BGC Project Memorandum

To: CANHUG
Attention: Meeting Participants

From: Kris Holm, BGC Engineering
Date: Jan 11, 2012
Subject: Informal Presentation, Chilliwack Flood Risk Assessment

This presentation provides an informal overview of a 2007-2008 flood risk assessment for the City of Chilliwack, including the assessment of damage and loss for three potential dike breach scenarios. This work formed an early Hazus – like approach to flood consequence assessment in British Columbia.

A flood frequency analysis was completed for the section of the Fraser River adjacent to Chilliwack. Generalized extreme value statistics were used to compute a frequency-magnitude relationship for return periods up to 1000 years. Three dike breach scenarios were modeled using MIKE FLOOD, based on design flood discharges estimated for the 1894 event. Dike breach locations were selected as the most likely flood defense failure locations, should a failure occur.

Direct consequence measures included a summary of estimated direct damage losses for buildings (organized by building type); identification of loss-of-use zones for critical facilities; damage potential maps for roads; agriculture and oil and gas distribution; and identification of zones of relatively higher human vulnerability. Detailed development data were used in combination with depth-damage curves sourced from HAZUS data inputs, to compute total direct losses, based on combined maximum flood values (maximum extent and depth) for the three dike breach scenarios. Combined maximum flood values were used as a conservative measure because the likelihood of breaches, either singly or in combination, is not known.

Approximately 10,000 buildings are located in non-Reserve areas inundated by the combined breaches for the design flood, corresponding to 43% of about 23,000 buildings within the study area. Of these, about 7,000 buildings are subject to maximum flood depths > 1 m above the estimated top floor elevation (which is the same as the first floor elevation for single story houses). Of these, 136 buildings have maximum flood depths exceeding minimum rooftop height, estimated as 3 m above the top floor. Estimated total building structure damage amounted to approximately $450 million, not including contents or inventory. These costs were based on 2006 BC Assessment building values; actual market replacement values would likely be higher.
Quantitative Flood Risk Assessment, Chilliwack, BC

BGC Engineering Inc.
Presentation Outline

• Introduction
  – Background: floods on the Fraser

• Chilliwack Flood risk assessment
  – Flood frequency analysis (UBC)
  – Hazard modeling
  – Flood Consequence Assessment

• Future directions
CHILLIWACK DIKES

Setback Dykes
Cattermole Dyke
Hope Slough Floodwall
East Dyke
Railway
Highway 1

Breach 1
Breach 2
Breach 3

East Dyke
Town Dyke
Island 22 Wing Dyke

CHILLIWACK DIKES
Flood of 1894:
Downtown Chilliwack

Source: BC Dairy Foundation (2007)
Flood of 1894

Mill Street, Chilliwack, during the flood of 1894.

Source: BC Dairy Foundation (2007)
130 years of Flood Mitigation in BC

Proposed Dykes - 1876 (not built until 1923)
Historic Flood Management in BC

• Late 1800’s and early 1900’s - settlement and diking

• After 1948 Flood
  – *Dike Maintenance Act* – provincial oversight of dikes and diking authorities
  – Fraser River Board – upstream storage studies
  – Fraser River Flood Control Program (diking) 1968 to 1994 - $300M 1994 dollars

• After 1972 Flood (damage in BC interior)
  – Floodplain Development Control Program (1975 to 2003)
  – Floodplain Mapping Program (1987 to 1994)
  – BC Diking Projects (i.e. Squamish dikes in 1980’s)
  – River Forecast Centre

• 1990’s to date
  – Funds for diking, floodplain mapping and land development control programs gradually discontinued
  – Fraser River model studies (1999 to 2006) – new flood profile
  – 2007 Freshet - Urgent Mitigative Flood Works - $30M
  – Fall 2007 funding announcement by Premier Gordon Campbell
1948 Flood

- Inundated ~22,000 hectares
- Numerous dyke breaches
- ~2000 homes destroyed

Source: BC Dairy Foundation (2007)
Greendale & Chilliwack from Sumas Mountain, June 7, 1948
Greendale (southwest study area)
Fraser Valley Flood Risk Increase Over Time

- **Flooded Properties**
  - 1894: ~10
  - 1948: ~100
  - ????: ~1,000
  - 10,000

- **Casualties**
  - 1894: ~1
  - 1948: ~10
  - ????: ~100
  - 1,000

The graph shows a significant increase in the number of flooded properties and casualties over time.
Design Event Limitation

Total Damage (B $)

Flood Return Period

Zone of Current Planning
"Risk analysis is a precursor to Flood Mitigation"

- Identified as high priority by office of Inspector of Dykes
- Primary focus of BGC’s pilot project
Project Objectives

1. Improve estimates of extreme flows
2. Model dyke breach scenarios
   - including extreme flows (500 & “1000” year)
3. Develop database of infrastructure at risk
4. Quantify damage and loss; estimate vulnerability
   - Percent damage, damage cost (buildings)
   - Potential damage (general infrastructure, agriculture)
   - Potential Life Loss (vulnerability)
   - Identification of loss of function of critical facilities
   - Indirect Economic loss due to severing of Highway 1

• Intended as pilot project
Stakeholders:

- City of Chilliwack,
- Ministry of Transportation,
- Ministry of Environment,
- Kinder Morgan,
- Terasen Gas,
- Fraser Basin Council
Estimating Extreme Flows

• Peak flow estimates for Fraser River at Hope
  – Analysis by Professor Harry Joe (UBC, Department of Statistics)

• Objectives:
  – Identify any long-term trends in flows
  – Improve estimates of peak flows in 1894 and 1948 at Hope
  – Improve flood frequency-discharge relationships for large flows
Extrem Flows and Trends

