accessible industrial lands.

To further assist the dike widening initiative, this strategy may be combined with a transfer of density rights program. Richmond dikes may be considered an amenity; the dikes are integral to the City's trail system and dike widening provides greater protection from flood hazards. Density rights may be transferred to development on land encroached by dike widening and set backs. Input and approval from the Agricultural Land Commission would also be required.

7.0 REVIEW OF DIKE SOLUTION OPTIONS

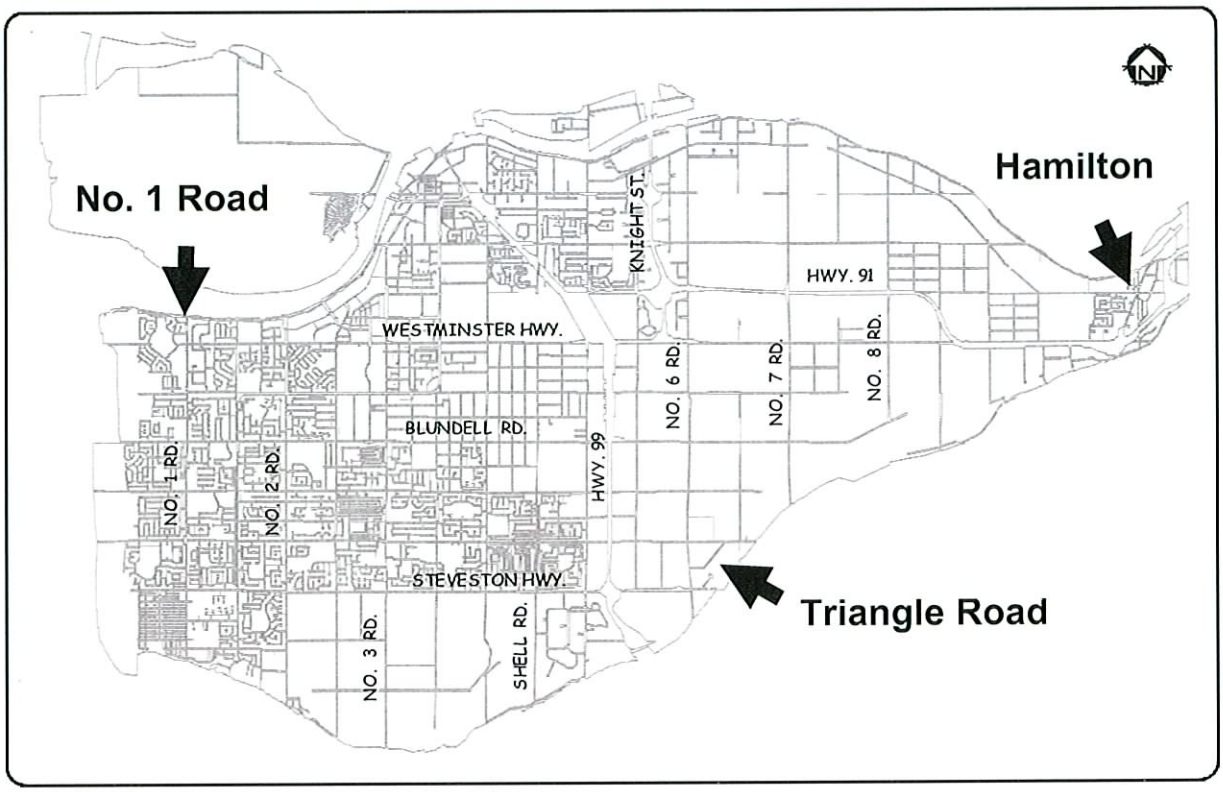
An assessment was completed of the potential effectiveness of dike improvements as a means of providing enhanced flood protection. A series of computer model simulations of dike breaches was prepared to identify the extent of land inundated, and to indicate the probable effectiveness of alternative solutions, including the development of an internal barrier, which formed a contentious element in the 1989 Strategy.

The dikes surrounding Lulu Island are highly variable with respect to their height, width, side slopes and nature of the land adjacent to the dike which varies from a toe ditch to high fill. A number of possible breach locations were identified based on these factors. Out of these, three geographically representative locations were selected for dike breach modeling.

7.1 Dike Breach Models

The breach models assumed a 1:1,250 year flood event. The three breach locations modeled were selected to show the differences between a river flood, a sea flood, and a mixed river/tide influenced flood at three widely-spaced locations along the perimeter dike. The breach locations modeled include the west Hamilton area, the north end of No. 1 Road, and Triangle Road at the south of Lulu Island. These locations are identified in Figure 3.

Figure 3 – Dike Breach Locations



7.2 Internal Barrier Models

Modeling was also completed to test the effectiveness of a possible internal barrier. Locations for such a barrier included:

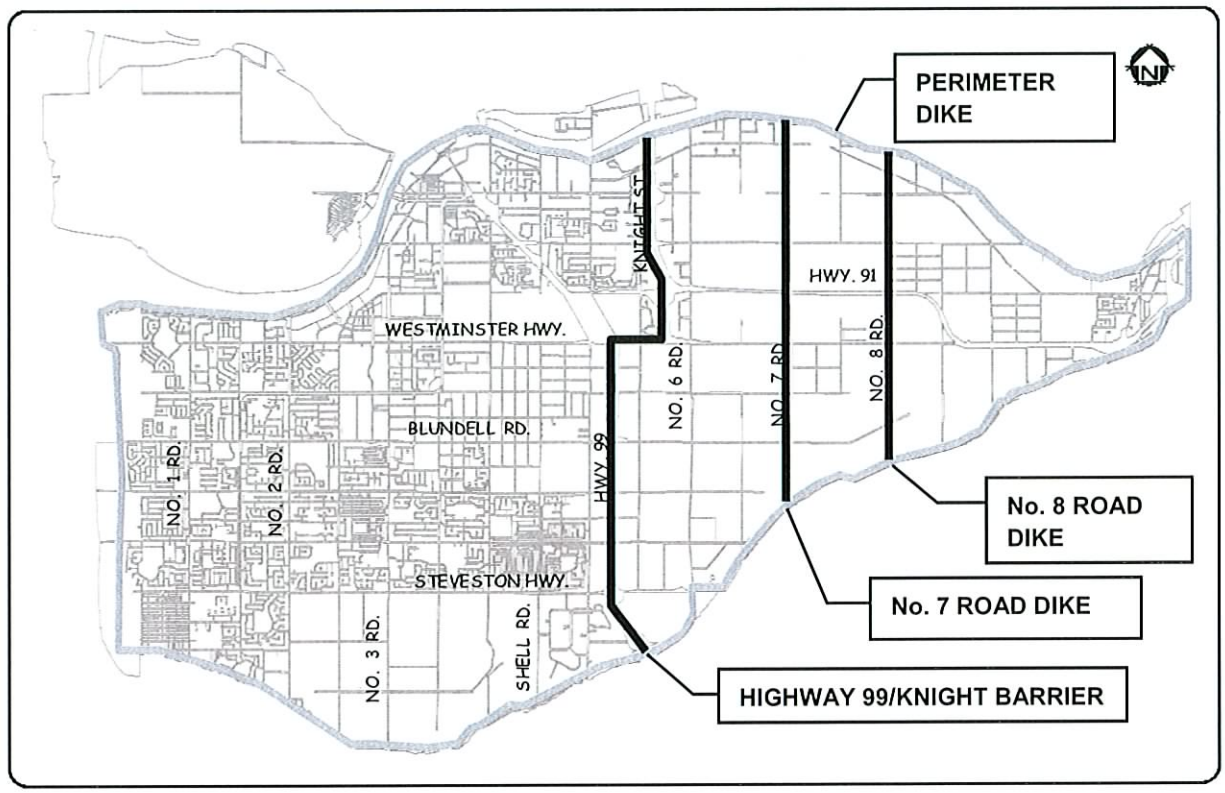
- No. 8 Road Dike
- No. 7 Road Dike
- A barrier along the alignment of Knight Street/Highway 99
- No internal barrier

