Assessing Climate Change Risk to Stormwater & Wastewater Infrastructure

Welland, Ontario

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Marvin Ingebrigtsen, & Erik Nickel (City of Welland)

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5. City of Welland Storm & Wastewater (Combined) System
6. Climate Variables
7. Intensity – Duration – Frequency Rainfall Relationship Update
8. Risk Assessment
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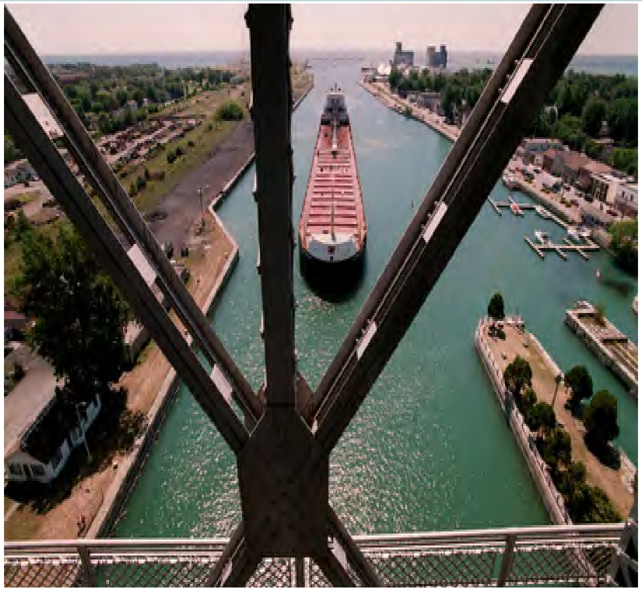
1. Acknowledgments & Project Partners



1. Acknowledgments & Project Partners

Co- Authors:

Ron Scheckenberger AMEC Environment and Infrastructure (Burlington, ON)
Peter Nimmrichter, AMEC (Mississauga, ON)
Ben Harding, AMEC (Boulder, CO)

Project Partners

Niagara Region

WaterSmart NIAGARA Implementing the Niagara Water Strategy

Niagara Water Strategy

engineerscanada

PIEVC CVIIP

Ontario MINISTRY OF THE ENVIRONMENT

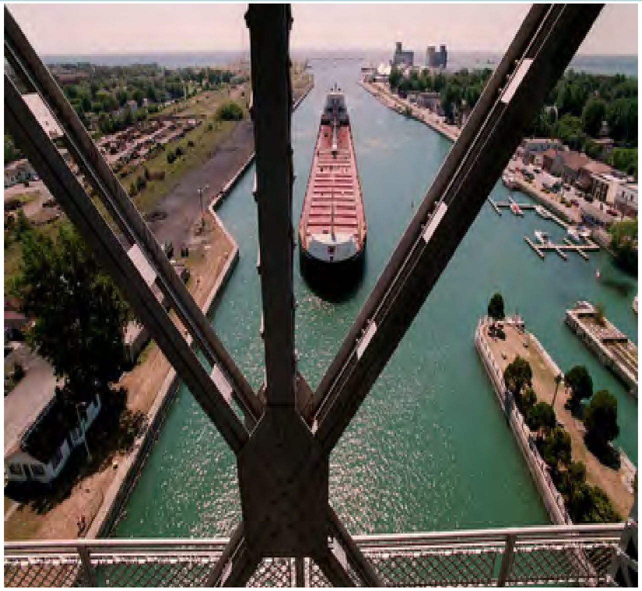
Environment Canada Environnement Canada

Great Lakes & St. Lawrence Cities Initiative
Alliance des villes des Grands Lacs et du Saint-Laurent

1. Acknowledgments & Project Partners

- $120,000 total project funding
- Engineers Canada (CCPE) - $40,000
- Ministry of Environment (MOE) - $30,000
- WaterSmart Niagara - $50,000

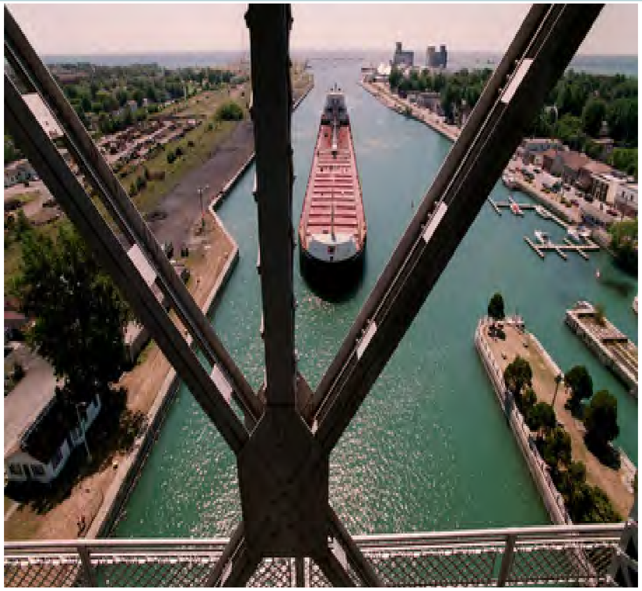
2. Study Objectives & Purpose



2. Study Objectives & Purpose

- 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 selected as a case study to add to the National data base.
- Additional investigation of updating Welland's Intensity – Duration – Frequency – Information for Rainfall.
- Faced with the prospect of ongoing sewer separation and aging infrastructure, Welland wanted to confirm that new assets are designed to an appropriate standard that would prevent obsolescence in the face of climate change.

