Assessing Climate Change Risk to Stormwater & Wastewater Infrastructure
Welland, Ontario
August 18, 2014 American Public Works Association Congress

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Peter Nimmrichter, P.Eng., AMEC Environment & Infrastructure, Burlington, Ontario

Presentation Overview

1. Acknowledgments & Project Partners
2. Study Objectives & Purpose
3. Study Area
4. The PIEVC Protocol
5. City of Welland Storm & Wastewater (Combined) System
6. Climate Variables
7. Intensity – Duration – Frequency Rainfall Relationship Update
8. Risk Assessment
10. Next Steps
11. Assessment of an Updated Storm Drainage Design Standard

1. Acknowledgments & Project Partners
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Co-Authors:
Ron Scheckenberger, AMEC Environment and Infrastructure (Burlington, ON)
Peter Nimmrichter, AMEC (Mississauga, ON)
Ben Harding, AMEC (Boulder, CO)

Project Partners

Total project funding - $120,000

- Engineers Canada - $40,000
- Ministry of Environment - $30,000
- WaterSmart Niagara - $50,000

2. Study Objectives & Purpose
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- Engineers Canada is assessing vulnerability issues and adaptation approaches for Canadian infrastructure in four (4) categories:
  - Buildings
  - Roads
  - Stormwater and wastewater systems
  - Water resources.
- Welland’s storm and wastewater (combined) system was selected as a case study to add to the National data base.
- Additional investigation of updating Welland’s Intensity – Duration – Frequency (IDF) rainfall information.
- Climate change to be considered when constructing new assets.

3. Study Area

- Ontario
- New York City of Welland Urban Boundary (approximate)
3. Study Area

Welland Canal

4. The PIEVC Protocol

National Protocol developed through Engineers Canada
- Public Infrastructure Engineering Vulnerability Committee (PIEVC) formed to develop protocol to assess Canadian infrastructure at risk from Climate Change
- First protocol established in 2005, (Version 9) applied in the study
- Current protocol is Version 10

Adapting to Climate Change
Canada’s First National Engineering Vulnerability Assessment of Public Infrastructure
AMEC 2008
4. The PIEVC Protocol

1. Infrastructure of interest?
2. Do we have data?
3. Loads and impacts?
   2020 & 2050
4. More analyses required?
5. Recommendations

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Step 1 – Project Definition

- Infrastructure Details
- Site Setting
- Climate Overview

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Step 2 – Data Gathering

- Judgment on Significance
- Judgment on Likelihood
- Judgment on Response
- Judgment on Uncertainty
- IDF analyses
5. City of Welland Storm & Wastewater (Combined) System

Assessing Climate Change Risk to Stormwater and Wastewater Infrastructure 2014 APWA Congress

Infrastructure by Age

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Infrastructure by Condition

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<table>
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<tr>
<th>Descriptor</th>
<th>Storm</th>
<th>Sanitary/Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Pipes</td>
<td>1,717 (laterals)</td>
<td>17,101 (laterals)</td>
</tr>
<tr>
<td></td>
<td>2,906 (mains)</td>
<td>3,789 (mains)</td>
</tr>
<tr>
<td>Total Length</td>
<td>186 km</td>
<td>206 km</td>
</tr>
<tr>
<td>Maximum Size</td>
<td>3,000 mm</td>
<td>2,700 mm</td>
</tr>
<tr>
<td>Minimum Size</td>
<td>150 mm</td>
<td>125 mm</td>
</tr>
<tr>
<td>Average Age of Pipes</td>
<td>30 years</td>
<td>42 years (sanitary)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>66 years (combined)</td>
</tr>
<tr>
<td>Oldest Pipes</td>
<td>106 years</td>
<td>111 years (sanitary)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>110 years (combined)</td>
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6. Climate Variables

The Long List of Variables:
- High/Low Temperature
- Heat & Cold Waves
- Extreme Diurnal Temperature Variability
- Freeze Thaw Cycles
- Heavy Rain
- Daily Total Rainfall
- Winter Rain
- Freezing Rain
- Ice Storm
- Snow Accumulation
- Blowing Snow/Blizzard
- Lightning
- Hail Storm
- Hurricane/Tropical Storm
- High Winds
- Tornado
- Drought/Dry Period
- Heavy Fog

How might these variables change in the future ... 2020 & 2050?
6. Climate Variables