Locations for potential interior barriers are defined on Figure 4. For the hydraulic computer models (using MIKE 11 software) a number of scenarios with various combinations of breach locations and internal barriers were considered. This included the West Hamilton perimeter dike and Triangle Road perimeter dike breach locations assuming a scenario without internal dikes, plus a model run with assumed internal dikes situated alternatively at No. 7 Road, No. 8 Road, or the Highway 99/Knight Street barrier.

For the No. 1 Road breach scenario no internal dike was modeled since the flood water did not spread past the nearest barrier (Highway 99/Knight Street).

All three internal dike scenarios for a breach at the No. 1 Road location show the same results as the "No Internal Barriers" model.

Figure 4 - Internal Barrier Locations



To obtain a conservative estimate of flood damages, it was assumed that:

a. no action is taken to try to close the breach for the entire length of simulation

b. no emergency internal barriers (berms or sandbags) are constructed during the flood

c. no dikes on the west side of Lulu Island are breached to relieve some of the flooding during a river flood

ArcView GIS and MIKE 11 GIS software were utilized to produce flood depth maps and flooding animations. The 24 hours and 48 hours post-breach and maximum flood depth maps were prepared to illustrate the results.

7.3 Flood Modeling Summary

1. From a breach of the perimeter dike near the north end of No. 1 Road none of the internal dike alignments were effective in reducing potential flood risk and damages. This conclusion would probably also apply to breaches occurring anywhere west of No. 2 Road.

2. The internal barriers that were modeled appeared to be best suited to minimize the flood impact for the Hamilton area breach. All three internal barrier alignments tested had the effect of greatly reducing the flooded area. However, flooding depths increased on the upstream side of these barriers. The internal barriers showed significant reduction in the total volume of water that would enter Lulu Island.
3. For the Triangle Road Breach, the internal barriers had the effect of eliminating flooding in one area by diverting flood water elsewhere resulting in shallow flooding in areas that would have otherwise stayed dry.
4. For the Highway 99/Knight Street median barrier (as it currently exists), the assumption that the barrier would tip over but remain intact could have a large impact on the model results. If the assumption had been that the barrier remains standing, the flooded area may have been reduced. However, the areas on the upstream side of the barrier would have likely experienced deeper inundation. If the assumption had been that the barrier would be washed away completely, the flood would have likely spread to areas that appeared to remain dry in other modeled results.
5. Culverts, flood boxes, and pump stations were not modeled. The culverts under the roads would have tended to allow further spreading of floodwaters. They would have also allowed some water to spread sooner, long before the road would be overtopped. The pump stations and flood boxes tend to relieve some of the flooding thereby at least partially offsetting the effects of culvert flow flooding.
6. In general, the success of a flood management strategy that depends on internal dikes depends on the location of actual future breaches in the perimeter dike. In every case, the primary intention behind the internal dike concept, which is to decrease flood risk and reduce flood damages, is defeated for part of the community. The damages could be made worse by the internal dike for that part of the community on the wrong side of the internal dike. The strategy could be viewed as successful in an overall sense when the part of the community that is impacted worse has much lower population and less potential damages than the part of the community that is protected.
7. From the perspective of hydraulic effectiveness alone, (without considering economic, social and environmental factors) the model simulations suggest that, of the three internal dike alignments, the Highway 99 / Knight Street route appears to provide the best compromise between protection and risk to the built-up part of West Richmond. This is primarily due to the fact that this alignment is closest to the border between the urban and rural parts of Richmond.

7.4 Modeling Limitations

The results of the modeling has limitations:

a. The area blocked by buildings and small fill features in the path of the floodwaters was not precisely represented in the model. Instead, a portion of the cross section in these

areas was effectively blocked by making a percentage of the cross section non-conveying. This percentage was based on the approximate building density observed in aerial photographs taken in 2002.

b. Not all barriers to flow were entered into the model. Only selected high and continuous barriers, typically roads and railways, were surveyed and used in the model. These barriers were assumed to remain unbreached for the duration of the flood.

c. Ditches, pump stations, culverts, and flood boxes were not included in the model. Including the culverts under the existing barriers in the models could have changed the results slightly in two ways. Firstly, flood water would have entered downstream cells earlier in the simulation. However, once the barrier is overtopped, the volume passed by the culvert would become insignificant. Secondly, flood water would have reached the downstream side of barriers that were not overtopped and over time may have resulted in some shallow flooding. Pump stations tend to counteract any flooding resulting from flow through culverts. The absence of the culverts in the models partly offsets the effect of the absence of the pump stations.

d. The New Westminster portion of Lulu Island was not included in the model. No ground elevations were obtained for this area.

e. The level of detail of the model did not allow for the simulation of the failure of each cranberry farm ring dike in the east portion of Lulu Island. Instead, additional roughness was added to the model at appropriate elevations and locations to account for the delay in the initial flood wave progression that would have been offered by the ring dikes before they breached.

f. The model is not intended for assessing detailed local flooding concerns as it does not include enough detailed information to provide accurate small scale model results.

g. The modeled dike breach scenarios do not encompass all possible dike breach consequences and may not necessarily represent a worst case scenario for all areas of Lulu Island. For example, if a dike breach near the Knight Street Bridge was modeled for a 1250-year extreme water level, the results may have showed deeper flooding in that location than the breach scenarios modeled in this study.