3. Study Area



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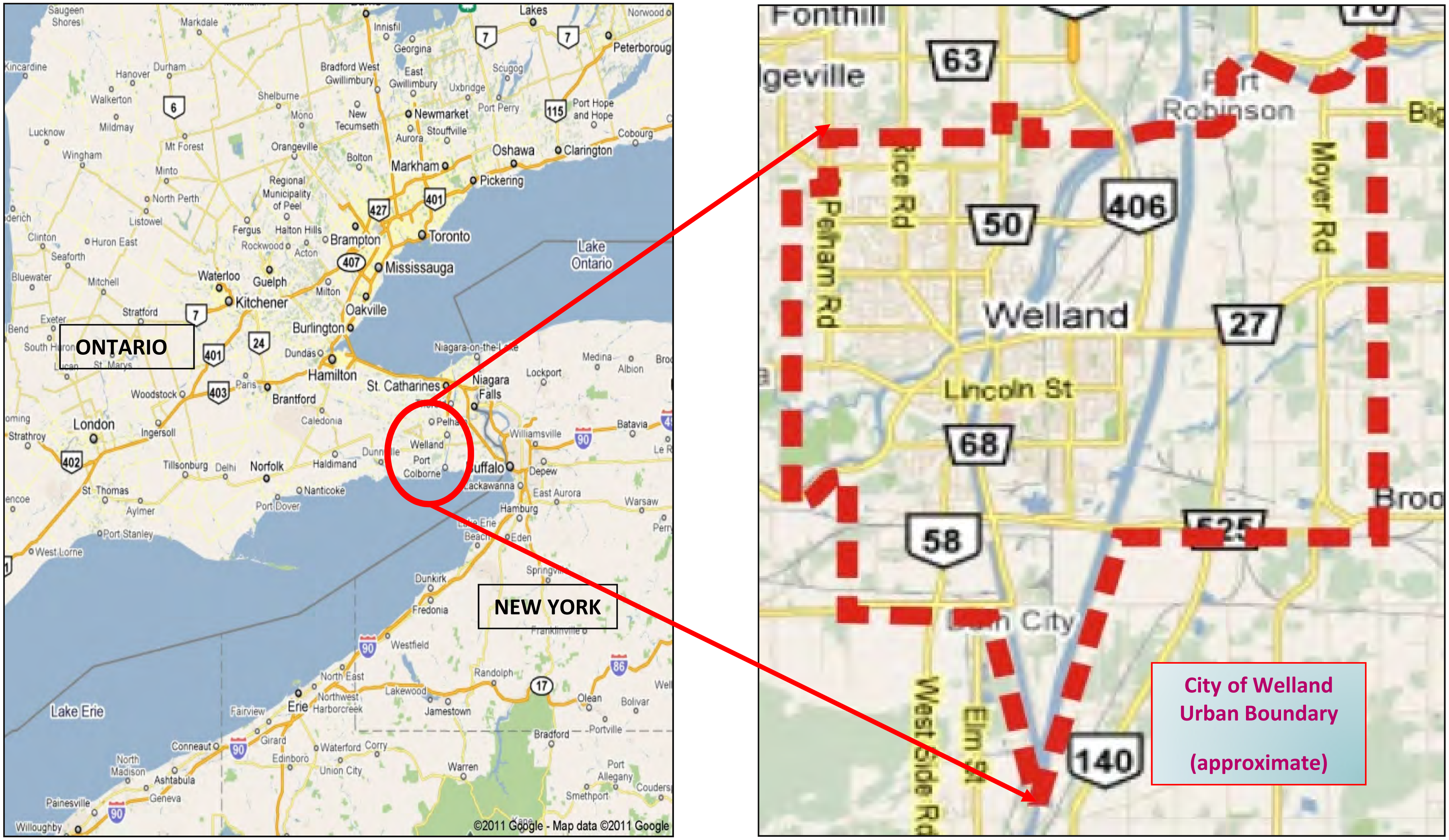
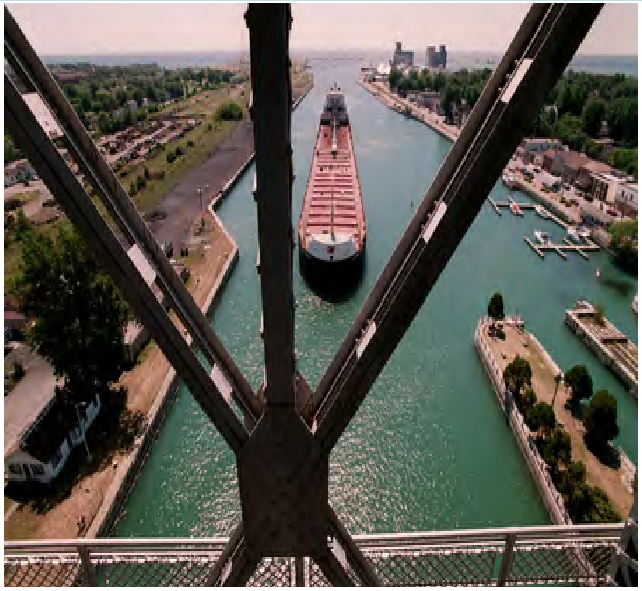
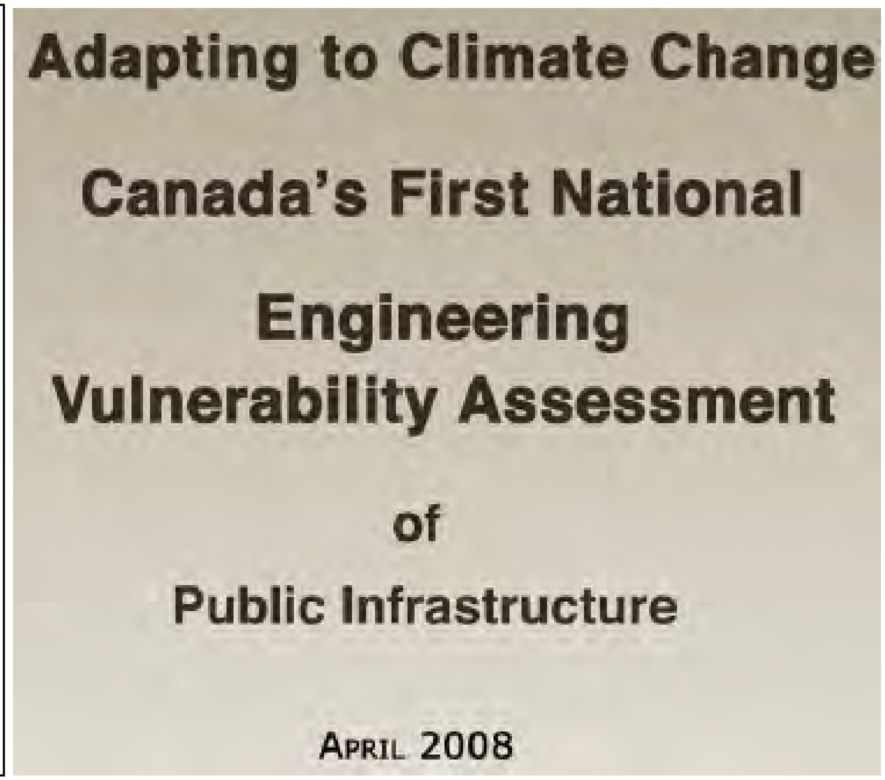