**Assessing Climate Change Risk to Stormwater and Wastewater Infrastructure** 2014 APWA Congress

**Climate Normals**
- 1961 – Existing IDF
- 2000 – Available IDF
- 2020 – Projected IDF
- 2034–2064

**Projected IDF**
- 2050 – Projected IDF

**Available Short Duration Rainfall Data**

**Climate Variables**

**General Outcomes**
- PIEVC protocol, premise based on two future time frames 2020 & 2050
- Number of days/yr with temperature exceeding 35 deg °C to remain same through 2020 but increase by 4 times through 2050
- Number of days/yr with temperature below -20 deg °C to decline through 2050
- Occurrence of heat waves to hold through 2020 with slight increase through 2050
- Days/yr of freeze/thaw cycles to decline
- Total rainfall & severity of rain events expected to increase
- Occurrence of drought/dry periods expected to double through 2020
7. Intensity – Duration – Frequency Rainfall Relationship Update

- IDF curves are used to determine storm sewer sizes
- Current City standards based on 1963 IDF data and 2 year return frequency
- Original 1963 IDF data was based on Buffalo weather data
- New IDF data based on Environment Canada data from Port Colborne weather station up to year 2000
7. Intensity – Duration – Frequency Rainfall Relationship Update

- 40 years of data available

- Output from 112 Global Climate Models used to project 2020 & 2050 IDF curves

- Comparison between 1963 Buffalo and the projected 2020 and 2050 IDF data revealed that 1963 was in fact quite conservative. This is explained by the location and difference in climate in Buffalo (extreme eastern end of the lake) versus Welland's more inland character and setting.

- What curve should be used? Further analysis required.

Source of uncertainty

- GCM uncertainty
- Observed data

Consider uncertainty when applying projected IDF data

- Top 10% of projections show large increases in precipitation
- Consider all sources of information. Where did info come from?
- Use your judgment!
8. Risk Assessment

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Risk assessment was performed by a team of specialists to evaluate potential risks related to climate change.

Qualitative assessment based on professional judgment and experience used to determine the likely effect of individual climate events on individual components of the infrastructure.
## 8. Risk Assessment

Focused on interactions (between climate and infrastructure) requiring further assessment

Numerically assess:

- **Total load on infrastructure** = Current load + Projected change in load due to climate change + Projected change in load due to other factors
- **Total capacity of infrastructure** = Existing capacity + Projected change in capacity due to aging/use + Projected change in capacity due to other factors

From this assessment:

- **Vulnerability exists** when Total Load > Total Capacity
- **Adaptive Capacity exists** when Total Load < Total Capacity

### Parameter Notation Value

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<thead>
<tr>
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<th>Notation</th>
<th>Value</th>
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<tr>
<td>existing load</td>
<td>LE</td>
<td>100</td>
</tr>
<tr>
<td>anticipated climate change load</td>
<td>LC</td>
<td>20</td>
</tr>
<tr>
<td>other change loads</td>
<td>LO</td>
<td>0</td>
</tr>
<tr>
<td>total load</td>
<td>LT</td>
<td>120</td>
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<tr>
<td>existing capacity</td>
<td>CE</td>
<td>64</td>
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<tr>
<td>projected change in capacity due to aging/use</td>
<td>CM</td>
<td>15</td>
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<td>additional capacity</td>
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<td>project total capacity</td>
<td>CT</td>
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<td>vulnerability ratio</td>
<td>VR</td>
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<td>capacity deficit</td>
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### Categories

1. Remedial engineering or operations action required *(Adjust sewer design standard)*
2. Management action required *(More infrastructure funding)*
3. Additional study or data required *(what IDF curve to use?)*
4. No further action required

ASAP Recommendation Highlights

1. Evaluate the implications of using revised IDF curves for storm sewer design, 1963 vs. P.C. 2000 and projected 2020 & 2050

2. Evaluate implications of revising storm design standard from the current 2 year to 5 or 10 year

10. Next Steps
10. Next Steps

1. Final Study Report has been made available on City of Welland website

2. Welland Study results added to the Engineers Canada national database of case studies


4. WaterSmart Niagara - study referred to in the “Adapting to Climate Change: Challenges for Niagara” report

5. City of Welland advancing higher priority ‘ASAP’ & ‘Short Term’ recommendations, including:
   - IDF & drainage design standard review
   - Pollution Control Plan Update
   - Development of a City wide sanitary sewer model

11. Assessment of an Updated Storm Drainage Design Standard

Project Objectives

- Update the projected IDF relationships incorporating new rainfall data
- Assessment of the influence of the various new IDF rainfall relationships on the design of stormwater management end-of-pipe systems and conveyance systems
- Assessment of a shift in the current municipal design criteria (2 year) for sizing of storm sewers to a 5+ year return period
Comparison of 1963 IDF Data with 2012 IDF Data