7.5 Cost-Benefit Analysis

Additional analysis was carried out to examine the relative costs and benefits of the three alternative internal barriers (No. 8 Road, No. 7 Road and Highway 99/Knight Street). The option of no internal barrier forms the basis for comparison.

The cost for each internal barrier was derived by estimating the construction cost. The benefit was estimated by estimating the reduction in flood damage attributable to each internal barrier in the event of a single dike breach during a 1250-year high water condition in either the Fraser River or Georgia Strait. This benefit was calculated as the difference in damage between the no

internal dike case (the do-nothing approach), and the damage that would result if the internal dike was built.

The extent of flooding was estimated using computer model simulations of the dike breach scenarios with each internal barrier for a 72 hour event following a dike breach. This period was selected on the assumption that flood fighting measures would limit the spread of water after the initial 72 hour period. For the purpose of estimating flood damages the agriculture areas were divided into cranberry and non-cranberry farms. Other land uses included single-family, two-family and townhouse dwellings, apartments, and commercial/industrial. Flood damages were based on tabulated property value data, land use and flood depth. Damage can be both tangible and measurable, such as property damage, or intangible, such as mental anguish and social disruption. The analysis is based on measurable damage.

7.6 Greatest Damage Estimates

Of the dike breach scenarios tested, the greatest estimated damages [$1.9 billion (2004 dollars)] were associated with the combination of a dike breach in the West Hamilton area and no internal dikes. The analysis confirmed that, for this type of a flood scenario, any internal dike would be highly effective in reducing damages.

The second largest flood damage estimate ($1.8 billion) was that associated with the dike breach simulated at the north end of No. 1 Road. This damage value is completely unaffected by all of the internal dike options. In contrast with the Hamilton area breaches, the internal dikes provide no benefit in reducing any flood damages if a dike breach occurs west of the Highway 99/Knight Street route.

Agricultural crop, livestock and economic losses varied from less than 1% to almost 15% of the total for the various breach scenarios tested. The Highway 99 / Knight Street barrier results in significantly greater total agricultural damages than either the No. 7 Road or No. 8 Road dikes for all perimeter dike breach scenarios in the east side of Lulu Island.

7.7 Probability Estimates

An estimate was also made of dike vulnerability to assess the probability of a perimeter dike breach. The preliminary assessment of vulnerability was based on visible dike characteristics including dike width, dike top material, and potential for large water pressure differentials to develop. This vulnerability assessment combined with an acknowledgement that the presence of structures like pump stations may represent point locations of increased breach potential, was used as a basis to estimate relative dike breach probabilities. However, no consideration was given to the variability of subsurface, as these are largely unknown. Figure 5 illustrates the classification of dikes in relation to their assessed vulnerability.

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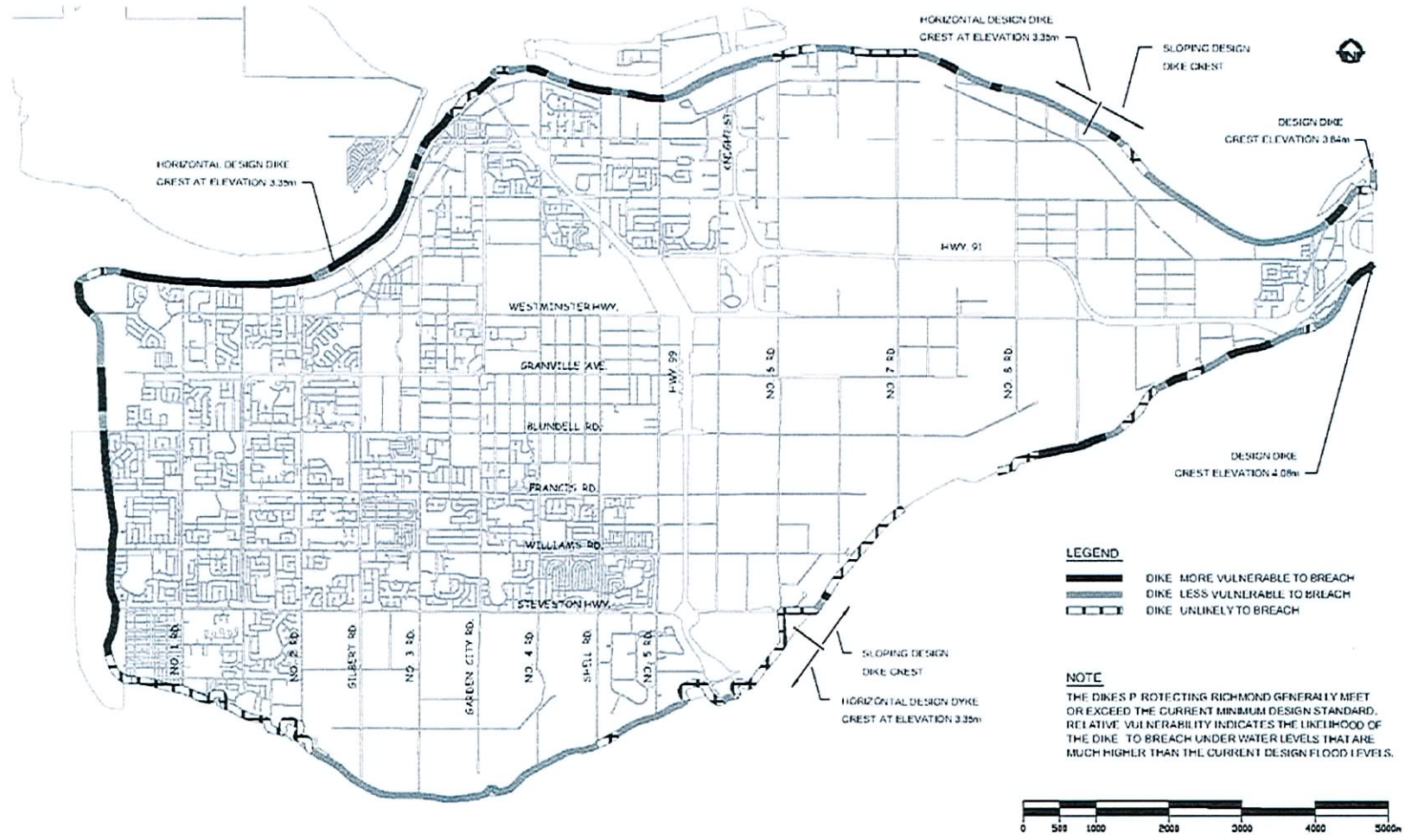


City of Richmond
Flood Management Strategy

0947-028-01-02
May 2006

Preliminary Assessment of Relative Dike Vulnerability

Figure 5

Dike breach probability estimates indicate that, when a dike breach occurs, it would be three times more likely to occur west of Highway 99/Knight Street than to the east of it. Also the probability that such a breach will occur on the west side of the barrier increases as the barrier is moved eastwards, ranging from 76% for the Highway 99/Knight Street barrier to 83% for the No. 8 Road dike. A dike breach has a very small probability of occurring in West Hamilton, although this would likely result in the worst case flooding if river levels are high.