ONTARIO
NEW YORK
Lake Ontario
Lake Erie
Toronto
Mississauga
Hamilton
St. Catharines
Niagara Falls
Welland
Port Colborne
Buffalo
London
Kitchener
©2011 Google - Map data ©2011 Google
Fonthill
Port Robinson
Welland
Lincoln St
Pelham Rd
Rice Rd
Moyer Rd
West Side Rd
Elm St
City of Welland Urban Boundary
(approximate)

4. The PIEVC Protocol


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

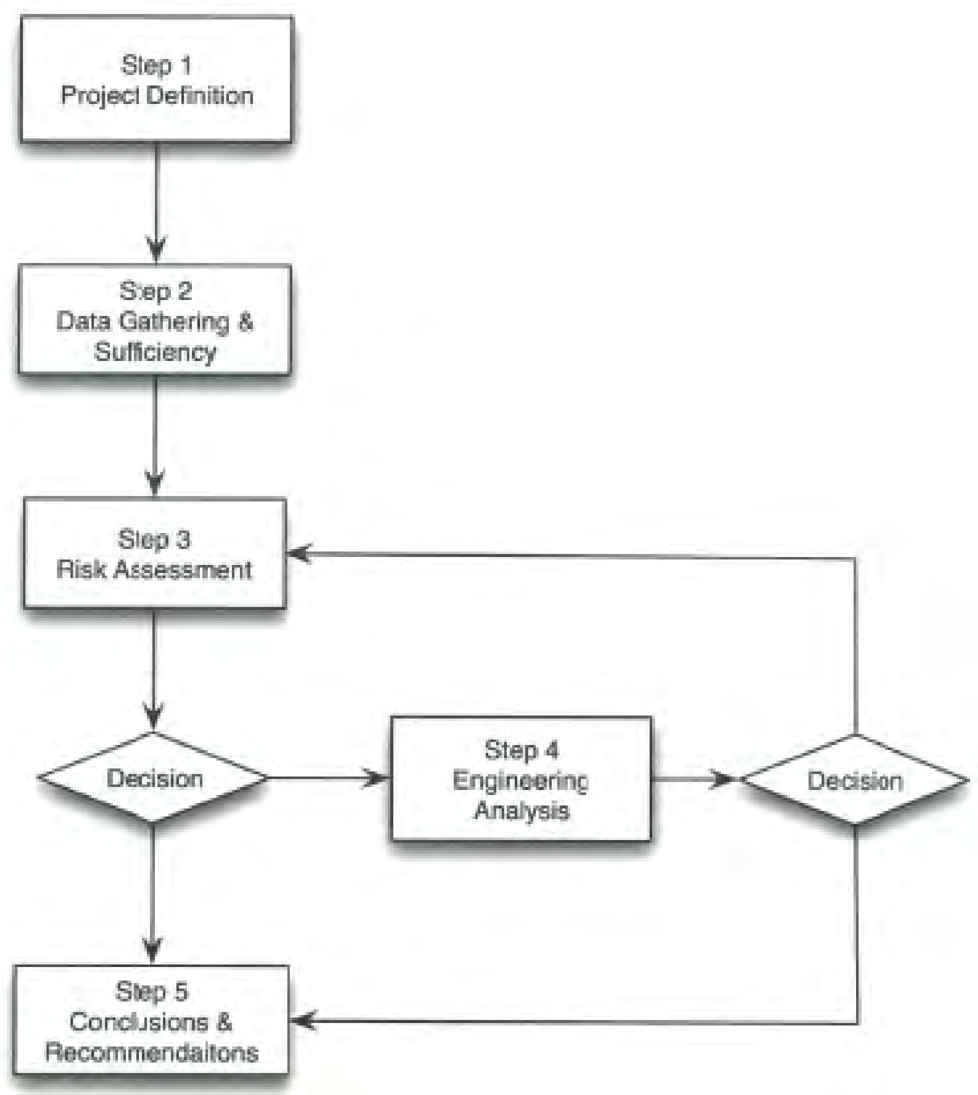
of

Public Infrastructure

APRIL 2008

4. The PIEVC Protocol

- Infrastructure of interest?
- Do we have data?
- Loads and impacts?
- More analyses required?
- Recommendations