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<th>Duration</th>
<th>Return Interval, Years</th>
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<th>5</th>
<th>10</th>
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<td>12.0%</td>
<td>15.2%</td>
</tr>
<tr>
<td>10 min</td>
<td>4.5%</td>
<td>9.3%</td>
<td>11.8%</td>
<td>12.6%</td>
<td>13.5%</td>
<td>9.3%</td>
<td>11.8%</td>
</tr>
<tr>
<td>5 min</td>
<td>0.2%</td>
<td>0.7%</td>
<td>0.7%</td>
<td>0.7%</td>
<td>0.7%</td>
<td>0.7%</td>
<td>0.7%</td>
</tr>
<tr>
<td>1 hr</td>
<td>1.1%</td>
<td>3.2%</td>
<td>2.8%</td>
<td>2.7%</td>
<td>2.6%</td>
<td>3.2%</td>
<td>2.8%</td>
</tr>
<tr>
<td>10 min</td>
<td>-0.9%</td>
<td>-1.1%</td>
<td>-2.0%</td>
<td>-2.0%</td>
<td>-2.0%</td>
<td>-1.1%</td>
<td>-2.0%</td>
</tr>
<tr>
<td>5 min</td>
<td>-6%</td>
<td>-2%</td>
<td>-1%</td>
<td>-6%</td>
<td>-6%</td>
<td>-6%</td>
<td>-6%</td>
</tr>
</tbody>
</table>

Comparison of 1963 IDF Data with Projected 2012 IDF Data

Indicates 2012 IDF data > 1963 IDF data

11. Assessment of an Updated Storm Drainage Design Standard

Influence IDF Relationships on Design

- Proposed 25 lot residential development
- Stormwater infrastructure includes quantity control facility (pond) and storm sewer network (separated)
- Designed to current City of Welland municipal IDF relationship
- Performance and design evaluated using projected Intensity-Duration-Frequency relationship for 2020 and 2050 as one means of identifying vulnerability
### 11. Assessment of an Updated Storm Drainage Design Standard

#### Existing SWM Pond Performance with Alternate Rainfall

<table>
<thead>
<tr>
<th>Pond Maximum Level (m)</th>
<th>2020</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Period (yrs)</td>
<td>2010</td>
<td>2010 Mean</td>
</tr>
<tr>
<td>2</td>
<td>183.85</td>
<td>-0.11</td>
</tr>
<tr>
<td>5</td>
<td>184.09</td>
<td>-0.11</td>
</tr>
<tr>
<td>10</td>
<td>184.13</td>
<td>-0.09</td>
</tr>
<tr>
<td>25</td>
<td>184.21</td>
<td>-0.09</td>
</tr>
<tr>
<td>50</td>
<td>184.26</td>
<td>-0.09</td>
</tr>
</tbody>
</table>

#### Existing SWM Pond Performance with Alternate Rainfall

<table>
<thead>
<tr>
<th>Pond Maximum Volume (m³ - %)</th>
<th>2020</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Period (yrs)</td>
<td>2010</td>
<td>2010 Mean</td>
</tr>
<tr>
<td>2</td>
<td>1350</td>
<td>81%</td>
</tr>
<tr>
<td>5</td>
<td>1437</td>
<td>99%</td>
</tr>
<tr>
<td>10</td>
<td>1507</td>
<td>102%</td>
</tr>
<tr>
<td>25</td>
<td>1618</td>
<td>104%</td>
</tr>
<tr>
<td>50</td>
<td>1730</td>
<td>105%</td>
</tr>
<tr>
<td>100</td>
<td>1831</td>
<td>106%</td>
</tr>
</tbody>
</table>

#### Revised SWM Pond Design with Alternate Rainfall

| Comparison of SWM Facility Designs based on Alternate Design Rainfall |
|--------------------------|------------------|------------------|------------------|
| **Current Standard**     | 1.583            | 0.421            | 184.08           | 1831.6          | ----          | ----          |
| 2010                     | 1.618            | 0.426            | 184.09           | 2198.7          | 367.1         | 20%           |
| 2012                     | 1.598            | 0.425            | 184.08           | 2299.7          | 468.1         | 26%           |
| 2020 - Maximum           | 1.884            | 0.423            | 184.08           | 3280.4          | 1448.8        | 79%           |
| 2020 – 90th Percentile   | 1.716            | 0.426            | 184.08           | 2652.1          | 820.5         | 45%           |
| 2020 - Mean              | 1.658            | 0.432            | 184.08           | 2428.3          | 596.7         | 33%           |
### 11. Assessment of an Updated Storm Drainage Design Standard