Given the higher probability of a dike breach in the west part of Lulu Island and the high damages that could result there, it is clear that an internal dike addresses only a part of the total flood threat.

7.8 Cost Benefit Conclusions

The analysis found that:

- the route with the most favourable benefit-cost ratio is the No. 8 Road alignment;
- the Highway 99/Knight Street alignment is a close second, and
- the No. 7 Road alignment had the least attractive benefit-cost ratio.

However, the estimated costs for the three internal dike options did not include property acquisition, and traffic and construction issues and disruption associated with Knight Street/Highway 99. Property issues are likely substantial for the No. 7 Road and No. 8 Road dikes, but is insignificant for the Highway 99/Knight Street barrier. Traffic disruption during construction would likely be greatest for the highway median floodwall. At this stage of analysis the benefit-cost ratios for No. 8 Road and Highway 99/Knight Street should be viewed as essentially equal. Order of magnitude construction costs are summarized in the table below.

Construction Cost Estimates

Dike Element	Cost (2006)
Perimeter Dike (assumes construction to a 1 : 1,250 year flood event standard)	
• West and North Dike	$38.2 million
• South Dike	$53 million
Total Perimeter Dike	$91.2 million
Internal Barrier (assumes 1:1,250 year flood event standard)	
No. 8 Road Internal Barrier	$15 million
No. 7 Road Internal Barrier	$20 million
Knight St / Highway 99 Floodwall	$16.1 million

Sensitivity tests showed that the final ranking was sensitive to variations in the estimated construction costs for the internal dikes. A 10% shift in estimated construction cost could be enough to reverse the ranking of the benefit-cost ratios for No. 8 Road and Highway 99 / Knight Street.

7.9 Cost Benefit Analysis Limitations

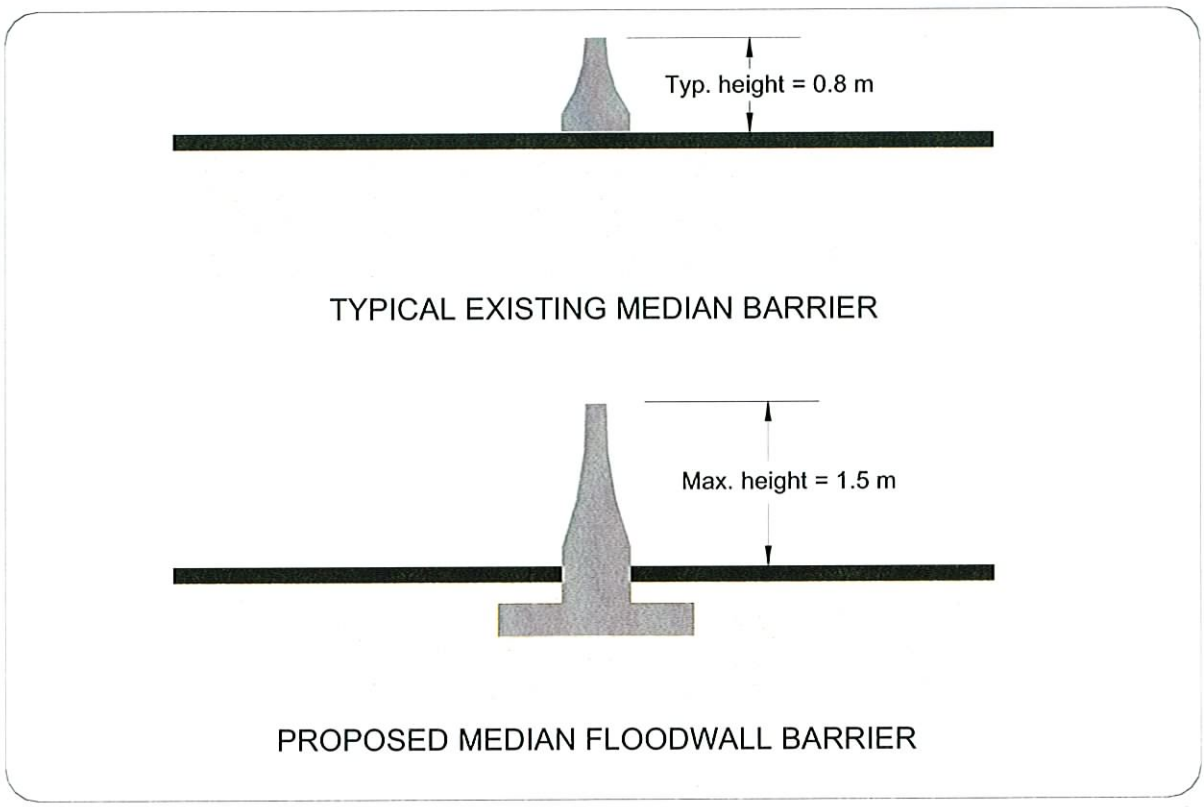
There are overall limitations in accuracy in the final estimates of benefit-cost ratios. These include:

- a limited number of flood simulations (4) were run;
- only one return period event (1250-year) was analyzed;
- a limited number of dike zones (4) were used;
- construction cost estimates still contain large contingencies and do not include property acquisition costs and traffic disruption issues;
- the failure potential of cranberry dikes could not be predicted, and
- the subsurface variability of dike breach probability due to subsurface conditions was unknown and not considered in the vulnerability assessment.

To better define damage impacts it is desirable to model three more dike breach locations and three more dike zones, thus enhancing the accuracy of damage estimates. A series of simulations for water levels with lower return periods than the 1250-year period will provide insight into the variation in damage costs, from the various breach locations if there was less water pressure driving floodwater into Lulu Island. A more detailed cost estimate for the Highway 99/Knight Street barrier and the No. 8 Road dike, and inclusion of the property acquisition costs, and disruption costs will improve the accuracy of the benefit-cost ratios. While the BC Ministry of Transportation generally concurs with the proposed median floodwall on Knight Street/Highway 99, informal discussions have indicated concerns about the ability to accommodate road drainage, and costs associated with construction (e.g. traffic disruption) that will need to be assessed as part of a larger Multiple Account Evaluation (MAE) that may be appropriate for all of the interior dike options.