PIEVC CVIIP

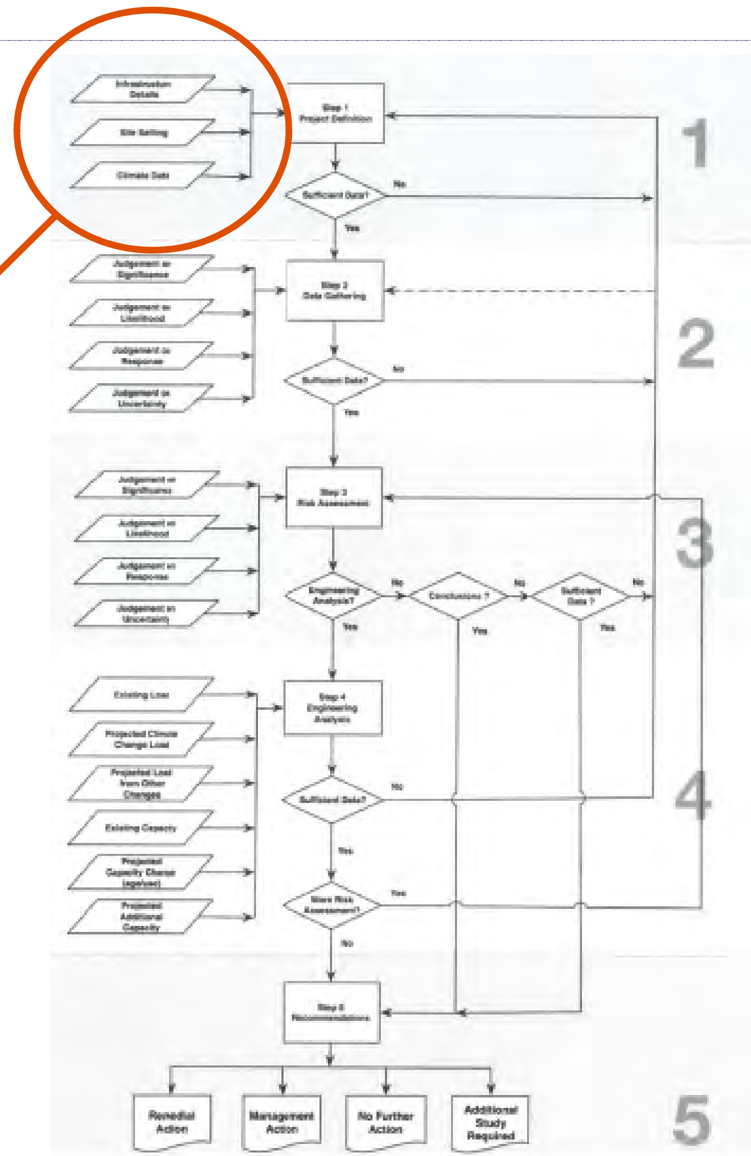
4. The PIEVC Protocol

- Step 1 – Project Definition

Infrastructure Details

Site Setting

Climate Overview



4. The PIEVC Protocol

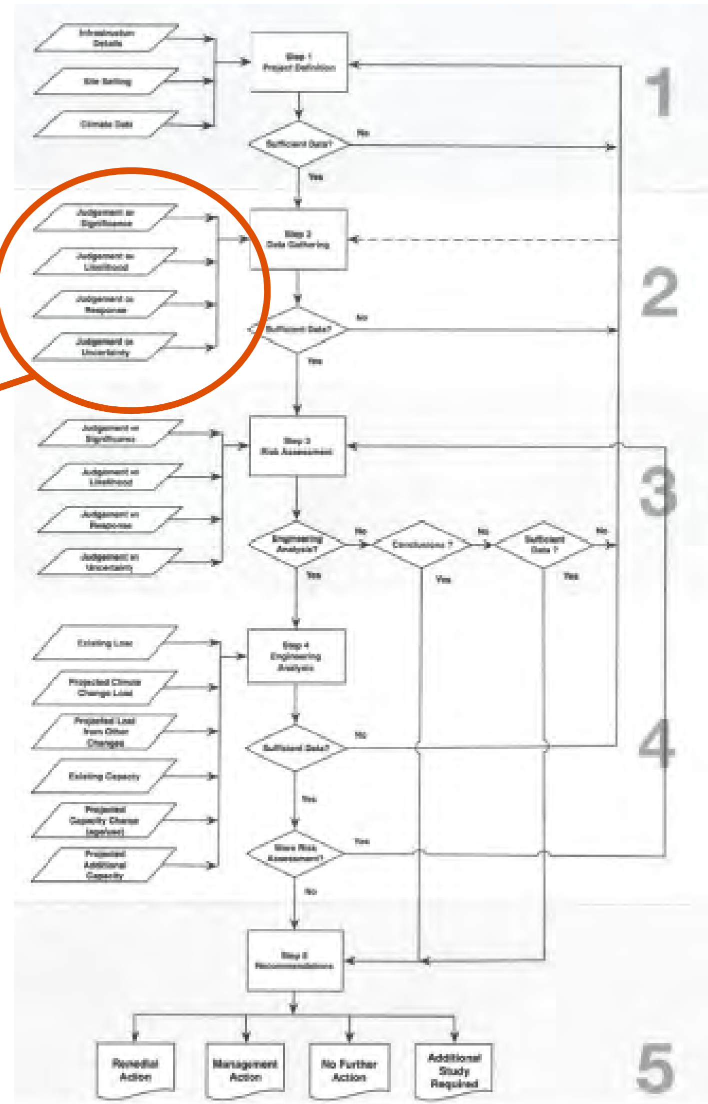
- Step 2 – Data Gathering

Judgment on Significance