#### SWM Pond Costs with Alternate Designs

<table>
<thead>
<tr>
<th>IDF</th>
<th>Facility Bottom Area (m²)</th>
<th>Facility Top Width (m)</th>
<th>Facility Top Length (m)</th>
<th>Land Required (m²)</th>
<th>Additional Land Required (m²)</th>
<th>Land Construction</th>
<th>Additional Construction Cost ($)</th>
<th>Total Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1537 24.4 103.7 2013.8</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>1537 24.4 126.9 2173.7</td>
<td>75.8 57.6</td>
<td>61.8 1.8</td>
<td>61.8 1.8</td>
<td>61.8 1.8</td>
<td>61.8 1.8</td>
<td>61.8 1.8</td>
<td>61.8 1.8</td>
</tr>
<tr>
<td>3</td>
<td>2010 1850 24.4 122.8 2996.4</td>
<td>465.7 18%</td>
<td>235.8 12%</td>
<td>235.8 12%</td>
<td>235.8 12%</td>
<td>235.8 12%</td>
<td>235.8 12%</td>
<td>235.8 12%</td>
</tr>
<tr>
<td>4</td>
<td>2010 1950 24.4 128.9 3145.2</td>
<td>614.5 24%</td>
<td>358.3 17%</td>
<td>358.3 17%</td>
<td>358.3 17%</td>
<td>358.3 17%</td>
<td>358.3 17%</td>
<td>358.3 17%</td>
</tr>
<tr>
<td>5</td>
<td>2020 - Maximum 2800 24.4 180.7 4409.9</td>
<td>1879.1 74%</td>
<td>1131.1 60%</td>
<td>1131.1 60%</td>
<td>1131.1 60%</td>
<td>1131.1 60%</td>
<td>1131.1 60%</td>
<td>1131.1 60%</td>
</tr>
<tr>
<td>6</td>
<td>2020 – 90th Percentile 2250 24.4 147.2 3591.6</td>
<td>1060.8 42%</td>
<td>648.5 35%</td>
<td>648.5 35%</td>
<td>648.5 35%</td>
<td>648.5 35%</td>
<td>648.5 35%</td>
<td>648.5 35%</td>
</tr>
<tr>
<td>7</td>
<td>2020 - Mean 2050 24.4 135.0 3294.0</td>
<td>763.2 30%</td>
<td>462.0 25%</td>
<td>462.0 25%</td>
<td>462.0 25%</td>
<td>462.0 25%</td>
<td>462.0 25%</td>
<td>462.0 25%</td>
</tr>
<tr>
<td>8</td>
<td>2020 - Maximum 2950 24.4 189.9 4633.0</td>
<td>2102.3 83%</td>
<td>1261.4 70%</td>
<td>1261.4 70%</td>
<td>1261.4 70%</td>
<td>1261.4 70%</td>
<td>1261.4 70%</td>
<td>1261.4 70%</td>
</tr>
<tr>
<td>9</td>
<td>2020 – 90th Percentile 2450 24.4 159.4 3889.1</td>
<td>1358.4 54%</td>
<td>815.2 45%</td>
<td>815.2 45%</td>
<td>815.2 45%</td>
<td>815.2 45%</td>
<td>815.2 45%</td>
<td>815.2 45%</td>
</tr>
<tr>
<td>10</td>
<td>2020 - Mean 2150 24.4 141.1 3442.8</td>
<td>912.0 36%</td>
<td>557.4 32%</td>
<td>557.4 32%</td>
<td>557.4 32%</td>
<td>557.4 32%</td>
<td>557.4 32%</td>
<td>557.4 32%</td>
</tr>
</tbody>
</table>

**Notes:**
1. The cost of the additional land required is based at $150 per square metre.
2. Construction costs estimated as $65 per cubic metre including excavation, landscaping and surface treatment.

#### Change in the Municipal Design Standard

- The general expectation of extreme rainfall in southern Ontario suggests less days with rain but larger rainfall events when they do occur.
- The current 100 year rain will become the future 50 year rain, the current 10 year rain will become the future 5 year rain, and so on.
- A change to a less frequent return period design rainfall may be considered good engineering judgment and a means of ensuring adequate performance of newly designed stormwater infrastructure.
11. Assessment of an Updated Storm Drainage Design Standard

Change in the Municipal Design Standard

- Proposed 25 lot residential development
- Sewer network of 6 pipes over a linear length of about 300m
- Designed to current City of Welland municipal IDF relationship

**Brookhaven Estates**

Approximate Limit of Brookhaven Estates

- Proposed 25 lot residential development
- Sewer network of 6 pipes over a linear length of about 300m
- Designed to current City of Welland municipal IDF relationship

**Webber Estates**

- Proposed 102 lot residential development
- Sewer network of 40 pipes ranging in size from 200 mm to 1200 mm diameter
- Designed to current City of Welland municipal IDF relationship