A schematic of the Knight Street/Highway 99 floodwall barrier is shown on Figure 6 below.

Figure 6 - Comparison of Median Floodwall with Existing Median Barrier



8.0 FLOOD PROTECTION MANAGEMENT STRATEGY

8.1 Flood Management Concept

The 2006 – 2031 Flood Protection Management Strategy Concept is to enable Richmond to be a safe place to live, work and play, in an environment that minimizes the hazards associated with flooding.

This Concept complements the Corporate Strategic Vision: To be the most appealing, livable and well managed City in Canada.

8.2 Flood Protection Management Strategy Principles

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

Safety: *Richmond's population and economic infrastructures are to be safeguarded from flood hazards*

Prevention: *on-going efforts are to be made to maintain and enhance the City's flood defence system*

Sustainability: *flood prevention mechanisms must be economically sustainable, environmentally sound, and be able to achieve long term planning and development objectives*

Cost effectiveness: *flood protection measures shall be appropriate to future land uses and shall recognize that such costs are part of development*

Partnerships and cost sharing: *the City will actively solicit partnerships with other levels of government, as well as the private sector, to share the benefits and costs of flood protection, and to achieve an appropriate level of flood preparedness*

Coordination: *the City will coordinate its efforts at flood protection with senior government, regional agencies, and emergency services*

Purpose of Strategy

The purpose of the Flood Protection Management Strategy is to enhance the City's ability to prevent flooding and minimize flood damage, by increasing flood protection, flood proofing and responses to floods.

8.3 Flood Risk Prevention

Regional

Currently, there is no regional flood protection management strategy.

The City is committed to the management of growth both within an overall regional context but also in relation to the objectives and policies contained in the Official Community Plan.

City

Every effort is to be directed to preventing the flooding of the community and also to minimize the impacts of a flood event, should such an event occur. As a community within the floodplain, the City acknowledges that an element of flood risk will always exist. The emphasis of the Strategy is to both prevent and minimize such risk.

Upgrade Perimeter Dike

Prevention can be enhanced by an active program of perimeter dike maintenance and upgrading in order to reduce the risk of flooding from both river flood and sea level flood hazards. To achieve this, a more conservative approach to the current flood standard is desirable. Key factors to support a more prudent standard include:

- the substantial increase in investment in urban and agricultural infrastructure;
- rapid urban growth, and significant redevelopment over the past few decades;
- prospects for future growth and development (e.g., through improved transportation infrastructure), and
- concerns about sea level rise and possible land subsidence.

All of these issues support a greater degree of caution in establishing standards for flood prevention and protection. UMA conditionally recommends adopting a higher level of flood protection by using a 1:1250 year flood event and upgrading dikes accordingly. Given the implementation and financial implications, the City should ensure appropriate direction from senior levels of government (i.e., if New Westminster does not upgrade their dikes then clarification of liability is required).

Improvements to the perimeter dike can be made to accommodate this increase in the margin of safety.

- One option is to increase the dike crest to account for long term sea level rise only. This could be an increase of 0.30 or 0.35 m, which would represent 100 years of sea level rise.
- Another possibility is to raise the dike for this same degree of sea level rise, plus an increase in the design water level that would represent a greater safety margin, or a more extreme high water event. The latter increment of increased dike height should achieve a consistent probability.

Figure 7 depicts how these two increments might affect an existing dike cross section with a 4 m wide crest width located near the east end of Lulu Island. At the west end of Lulu Island the

increment from the existing design water level to a 1250-year water level would be less than that required at the east end, assuming that no updating would be required for the wave height and wave runup criteria. The width at the base of the dikes may also need to be increased. The relative proportion of height increase on a minimum cross section is shown in the diagram.