Judgment on Likelihood

Judgment on Response

Judgment on Uncertainty



- **IDF analyses**

4. The PIEVC Protocol

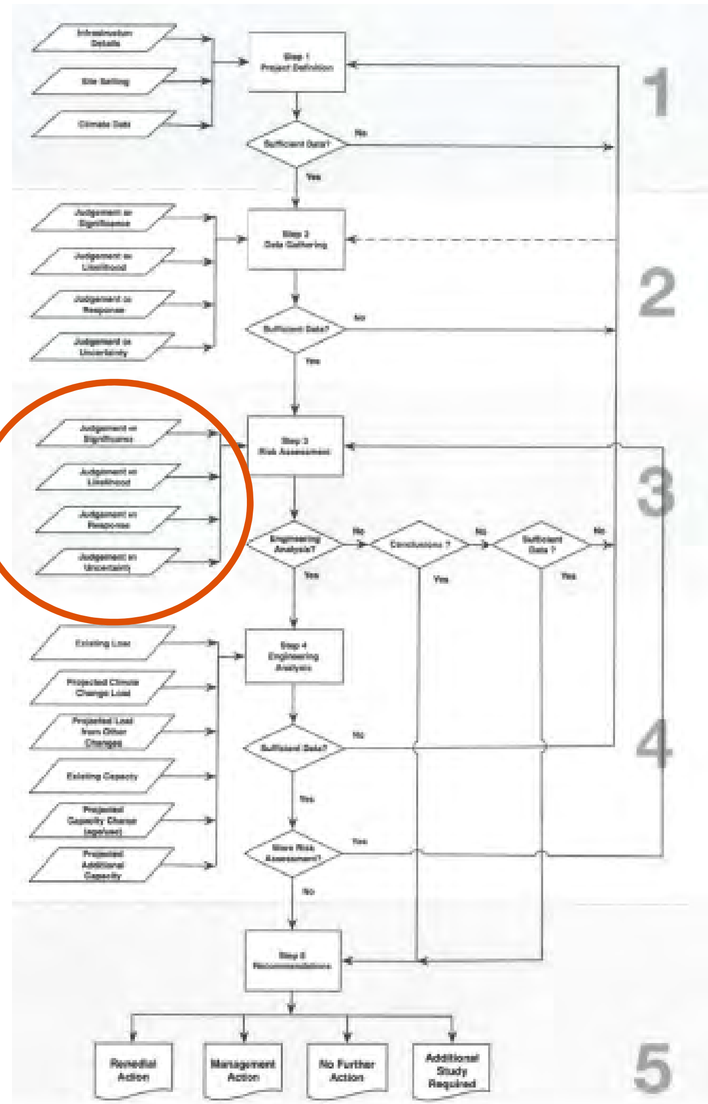
- Step 3 – Risk Assessment

Judgement on Significance

Judgement on Likelihood

Judgement on Response

Judgement on Uncertainty