**Storm Sewer Design Summary – Brookhaven Estates**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Current</th>
<th>Design</th>
<th>EC</th>
<th>IDF</th>
<th>90th Percentile</th>
<th>EC</th>
<th>IDF</th>
<th>Mean</th>
<th>IDF</th>
<th>Maximum</th>
<th>IDF</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>Pipe Sizes (mm) and Costs based on a 2 Year Design Rainfall</td>
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<td></td>
</tr>
<tr>
<td>% of Original Cost</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>124%</td>
<td>100%</td>
<td>100%</td>
<td>124%</td>
<td>111%</td>
<td>100%</td>
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</tr>
<tr>
<td>Pipe Sizes (mm) and Costs based on a 5 Year Design Rainfall</td>
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</tr>
<tr>
<td>Total Pipe Cost</td>
<td>$32,069</td>
<td>$32,069</td>
<td>$32,069</td>
<td>$35,102</td>
<td>$35,102</td>
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<tr>
<td>% of Original Cost</td>
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<td>113%</td>
<td>113%</td>
<td>124%</td>
<td>124%</td>
<td>113%</td>
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<td>124%</td>
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</tr>
<tr>
<td>Pipe Sizes (mm) and Costs based on a 10 Year Design Rainfall</td>
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</tr>
<tr>
<td>% of Original Cost</td>
<td>124%</td>
<td>124%</td>
<td>124%</td>
<td>124%</td>
<td>124%</td>
<td>124%</td>
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<td>124%</td>
<td>124%</td>
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<tr>
<td>Pipe Sizes (mm) and Costs based on a 25 Year Design Rainfall</td>
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<tr>
<td>Total Pipe Cost</td>
<td>$35,102</td>
<td>$35,102</td>
<td>$35,102</td>
<td>$45,144</td>
<td>$41,310</td>
<td>$35,102</td>
<td>$45,144</td>
<td>$42,142</td>
<td>$41,310</td>
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<tr>
<td>% of Original Cost</td>
<td>124%</td>
<td>124%</td>
<td>124%</td>
<td>159%</td>
<td>146%</td>
<td>124%</td>
<td>159%</td>
<td>149%</td>
<td>146%</td>
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</table>
11. Assessment of an Updated Storm Drainage Design Standard

<table>
<thead>
<tr>
<th>Feature</th>
<th>Current</th>
<th>2010</th>
<th>2012</th>
<th>2020</th>
<th>2050</th>
<th>2010</th>
<th>2020</th>
<th>2050</th>
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<tr>
<td>Storm Sewer Design Summary – Webber Estates</td>
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<td></td>
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<tr>
<td>Cost based on a 2 Year Design Rainfall</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Total Pipe Cost</td>
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<td>$310,580</td>
<td>$333,125</td>
<td>$312,289</td>
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<td>$323,656</td>
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<tr>
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<td>100%</td>
<td>100%</td>
<td>107%</td>
<td>101%</td>
<td>100%</td>
<td>107%</td>
<td>104%</td>
<td>100%</td>
</tr>
<tr>
<td>Cost based on a 5 Year Design Rainfall</td>
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</tr>
<tr>
<td>Total Pipe Cost</td>
<td>$333,125</td>
<td>$325,733</td>
<td>$325,733</td>
<td>$333,125</td>
<td>$332,865</td>
<td>$333,125</td>
<td>$337,132</td>
<td>$333,125</td>
</tr>
<tr>
<td>% of Original Cost</td>
<td>107%</td>
<td>105%</td>
<td>105%</td>
<td>107%</td>
<td>107%</td>
<td>107%</td>
<td>109%</td>
<td>107%</td>
</tr>
<tr>
<td>Cost based on a 10 Year Design Rainfall</td>
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<td></td>
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<tr>
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<td>$333,125</td>
<td>$333,125</td>
<td>$333,125</td>
<td>$360,730</td>
<td>$333,125</td>
<td>$333,125</td>
<td>$368,218</td>
<td>$337,132</td>
</tr>
<tr>
<td>% of Original Cost</td>
<td>107%</td>
<td>107%</td>
<td>107%</td>
<td>116%</td>
<td>107%</td>
<td>107%</td>
<td>119%</td>
<td>109%</td>
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<tr>
<td>Cost based on a 25 Year Design Rainfall</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total Pipe Cost</td>
<td>$352,083</td>
<td>$352,083</td>
<td>$352,083</td>
<td>$369,752</td>
<td>$369,752</td>
<td>$360,730</td>
<td>$370,496</td>
<td>$369,752</td>
</tr>
<tr>
<td>% of Original Cost</td>
<td>113%</td>
<td>113%</td>
<td>113%</td>
<td>119%</td>
<td>119%</td>
<td>116%</td>
<td>119%</td>
<td>117%</td>
</tr>
</tbody>
</table>

Recommendations

• The City give consideration to adopting the Environment Canada 2012 IDF relationship at minimum for design of SWM facilities
• The City give consideration to adopting either the 2020 Mean or the 2050 Mean IDF relationship as the new rainfall design basis for the City
• The City give consideration to adopting a 10 year design standard
• The City adopt a minimum freeboard requirement
• The City adopt a requirement for emergency overflows above the 100 year level for SWM facilities
• The City adopt a maximum allowable pipe flow restriction
• The City adopt a standardization of pipe sizes for flow computation