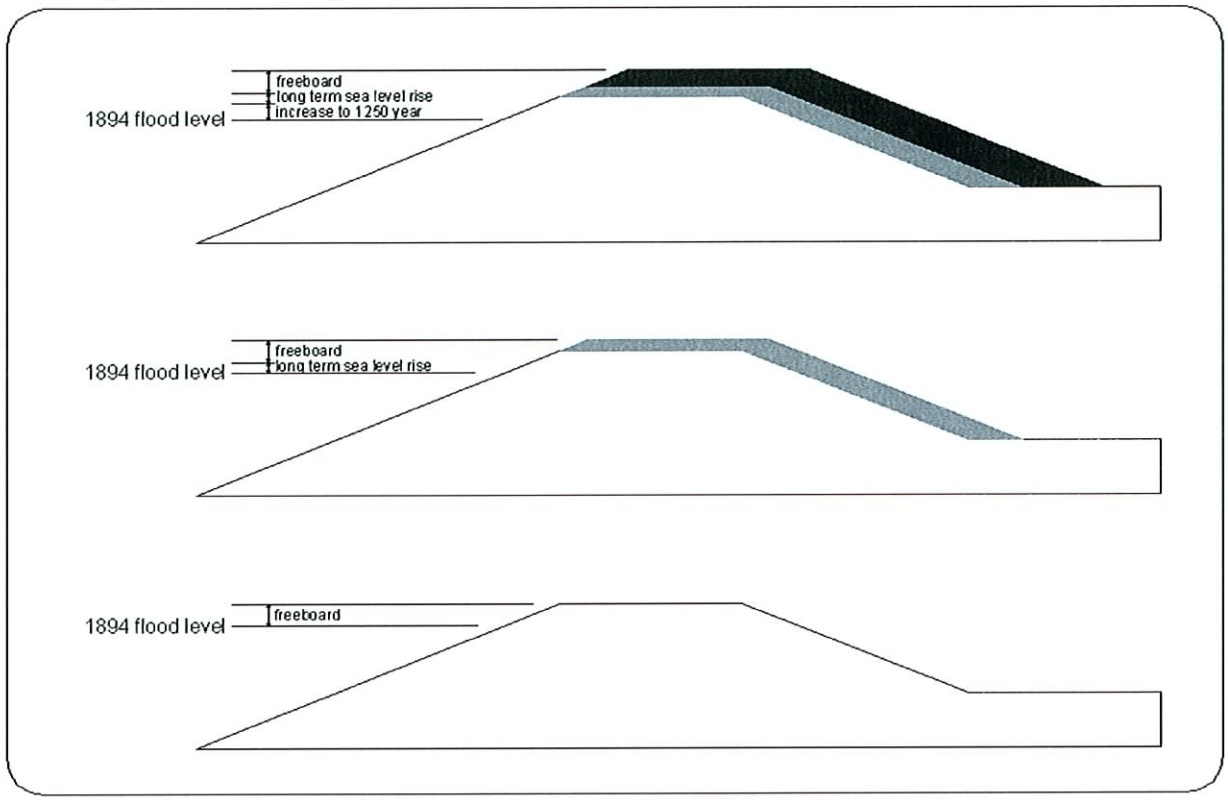


Figure 7 - Alternative Criteria for Dike Height Increases

Secondary Line of Defense

An interior flood barrier can provide a secondary line of defense, but requires further investigation to better predict areas for optimum investment. While the creation of a concrete barrier in the right of way of Knight Street and Highway 99 appears desirable, especially since little if any land acquisition is required, its construction will not necessarily provide added safety for all flood eventualities. This is especially true for a dike breach west of the Highway 99 route, since water will be impounded west of the flood barrier. The heavily developed urban sectors of the City will benefit from construction of a Highway 99 / Knight Street barrier given a breach in the Hamilton area, although this is achieved at the expense of agricultural areas.

8.4 Implementation Program - Key Actions

On-going actions are required to enhance the City's ability to prevent flooding and to improve knowledge on necessary physical improvements.

The Flood Protection Management Strategy will be implemented through the Implementation Program led by City departments with functional responsibility to ensure timely and cost effective decisions.

This requires a concerted as well as collaborative effort by City Department's including engineering, planning, finance, building approvals, development applications, environmental, and emergency response planning.

The City also recognizes that the Strategy requires the involvement and direction, specifically with regard to dike standards, of senior governments and that results will be achieved only through jurisdictional and economic/financial partnerships.

The key result areas, some cost estimates (where available), a general timeline for implementation, and an indication of Departmental responsibilities (as identified by the City) are noted in the Implementation Program chart:

Key Actions	Implementation Program Flood Protection Management Strategy		
	Short Term (2006)	**Medium Term (2007)**	**On-going and Longer Term (now – 2031)**
1. Planning	1. Refer the Flood Protection Management Strategy (FPMS) to the Ministry of Environment (MoE) Water Stewardship Division for review and comment (PLANNING) 2. Discuss with Ministry of Transportation (MoT) the mid-island barrier along Highway 99/Knight Street corridor (PLANNING; TRANSPORTATION; ENGINEERING) 3. Consultation with Provincial and Federal Governments to determine direction for increased perimeter dike standards (ENGINEERING) 4. Review the upcoming Fraser Basin Council study to determine the implications for setting a new perimeter dike standard (ENGINEERING; PUBLIC WORKS) 5. Examine and pursue senior government cost sharing to implement the FPMS (ENGINEERING; PUBLIC WORKS; FINANCE) 6. Review the City's Development Cost Charge Bylaw and Drainage & Dike Utility to determine municipal funding sources for the mid-island barrier and perimeter dike upgrading (ENGINEERING; PUBLIC WORKS; FINANCE) 7. Collaborate between Engineering and Planning to develop a phased plan for overall land grade increases (ENGINEERING; PLANNING)	1. Work with the MoT on a plan for the development 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) 2. Improve the City's ability to get data and undertake direct measurements (e.g., monitoring local sea level changes through City operated gauging stations (ENGINEERING; PUBLIC WORKS) 3. Direct staff to prepare an updated Flood Response Plan as part of the overall Emergency Response Plan (updated on basis of new modeling and technical information) (ENGINEERING; EMERGENCY & ENVIRONMENTAL PROGRAMS) 4. Establish a protocol for obtaining dike rights of way for Mitchell Island (ENGINEERING) 5. Work with VIAA to clarify jurisdiction, maintenance standards and improvement programs for the Sea Island dikes (ENGINEERING) 6. Encourage the City of New Westminster to harmonize their flood protection levels with Richmond's strategy (ENGINEERING) 7. Work with Department of Fisheries and Oceans on a plan for widening the perimeter dikes – inside and outside existing dikes, addressing related mitigation and compensation requirements (ENGINEERING) 8. Work with external agencies (such as the Agricultural Land Commission) to develop a	1. Prepare a plan to support increased density adjacent to dikes but require grade increases and contributions to dike improvements. Retain dike rights of ways and access (PLANNING) 2. Remove and relocate or replace toe ditches adjacent to dikes (ENGINEERING) 3. Co-ordinate between emergency facilities and development planning (e.g., ensure refuge areas are located in areas not subject to flooding) (ENGINEERING; EMERGENCY & ENVIRONMENTAL PROGRAMS; PLANNING) 4. Review plans and implement for refuge areas, emergency routes, and create public awareness (ENGINEERING; EMERGENCY & ENVIRONMENTAL PROGRAMS) 5. Direct staff to review the FPMS approximately every 5 years (to ensure new information is reflected) (ALL) 6. Consult at timely intervals with experts (MoE, Canadian Hydrographic Service, etc.) and monitor the latest long-range ocean/climate change forecasts for their implications (ENGINEERING)

Key Actions	Implementation Program Flood Protection Management Strategy		
	Short Term (2006)	**Medium Term (2007)**	**On-going and Longer Term (now – 2031)**
	8. Pursue and plan for appropriate grade changes in local area plans (e.g. City Centre Area Plan update) (PLANNING)	protocol that will allow for these changes in use through rezoning, development permits, etc. (PLANNING)	7. Based on better understanding of flood problem and threats (risks) develop on-going public evacuation and communication programs (ENGINEERING; EMERGENCY & ENVIRONMENTAL PROGRAMS)
2. Bylaw Related Actions	1. Prepare an interim floodplain bylaw (Estimated cost - $10,000 for legal input) (PLANNING; ENGINEERING, LAW) Some of the items the Interim Floodplain Bylaw would consider are: - Flood Construction Levels (FCL's) for the urban exempt area; - FCL's for all habitable residential space; - Require developments over 1 ha to raise grades to new FCLs (e.g., 2.6 m in urban exempt area), with provision for lower grades where lower edge conditions; - Incrementally raise the grade of smaller developments to over the crown of the road or the existing grade – whichever is greater; - Wet proofing for development below the FCL's; - Exemptions for commercial development but still seek modest grade increases over the crown of	1. Carry out additional computer modeling upon the selection of an interior barrier to gain an understanding of resultant flood levels with the proposed interior barrier in place, as this will influence the selection of the FCLs (Modeling cost estimate - $60,000, using 4 breach scenarios) (ENGINEERING; PLANNING). 2. Undertake floodplain mapping to establish flood levels, and agree upon reasonable FCL's (Flood mapping cost estimate - $100,000) (ENGINEERING; PLANNING) 3. Prepare a floodplain bylaw including the new FCLs and the requirement for covenants/ indemnity (Estimated cost - $7,500 for legal input) (ENGINEERING; PLANNING; LAW)	1. 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)