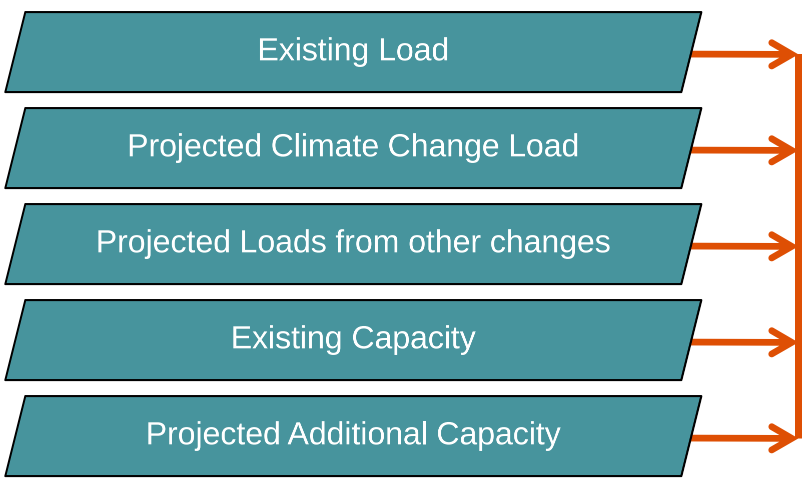


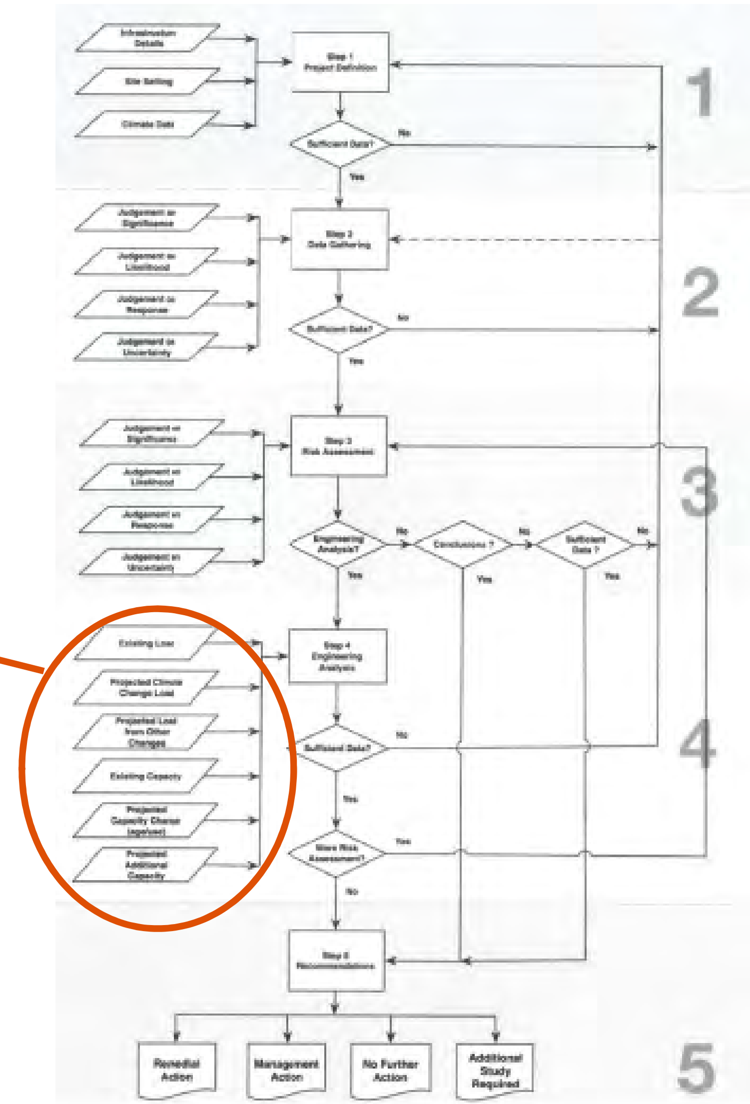
* Vulnerability assessment workshop

PIEVC CVIIP

4. The PIEVC Protocol

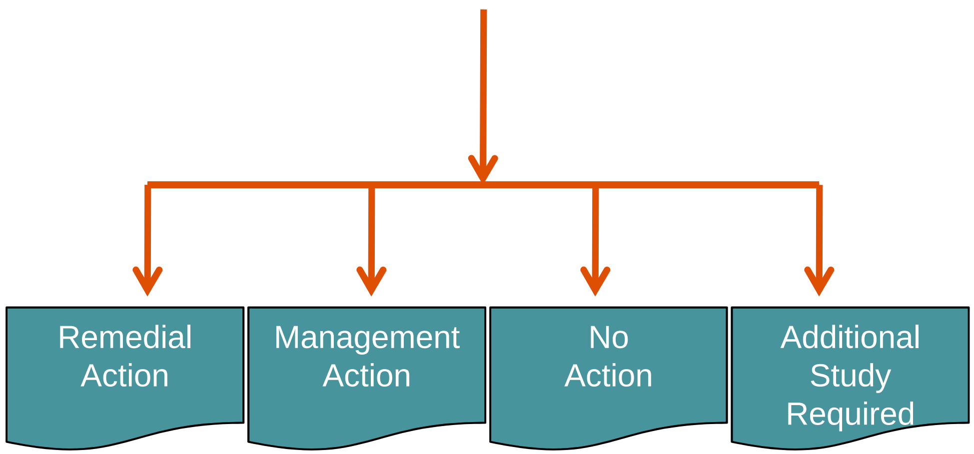
- Step 4 – Engineering Analysis

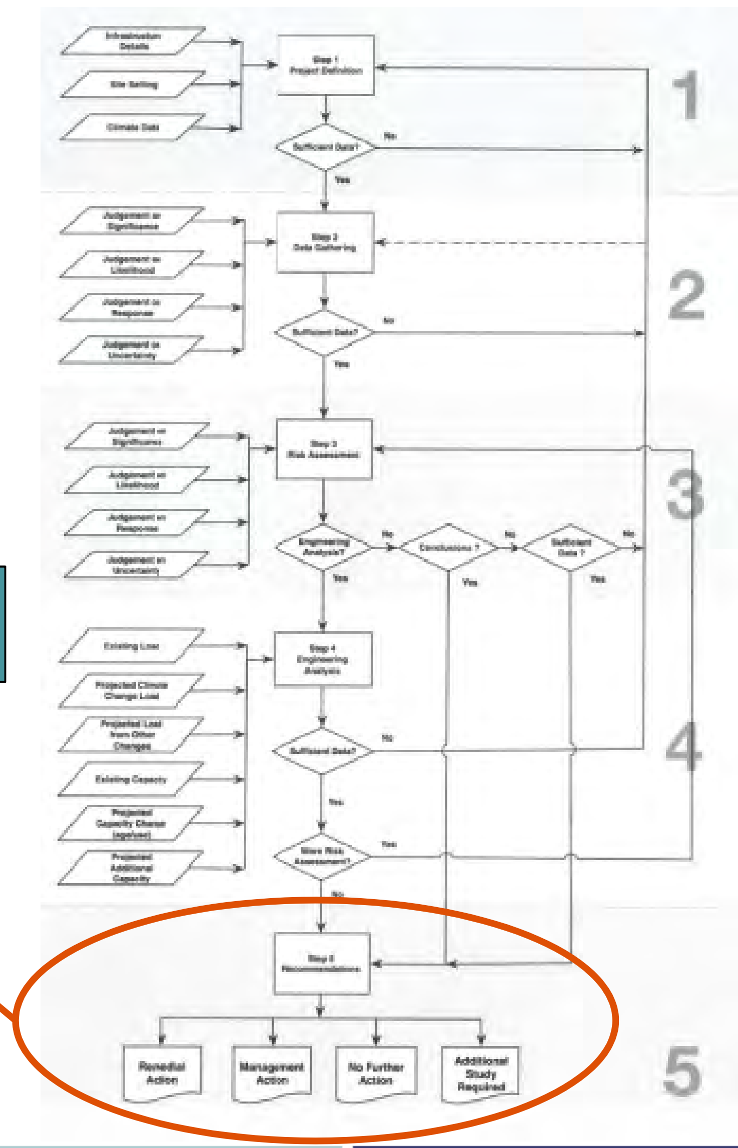




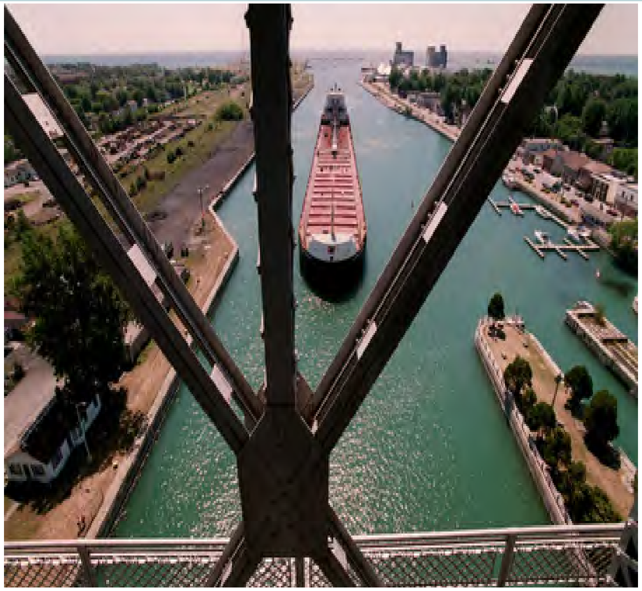