Contact Information

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Infrastructure Services - Engineering Division
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1100, 180 Elgin St
Ottawa, ON
Canada K2P 2K3
Tel: 613-232-2474 x 240
Email: david.lapp@engineerscanada.ca
Assessing Climate Change Risk to Stormwater & Wastewater Infrastructure
Welland, Ontario
August 18, 2014 American Public Works Association Congress

Thank you … Questions …

Climate Change Risk Assessment for Adaptation Planning and Implementation Workshop
August 20, 2014 8:30 – 10:45am American Public Works Association Congress

YOU PLAN FOR IT…THEN IT HAPPENS
A Flood Control District’s Reflection on the 2013 Colorado Floods

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
David Bennetts, P.E., CFM
Manager - Design, Construction, and Maintenance Program
Shea Thomas, P.E.
Project Manager, Master Planning Program
The Urban Drainage and Flood Control District works with local governments to address multi-jurisdictional drainage and flood control challenges in order to protect people, property, and the environment.
Master Planning – Develops watershed Master Plans and OSP’s, develops regional criteria and software, manages WQ activities including development and testing of regional BMP’s

Floodplain Management – Regional floodplain delineation and regulations, development review and master planning implementation, working with FEMA

Flood Warning Program – Develops regional flood warning plan including real-time forecasts and flood delineation, develops and manages the District’s GIS efforts

DCM – Program partners with local agencies to implement master planned improvements, and maintain regional drainage facilities

District Programs

1864 Flood

1912 Flood
1933 Flood

1965 Flood

- $2.95 Billion in Damages
- 21 deaths
Master Planning

267 major drainage basins
140+ master planning studies

Master Planning Goals

Reduce Flood Risks
With cost effective and safe public infrastructure

While promoting healthy streams

And recreation, active and healthy lifestyles, and educational opportunities.

Annual budget for master plans = $550,000
UDPCO funds up to 50%
Studies requested by local governments
Master Planning

- Baseline Hydrology
  - Rainfall amount
  - Land use
  - Soil type
  - Existing infrastructure

- Alternatives Analysis
  - Benefit-cost analysis
  - Recommended Plan
  - Selected Plan

- Conceptual Design
  - Proposed infrastructure
  - Cost estimate
  - Property acquisition

Hydrology

Hydrology
Conceptual Design

Two-Pronged Approach

Preservation

Mitigation
Mitigation

District Programs

2013 Flood

Average Annual Precipitation: 14.30”

Source: Colorado Water Conservation Board
Annual Precipitation

Fourmile Canyon Creek

Westerly Creek

Credits: Nolan Doesken, Colorado Climate Center; Denver Post
Construct Ponds

Expo Park

Jewell Wetlands

Kelly Road Dam

Westerly Creek Dam

Source: OMEGA
Twomile Canyon Creek

2013 Flood Damages

ESTIMATED DAMAGES COMPARISONS BY CITY

City of Aurora - $1,600,000

City of Boulder

<table>
<thead>
<tr>
<th>Damage Cause</th>
<th>Estimated Damage Amount</th>
<th>Estimated Number of Private Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater Infiltration</td>
<td>$60,394,401</td>
<td>3218</td>
</tr>
<tr>
<td>Flooding from Local Drainage</td>
<td>$71,640,776</td>
<td>1680</td>
</tr>
<tr>
<td>Sanitary Sewer Backup</td>
<td>$48,655,793</td>
<td>999</td>
</tr>
<tr>
<td>Flooding from Major Drainageway</td>
<td>$58,370,627</td>
<td>661</td>
</tr>
<tr>
<td>Other</td>
<td>$20,888,726</td>
<td>629</td>
</tr>
<tr>
<td>Total</td>
<td>$259,950,323</td>
<td>7186</td>
</tr>
</tbody>
</table>

2013 Flood Damages

- 18 counties, 11 qualified for Individual Assistance
- 200 miles of CO (north to south)
- 2,380 square miles
- 17,994 damaged homes
- 2,000 homes destroyed
- 10 fatalities
- 30 bridges destroyed
- 20 bridges damaged
- Estimated $2 to $3 billion in damages

Flood History - Totals

<table>
<thead>
<tr>
<th>DAMAGES</th>
<th>DEATHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. 2013 Flood – $1.3b (TBD)</td>
<td>2. Pueblo (1921) – 78</td>
</tr>
<tr>
<td>3. Pueblo (1921) – $1.1b</td>
<td>3. Bear Creek (1896) – 27</td>
</tr>
<tr>
<td></td>
<td>5. South Platte (1965) – 21</td>
</tr>
<tr>
<td></td>
<td>... 2013 Flood - 11</td>
</tr>
</tbody>
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THANK YOU!
www.udfcd.org

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
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Preparing for the Future, While Building on the Past
Toronto and Region Conservation Authority
Engineering

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2014 APWA International Congress & Exposition
Public Works Stormwater Summit
August 18, 2014

Outline
- Ontario’s Conservation Authorities
- Flood Risk Management
- Stormwater Management, Conservation Authority Context
- Climate Change
- What’s Next?