Fraser River at Hope

Peak Daily Discharge, 1912-2005

LONG TERM DECLINE FOR ALL FLOODS

BUT:
NO CHANGE FOR LARGE FLOODS (> 10,000 m³/s)
Incorporating Historical Water Levels

- Water levels at Mission are known as far back as 1876
- Using the correlation between Mission water levels and Hope flows (1912-1950) and taking into account changes in floodplain area, the Hope record is extended with an extra 20 years of data
Fraser River at Hope (1876 – 2005)

<table>
<thead>
<tr>
<th>Return period (years)</th>
<th>Peak flow (m$^3$/s) 95% confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10,600 – 11,700</td>
</tr>
<tr>
<td>200</td>
<td>13,400 – 17,200</td>
</tr>
<tr>
<td>1000</td>
<td>14,250 – 20,500</td>
</tr>
</tbody>
</table>

1948 flow estimate: 15,200 m$^3$/s
1894 flow estimate: 17,560 m$^3$/s
Maximum Water Depth (86hrs after breach)
Design Flood Modelling, Breach 2: East Dike

Maximum Water Depth (56hrs after breach)
Design Flood Modelling, Breach 3: West Dike

Maximum Water Depth (28hrs after breach)
### Consequence Assessment Summary

#### Elements at Risk

| Identification and Valuation of Buildings, Infrastructure, and Population Exposed to Flood Hazard |

#### Vulnerability

| Relations between flood extent, depth and damage |

#### Consequence

- Percent damage (buildings)
- Damage cost (buildings)
- Potential damage (general infrastructure, agriculture)
- Potential Life Loss (vulnerability)
- Identification of loss of function of critical facilities
- Indirect Economic loss due to severing of Highway 1
Data Sources

• BC Assessment Office
  – Building Locations and Assessed Values
• Canadian Census
  – Population and Building Counts
  – Census Blocks (geographic unit used to summarize results)
• M.O.T., City of Chilliwack
  – Roads
• Kinder Morgan
  – Pipeline infrastructure
• Terasen Gas
  – Gas distribution network
• Fraser Health
  – Critical Health Facilities
• BC Dairy, Abbotsford Agricultural Office
  – Livestock Data
• Dun and Bradstreet (D&B)
  – estimates of revenues and employment of each business in the Chilliwack area.
**Depth-Damage: Buildings**

*(Damage-Loss Functions)*

- Relate Flood Depth to Depreciated Replacement Cost
- Sourced from Hazus input data

<table>
<thead>
<tr>
<th>Flood Depth (m)</th>
<th>Percent Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>1</td>
<td>25%</td>
</tr>
<tr>
<td>2</td>
<td>50%</td>
</tr>
<tr>
<td>3</td>
<td>75%</td>
</tr>
<tr>
<td>4</td>
<td>90%</td>
</tr>
<tr>
<td>5</td>
<td>95%</td>
</tr>
<tr>
<td>6</td>
<td>99%</td>
</tr>
<tr>
<td>7</td>
<td>100%</td>
</tr>
</tbody>
</table>

- **Average Residential, one floor, no basement**
- **Average Residential, one floor, with basement**
- **Average retail, no basement**
- **Average apartment, living area on one floor**
DATA SIMPLIFICATION (Buildings)

13,000 Buildings on Floodplain (approx) → Summed/Block → 471 Census Blocks on Floodplain

262 BC Assessment Building Classes → Grouped → 44 Hazard Assessment Building Classes

457 Building Damage Function Classes → Grouped → 44 Average Building Damage Function Classes
Loss Estimation: General Building Stock (Combined Design Floods Scenario)

Flood Depth Grid Overlay

Census Block

Loss Curves

% Damage

BC Assessment

Building Values

\[ \sum \text{\$ Damage Area} \]

Tabulated Summary
Assessed value: $1.7 billion
Loss total: $800 million
Vulnerability, Critical Facilities

Chilliwack Hospital

Breach 1

Vulnerability estimate:

“loss of function” (water depth threshold exceedence)
Transportation & Oil/Gas Infrastructure

- Flood extent, depth in relation to infrastructure
Agriculture

- Flood extent in relation to crop type
Economic Loss (BC Stats)

- **Objectives:**
  - Economic impact to Chilliwack businesses
  - Economic impact to outside economy due to severing Highway 1 and railways

- **Data:**
  - Dunn and Bradstreet economic data (Chilliwack)
  - Economic data for rail and truck cargo, Vancouver port input/output, tourism and service volumes
  - Assumed percent loss of function

- **Results (preliminary):**
  - Canadian economy: ~$20M/day (x 10 days transportation loss)
  - Chilliwack economy: ~$6.5M/day
Many complex models depend on variables that are difficult or impractical to collect.
Vulnerability to Loss of Life

- Identify areas with greatest relative human vulnerability
- Relative vulnerability matrix based on inundation depth & velocity
- Two Population groups:

<table>
<thead>
<tr>
<th>Max flood depth (m)</th>
<th>Max water velocity (m/s)</th>
<th>Inside buildings</th>
<th>Outside buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>Lower</td>
<td>Lower</td>
</tr>
<tr>
<td>&gt; 1</td>
<td>Higher</td>
<td>Higher</td>
<td>Higher</td>
</tr>
</tbody>
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3.3 m

Top floor

First floor

4.3 m

Higher Vulnerability

Lower Vulnerability
Vulnerability Inside Buildings
Summary and Future Directions

- Further flood hazard modeling of dyke overtopping
- Refinement of loss estimates based on stakeholder input
- Expand model to other regions