Key Actions	Implementation Program Flood Protection Management Strategy		
	Short Term (2006)	**Medium Term (2007)**	**On-going and Longer Term (now – 2031)**
	the road or the existing grade – whichever is greater 2. Public consultation regarding Interim Flood Plain Bylaw (PLANNING) 3. Rescind Floodplain Management Implementation Strategy Policy 7000 (PLANNING)		
3. Dikes	1. Establish protocol for obtaining dike rights of way for Mitchell Island (ENGINEERING, LAW).	1. 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); 2. Prepare and implement a comprehensive perimeter dike improvement program (researching, strengthening and widening dikes to reduce the level of risk) (Engineering) 3. Establish a program for phasing/prioritizing perimeter dike improvement (e.g., seismically weak areas first, the mid island barrier, overall perimeter dike improvements) (Engineering)	1. Review dike maintenance programs at ongoing 3 to 5 year intervals (ENGINEERING; PUBLIC WORKS) 2. Support sustainable funding for a river dredging program to maintain river profile (ENGINEERING) 3. Establish in City budget annual amount for land for access rights to waterfront and dike areas (ALL) 4. Establish and maintain inventory of rights of way and access agreements to diking system (ENGINEERING) 5. Establish a protocol for dike restoration (e.g., procedural response plan by the City) (ENGINEERING; EMERGENCY & ENVIRONMENTAL PROGRAMS). 6. Update existing procedural policy of comprehensive dike maintenance (ENGINEERING ; PUBLIC WORKS).

Key Actions	Implementation Program Flood Protection Management Strategy		
	Short Term (2006)	Medium Term (2007)	On-going and Longer Term (now – 2031)
			7. Pursue development of the Highway 99 / Knight Street corridor as an internal barrier and as a secondary flood defence mechanism (Construction cost estimate - $16 million) (Engineering)

Notes:

1. Changes to perimeter dike standards are to await other flood studies.
2. Other Strategy Implementation Program elements proceed now.
3. Departmental responsibilities and timing reflect suggestions made by City of Richmond staff.
4. Detailed Implementation will be determined annually.

STRATEGY PRIORITIES AND DISCUSSION

1. Strategy Priorities and Discussion

   The Strategy emphasizes:
   - Strengthening And Improving The Perimeter Dikes
   - Pursue A Mid-Island Barrier Along The Highway 99 / Knight Street Corridor,
   - Preparing an Interim Floodplain Bylaw in 2006,
   - Preparing a Full Floodplain Bylaw
   - Implementing a planned approach to increase the overall land grades in the urban portions of the City.

   These priorities are discussed in below.

2. Strengthen And Improve The Perimeter Dikes

   A key Strategy recommendation is that the City's perimeter dikes continue to be upgraded, in a two-step manner, as follows:
   1. Continue normal upgrades based on current City ocean and river design flood events, and
   2. Review upcoming studies to determine if a 1:1250 year design flood event standard is practical.

   In consultation with the City's Strategy Technical Advisory Committee and experts in the field, UMA staff have proactively studied and conditionally recommend that the City consider increasing the level of flood protection afforded by the perimeter dikes:
   - from the City's current design flood level event standards,
   - to a 1:1250 year design flood level event standard.

   The preliminary briefing notes (see **Attachment 6**) indicate that the Provincial dike standards will likely need to be re-assessed with a view to increasing them.

   UMA's conditional recommendation for this more prudent (1:1250) standard is predicated upon factors such as the existing level of investment currently protected by the dikes, expectations for future growth and development (e.g., planned growth through the City Centre Area Plan), and the need to address sea level rise and land subsidence.

   The consultant acknowledges that there are many technical issues that need to be resolved first before settling upon any such increased standard – not all of which are within the City's control (e.g., it may do little good for Richmond to adopt a 1:1,250 standard if New Westminster maintains only its existing 1894 flood of record standard, or how much dike widening can occur in the wetted perimeter outside the dikes rather than the inland side of the dikes).

   City Staff:
   - agree with UMA's conditional recommendation regarding the adoption of the 1:1250 year design flood event standard, and
   - recommend not adopting the 1:1250 year design flood level event standard, until:
     - the Fraser River Hydraulic Modeling Study, currently being undertaken by the Fraser Basin Council/MOE has been completed and reviewed by the City, and
     - the City determines what standard is best.

   Note:
   - *Adopting the 1:1250 standard would result in the perimeter dikes being raised between* approximately 0.45 m to 0.90 m (1.4 ft to 2.9 ft) depending upon the location (refer to Figure 2 in the Strategy), at an estimated cost of $91 million dollars.
   - This estimate is preliminary *in nature, includes a large contingency factor and requires extensive consultation with stakeholders and partners.*

For these concerns, the Strategy recommends consulting with both the Province and the Federal governments to determine appropriate standards for the perimeter dikes. Direction from the Province, with consideration not only to Richmond, but the entire Lower Mainland should be sought – after which, City Staff will report back to Council with recommendations on the appropriate dike standards.

3. Pursue A Mid-Island Barrier Along The Highway 99 / Knight Street Corridor

A key recommendation of the Strategy is that Richmond pursue a mid – island barrier along the Highway 99 – Knight Street corridor, as opposed to a dike along the No. 8 or the No. 7 Road alignments.

This is the preferred option from the City's social, economic and environmental perspectives as it effectively:

- eliminates most of the concerns raised by the farming community regarding the impacts upon agricultural practices in East Richmond, and
- adds a second level of defence to the City's flood protection.

Discussions with the BC Ministry of Transportation (MOT) about the Highway 99 - Knight Street Barrier have occurred several times over the course of the Strategy's preparation. As recently as June 6, 2006, MOT staff indicates that the concept is supportable. MOT would like a Multiple Account Evaluation that compares the various mid-island dike location options, factoring in aspects such as traffic delay costs based upon Provincial formulas. This request appears to be a result of new procedures by MOT and had not been identified by MOT staff in previous discussions. The Multiple Account Evaluation has been accommodated in the Implementation Program.