What is a Conservation Authority?
Government agencies dedicated to conserving, restoring, and managing natural resources on a watershed basis
Our vision is for a new kind of community, *The Living City*, where human settlement can flourish forever as part of nature’s beauty and diversity.

**Sound Conservation Principles**
1. Healthy Rivers and Shorelines
2. Regional Biodiversity
3. Sustainable Communities
4. Business Excellence

**TRCA’s Jurisdiction**
- Etobicoke Creek
- Mimico Creek
- Humber River
- Don River
- Highland Creek
- Rouge River
- Petticoat Creek
- Duffins Creek
- Carruthers Creek

The TRCA’s jurisdiction also extends into Lake Ontario to a point defined by the Territorial Divisions Act, R.S.O. 1980.

**Greater Toronto Area Population**
- 5.9 Million
- 4th largest city in North America
- 961 km² water-based
- 2,506 km² on land
- 3,467 km² (~ 850,000 acres)

**Regulatory Environment**
TRCA Engineering and Floodplain Management

- Regulatory Floodplain Mapping
- Technical modelling: hydrology, hydraulic, groundwater
- Water Management Policy
- Development Application Review & Permitting
- Research & Development
- Flood Forecasting and Warning

The Evolution of Floodplain Management

Pre-Hazel:
- Development Near Water

Infrastructure Era:
- Water Control and Conveyance

Floodplain Protection:
- Allow Natural Channel Process
  Build Outside Floodplain

Hurricane Hazel October 1954

60 Years Later
Thunderstorms (July-August)
Rain on Snow (December - February)
Hurricanes (August - October)
Spring Melt (March….if at all)

Flood Management

Floods Happen. Are You Ready?
www.trca.on.ca/flood

Flood Control Infrastructure

10 dams
15 flood control structures
1950’s – 1970’s construction
Are they still performing?
What is the long-term plan?
Real-Time Gauges

16 Stream
9 Precipitation
125+ Stations

www.trcagauging.ca

Flood Protection & Remedial Capital Works

Economic
Environmental
Social factors

Downtown Brampton SPA

Special Policy Area Comprehensive Flood Risk and Management Analysis

Flood Mitigation Feasibility Study
Flooding in Urban Areas

450+ Reported Erosion Sites

$30M Estimated Costs to Repair

Risk to Life and Property

Flooded Roads
Surcharged Sewers
Basement Flooding
Critical Infrastructure
Social Media

10 ways to wash your Ferrari!
The Evolution of Stormwater Management

Early 1980s:
Quantity Control

Early 1990s:
Quantity, Quality, Erosion

Today:
Treatment, Fisheries, Stream Morphology, Groundwater Protection

Stormwater Management

“Stormwater run-off is the single greatest factor affecting water quality and the health of our rivers” (TRCA Living City Report Card)
Poor Stormwater Management

- Stream bank erosion and bed degradation
- Increased peak flows - flooding
- Increase pollutant loading (including thermal impacts)
- Reduction of groundwater and baseflow
- Loss of aquatic habitat and natural features
- Risk to Infrastructure

Water Quality

2003-2007 RWQMN Median Values for Don River Stations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PWQO Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. coli (counts / 100 mL)</td>
<td>100</td>
</tr>
<tr>
<td>Chloride (mg/L)</td>
<td>150</td>
</tr>
<tr>
<td>Phosphorus (mg/L)</td>
<td>0.03</td>
</tr>
<tr>
<td>Total Suspended Solids (mg/L)</td>
<td>30</td>
</tr>
</tbody>
</table>

* Stations with less than 30 samples

Percent of Samples Exceeding PWQO Guidelines
WHERE WE ARE TODAY

- 77% of urban areas do not have adequate stormwater controls (mostly older areas that were developed prior to the required implementation of stormwater management controls)
- Over 800 SWM Ponds have been constructed
- Very few Source and Conveyance Controls (Low Impact Development)
End of Pipe Controls (SWM Ponds)

- Mitigates increased peak flows from urban areas (no volume control)
- Reduces pollutant loadings (does not provide thermal benefits)
- Currently the standard practice for stormwater treatment (usually the only practice employed in the “treatment train”)


- Mitigates impacts to hydrologic cycle and restores natural flow pathways and patterns (protection of aquatic and terrestrial habitat)
- Reduces generation of excess runoff volume (mitigates erosion and water quality impacts, including temperature)
- Addresses climate change (more resilient stormwater system)
- Opportunity to incorporate into new development and redevelopment
**Stormwater Management Criteria and Policy (2012 - 2014)**

**Goal:** That stormwater management effectively mitigate the impacts of urbanization on the natural water cycle (Water Balance Approach)

**Objectives:**
- To prevent increases in flood risk;
- To prevent undesirable geomorphic changes in watercourses;
- To protect water quality;
- To preserve groundwater and baseflow characteristics;
- To maintain an appropriate diversity of terrestrial and aquatic life and opportunities for human use.