4. The PIEVC Protocol

- Step 5 – Recommendations





5. City of Welland Storm & Wastewater (Combined) System.



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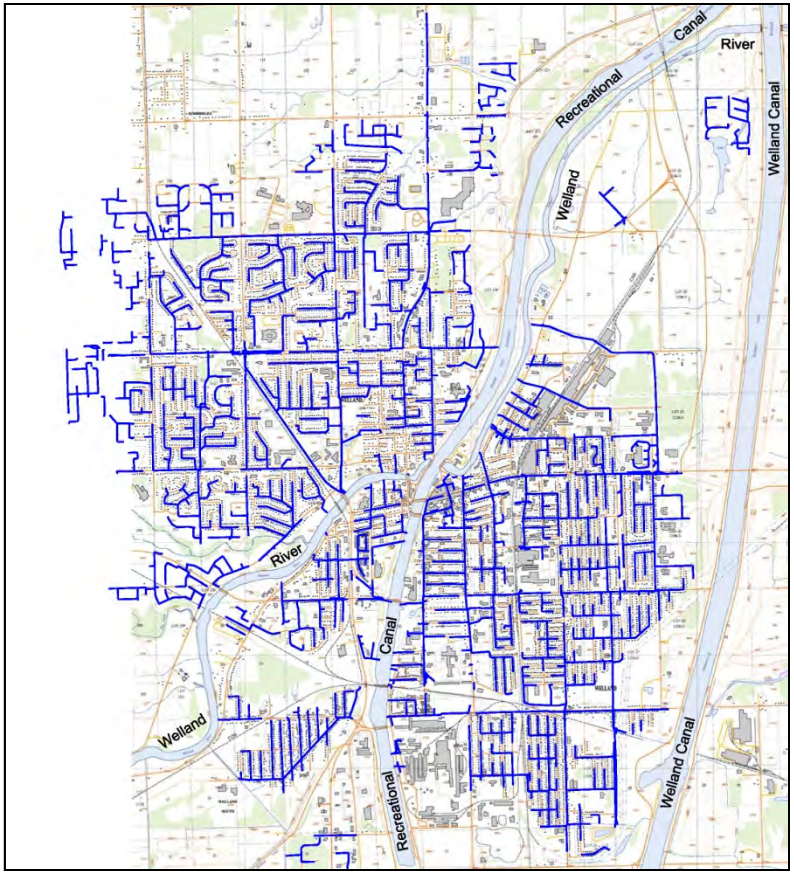
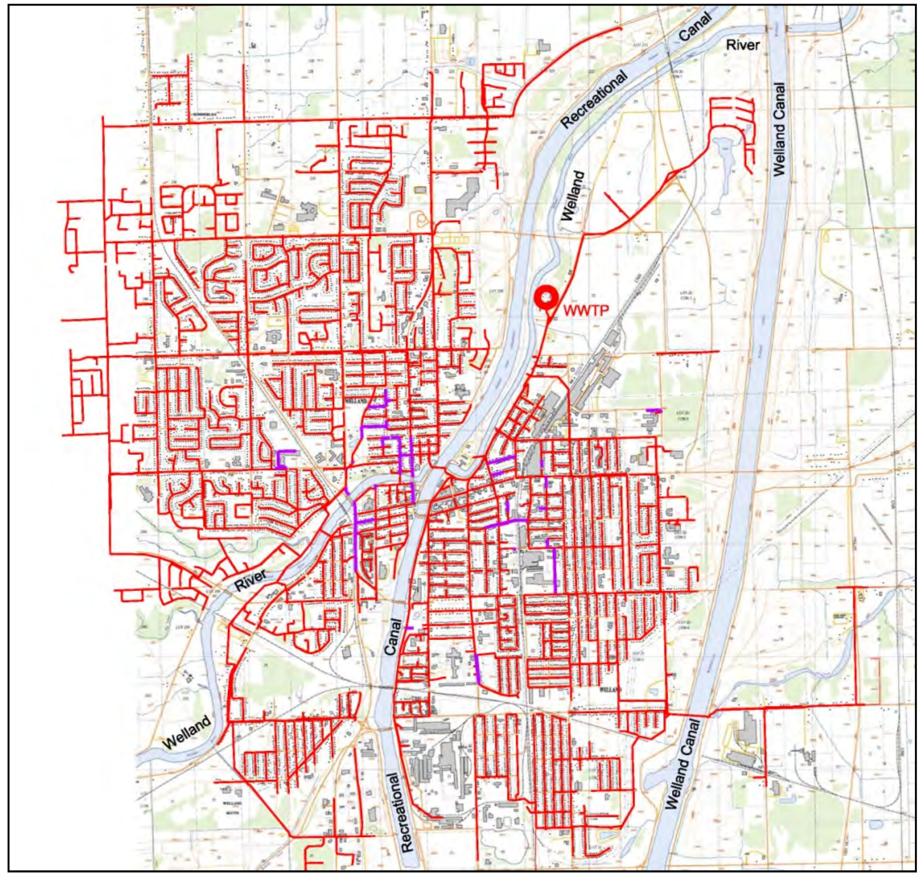
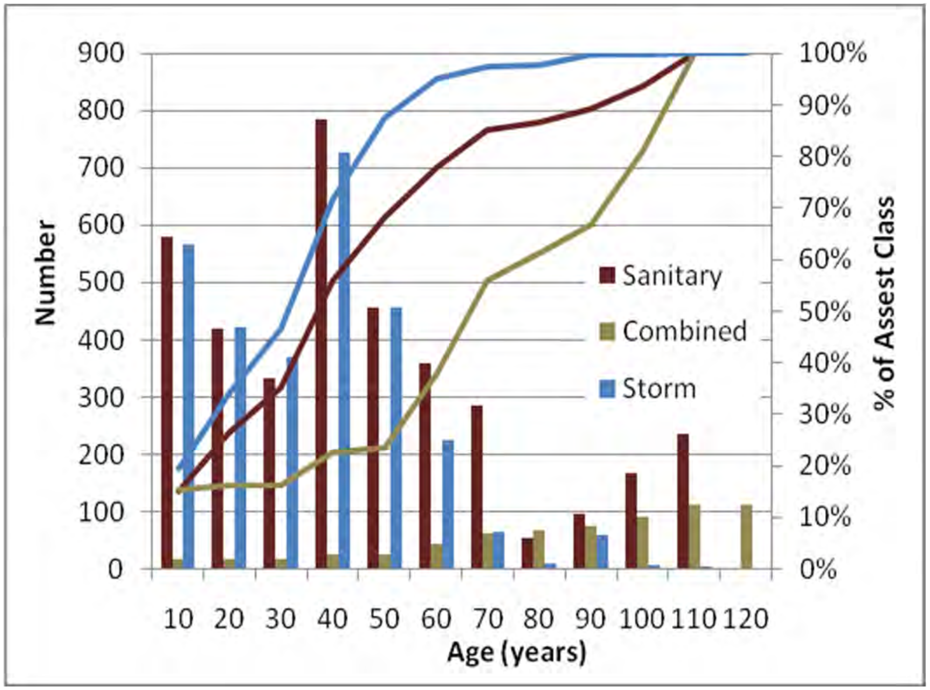