***Note**: In the most recent City-MOT discussions, MOT has introduced the idea of combining the proposed Highway 99 - Knight Street mid-island barrier and other identified mid-island dike option evaluations, with overall road improvement evaluations, including possible No 8 Road improvements to the FRPA lands.*

City staff have indicated to MOT, the City's position:

- *not to have a mid-island dike along No 8 Road, and*
- *to improve access to the FRPA lands by:*
  - *a new Highway 99/Blundell Road interchange, and*
  - *Blundell Road improvements between Highway 99 and the FRPA lands.*

As directed by Council, City staff will continue to advise MOT of Council's preferences as the Highway 99 - Knight Street mid-island barrier is explored and as current MOT FRPA access road studies are finalized.

It is estimated construction cost of the Highway 99 – Knight Street mid island barrier is:

- $16 million for construction, and
- $100,000 for the Multiple Account Evaluation required by MOT).

It is recommended that:

- this barrier be constructed now, subject to senior government and stakeholder cost sharing, and
- staff (Engineering) be directed to seek senior government and stakeholder cost sharing.

If The Barrier Is Not Built

If the proposed Highway 99 / Knight Street mid island barrier is not built:

- the Habitable Flood Construction Level (FCL) would need to be 3.5 m GSC, for the whole City, and
- there would be no second line of flood defence.

If Barrier Is Built

Based on the proposed Highway 99 / Knight Street mid island barrier, the FCL will be less than 3.5m GSC for areas to the west of the barrier. Areas to the east will be 3.5 m GSC.

4. Covenants
   - Begin requiring Flood Covenants, including indemnity clauses, for all discretionary development applications (e.g., subdivision, rezoning, development permits).

5. Floodplain Bylaw

The following actions are recommended:

(1) Preparing an Interim Floodplain Bylaw** in 2006,

- It is recommended that the Interim Floodplain Bylaw be prepared now.
- This involves:
  - preparing the Bylaw based on existing studies,
  - establishing new building flood construction elevations,
  - $10,000 (est.) for legal input to prepare a Floodplain Bylaw and flood covenants with indemnification for the City.
- The funding source for this work is proposed to be from the 2006 General Contingency Account.
- The work would be led by Policy Planning with assistance from Engineering and Law.

(2) Preparing a Full Floodplain Bylaw:**, in 2007:

- It is recommended that work begin on preparing the full Floodplain Bylaw, in 2007.
- This involves:

a) Studies:

- $7,500 (est.) for legal costs,
- $5,000 (est.) for sea level rise / land subsidence research,
- $60,000 (est.) for additional modeling,
- $100,000 (est.) for floodplain mapping,

The funding sources for this work would be determined in the 2007 Budget.
The work would be led by Engineering with assistance from Policy Planning and Law.

b) Based upon these studies a full bylaw would be prepared with more accurate flood construction levels.

- Floodplain Mapping
  - A floodplain map best delineates the area that can be expected to flood, on average, once every, for example. 200 years. (If 1:200 years, it is called the 200-year flood.)
  - A flood can occur at any time in any given year;
  - The indicated flood level may be exceeded; and portions of the floodplain can flood more frequently.
  - Floodplain maps accurately show:
    - the location of the normal channel of a water course,
    - surrounding features or developments,
    - ground elevation contours,
    - flood levels, and
    - floodplain limits (the elevation and horizontal extent of the high water marks of a, say, 200-year flood).
  - Flood Level Isograms
    - Within the floodplain, flood level isograms show the water elevation during a, say 200-year flood.
    - The maps may also include the 20-year flood level, which is used in applying Health Act requirements for septic tanks.
    - A flood level isogram is a line which spans the floodplain, plotting the location at which the floodwater is expected to reach the indicated elevation.
    - The elevation of floodwater between each isogram can be interpolated.

- Both Bylaws involve implementing a planned approach to increasing the overall land grades in the urban portions of the City (cost to be determined and borne by the development community).

** Note that a distinction is being made between preparing an Interim Floodplain Bylaw versus a Full Floodplain Bylaw.

- Interim Floodplain Bylaw
  - MOE staff have indicated that the modeling work done as part of the Strategy's development, plus the previous work undertaken by Hay and Company, is sufficient to develop an Interim Bylaw based upon a mid-island barrier along the Highway 99 / Knight Street corridor.
  - Considerable work is required in preparing an Interim Bylaw (e.g., determination of exemptions, establishment of a 2.6 m flood construction level in the former 0.9 m Urban Exempt Area, consultation with the public and development community).

- Full Floodplain Bylaw
  - For a Full Floodplain Bylaw, City Staff have been advised by MOE that additional breach modeling will be required to determine the new flood construction elevations. This extra level of work was not undertaken by UMA Consulting as their modeling work was largely completed prior to the changes in Provincial legislation and no internal decision had yet been made in selecting one mid-island dike option over another.
  - The modeling analysis was primarily oriented toward evaluating the various mid island dike options.
  - The derived flood construction elevations can vary significantly between options, since the location of the mid island dike has an impact upon the depth of potential flooding in the event of a breach.
  - Sea level rise would also need to be incorporated into the modeling work.

Prepared by the City Of Richmond

Summary of Strategy Implementation Program Costs Based on the 2006-2031 Flood Protection Management Strategy					
2006		**2007**		**2008 – 2031**	
Short term		**Medium Term**		**Now and Longer term**	
Action	**Cost**	**Action**	**Cost**	**Action**	**Cost**
Planning					
		1. Highway 99/ Knight Street Mid Island Barrier Study - Led by Engineering - Source: TBD in the 2007 budget	$100,000	TBD	TBD
		2. Computer Modeling of 4 Dike Breach Scenarios - Led by Engineering with assistance from Policy Planning - Source: determined in the 2007 budget.	$60,000		
Bylaw Related Actions					
1. Interim Floodplain Bylaw - legal advice - Led by Planning with assistance from Engineering and Law. - Source: 2006 General Contingency Account	$10,000	3. Floodplain Mapping - Led by Engineering with assistance from Policy Planning. - Source: TDB in the 2007 budget.	$100,000	TBD	TBD
		4. Full Floodplain Bylaw FCL and covenants - Led by Engineering, with assistance from Policy Planning and Law. - Source: TBD in the 2007 budget.	$7,500		
Dikes					
		5. Sea level, Subsidence Study - Led by Engineering. - Source: TBD in the 2007 budget	$5,000		
				6. Mid Island Barrier construction (2006 dollars) - Led by Engineering. - Source: TBD in the 2007 budget - Subject to senior government and stakeholder cost sharing.	$16 million
	$10,000		$272,500		+ $16 million

NOTE: Funding for items TBD, by City:

- through cost sharing negations with senior government and stakeholders, and
- based on available City funding.

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