**Stormwater Management Practices**

Impacts are mitigated through the implementation of Stormwater Management Practices consisting of:

- **Source Controls**
  - Porous Pavers
  - CWC / Infiltration Systems

- **Conveyance Controls**
  - Wet Pond

- **End-of-Pipe Controls**
  - Treatment Train Approach

**Stormwater Management Criteria Overview**

<table>
<thead>
<tr>
<th>SWM Objective</th>
<th>SWM Criteria</th>
<th>What's New</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flood Protection</td>
<td>Control Peak Flow to Pre-Development Levels for 2-100 year events</td>
<td>Need to assess impacts to Regulatory Storm as well as the 2-100 year design storms.</td>
</tr>
<tr>
<td>2. Erosion Protection</td>
<td>Mitigate increases in flow rates and volumes to protect watercourses from stream bank erosion</td>
<td>Need for volume control (site retention of stormwater through infiltration, evapotranspiration and/or reuse - LID). Minimum 5mm for small sites that do not require a detailed analysis.</td>
</tr>
<tr>
<td>3. Water Quality Control</td>
<td>Enhanced level of protection (80% TSS Removal MOE, 2003)</td>
<td>Need for thermal protection for coldwater species and the need for clean water (e.g. roof drainage) to wetlands.</td>
</tr>
<tr>
<td>4. Water Balance</td>
<td>Maintain Water Balance for Significant Recharge Areas and Ecologically Significant Areas (sensitive wetlands and woodlots)</td>
<td>This is relatively new criteria, need for LID in environmentally sensitive areas.</td>
</tr>
</tbody>
</table>
Stormwater Management Retrofit

For older areas that do not currently have Stormwater treatment, Stormwater retrofits are needed.

Toronto Wet Weather Flow Management Master Plan

Examples of Completed Retrofit Projects

- Terraview/Willowfield Park - Toronto
- Pioneer Park – Richmond Hill
- Earl Bales Park - Toronto

Multiple Benefits of Retrofits:
- Water Quality
- Flood Protection
- Erosion Protection
- Habitat
- Recreation
- Rainwater Reuse

Sustainable Neighbourhoods

- Implement big picture strategies at a local scale
- Accelerate uptake of sustainable practices and seek efficiencies in use of land and funds

Address urban retrofit challenges:
- Lack of trigger for deep change
- Many landowners, stakeholders
- Competing demands on limited land
- Technical constraints
- Attitudes, standards
- Cost, need business case
1. Implement Municipal Stormwater Retrofit Projects (e.g. Toronto Wet Weather Flow Management Plan and Municipal SWM Pond Retrofits such as Pioneer Park and Earl Bales Park)

2. Maintain existing stormwater management infrastructure (e.g. pond clean-outs)

3. Encourage existing communities to implement lot level controls on private property (e.g. SNAP Projects, rain gardens, rain barrels, etc.)

4. Ensure that all new developments (including redevelopments) are designed to comply with updated Stormwater Management Policies and Criteria

The Evolution of Climate Change in Watershed Management

- Pre-1990's: Business as Usual
- 1990's - Present: Incremental Changes to Engineering Practice
- Moving Forward: Risk-Based Management Acknowledging Uncertainty
IDF Curves – The Answer?

1. Climate models aren’t great with precipitation
2. Climate models don’t resolve thunderstorms
3. No standard methods for translating climate projections into IDF curves

Stormwater Design Uncertainties

- Design storms do not replicate local rainfall patterns
- Non-uniform rainfall
- Storm return period does not equal flood return period
- IDF events often ‘embedded’ in larger events
- Antecedent conditions
- Hydrologic modelling error

TRCA Jurisdiction
TRCA Jurisdiction

Humber River Watershed Development Scenarios
Existing (2002) = 26% Urban
Approved OP = 36% Urban
Full Build-Out = 49% Urban

April 10-20 1992 - Main Humber Upstream of Woodbridge

Even with detention, peak flows increase

Rainfall
Scenario 1
Scenario 2
Scenario 5
Design Storms vs Real Storms

Managing Risk
Dealing with Excess Runoff

Managing Risk
Addressing Vulnerable Locations
Managing Risk
Robust Design at Watershed Scale

The Next Big Thing? EROSION

Sound Conservation Principles
1. Healthy Rivers and Shorelines
2. Regional Biodiversity
3. Sustainable Communities
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Thank you

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