Stormwater Collection System

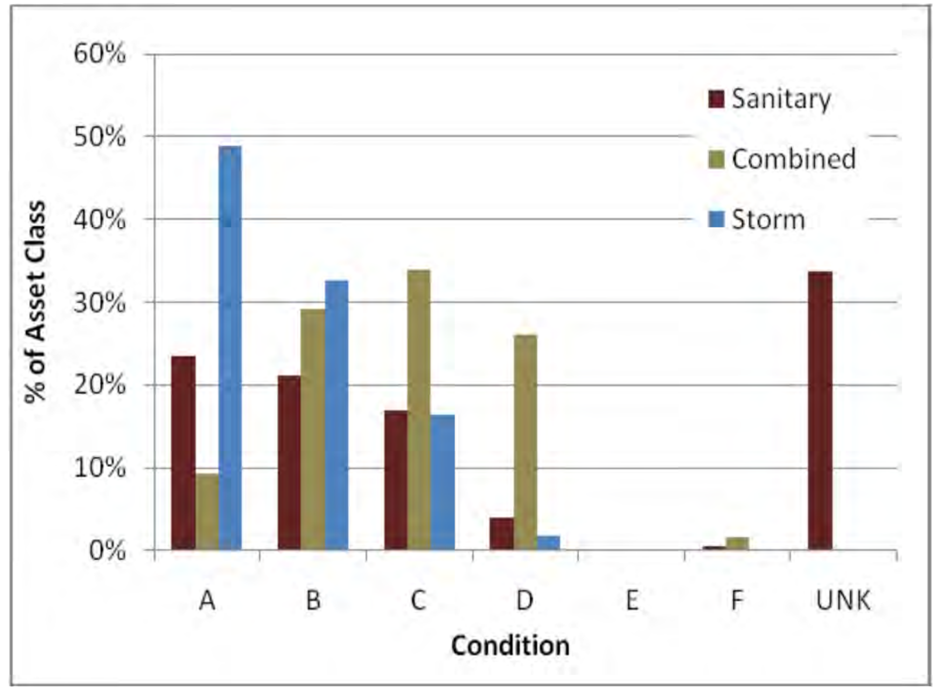


Wastewater / Combined Collection and Treatment System

5. City of Welland Storm & Wastewater (Combined) System.



Infrastructure by Age



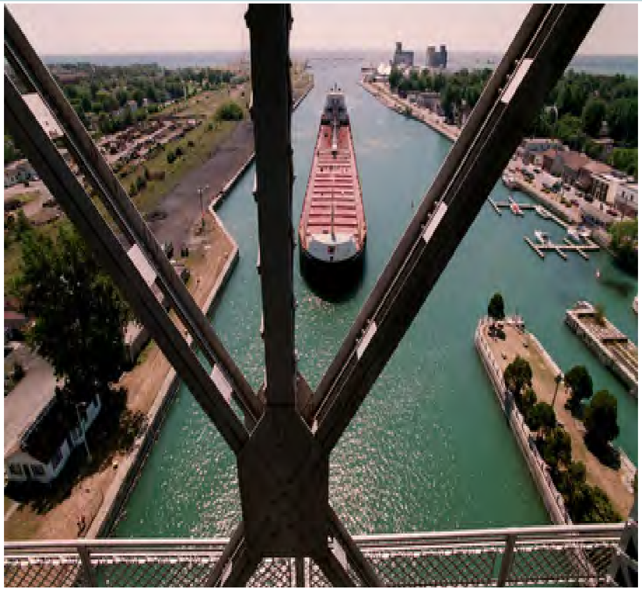
Infrastructure by Condition

Rating	Description	Useful Life Remaining
A	Newly installed or like new	>64%
B	First signs of aging	≥ 45% and ≤ 64%
C	Moderate aging/ deterioration	≥ 29% and ≤ 44%
D	Asset functioning with deterioration	≥ 18% and ≤ 28%
F	Loss of function imminent	< 18%
UNK	Unknown	

5. City of Welland Storm & Wastewater (Combined) System.

Descriptor	Storm	Sanitary/Combined
# of Pipes	1,717 (laterals) 2,906 (mains)	17,161 (laterals) 3,789 (mains)
Total Length	186 km	268 km
Maximum Size	3,000 mm	2,700 mm
Minimum Size	150 mm	125 mm
Average Age of Pipes	30 years	42 years (sanitary) 66 years (combined)
Oldest Pipes	106 years	111 years (sanitary) 110 years (combined)

6. Climate Variables

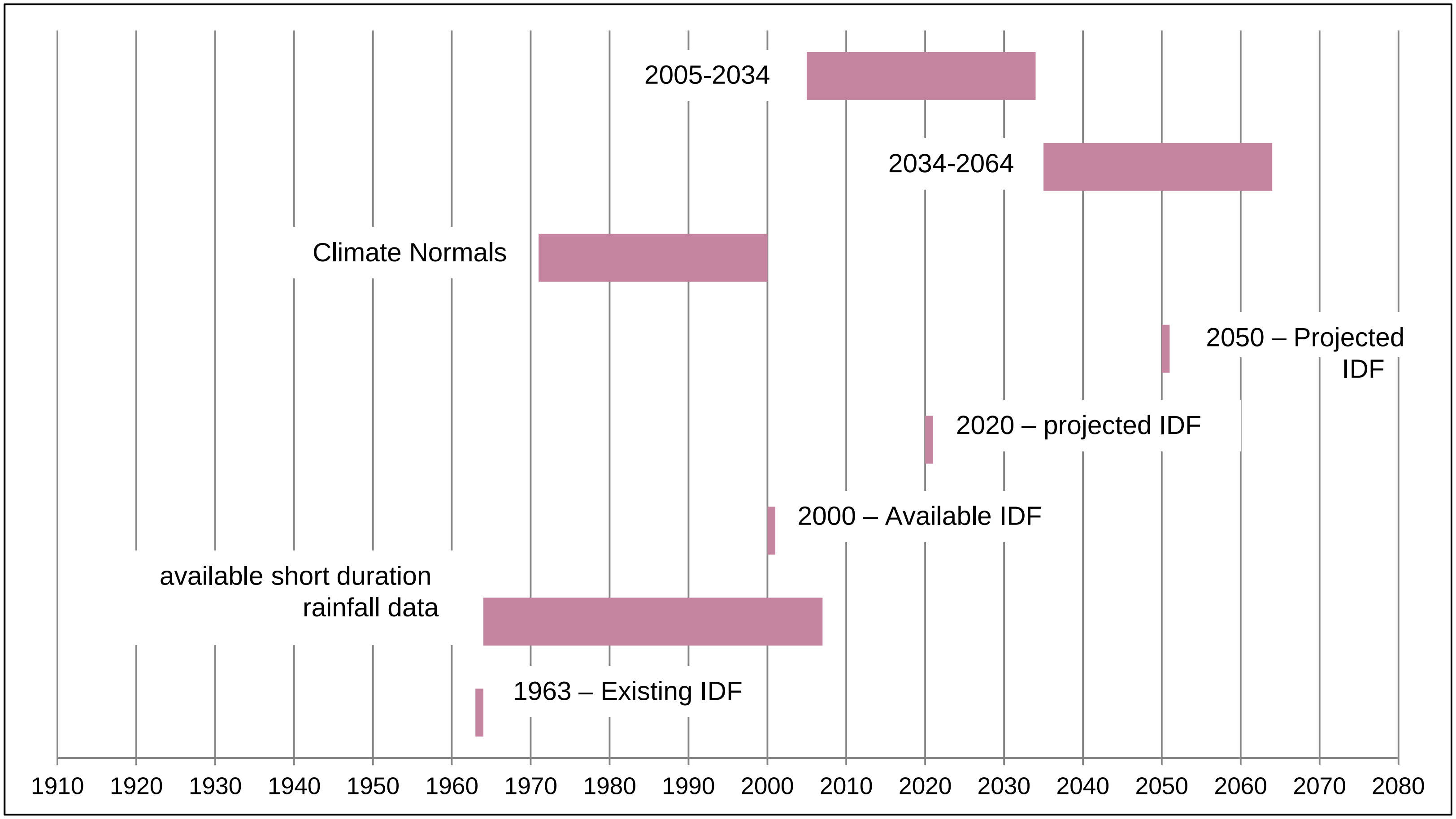


6. Climate Variables

The Long List of Variables:

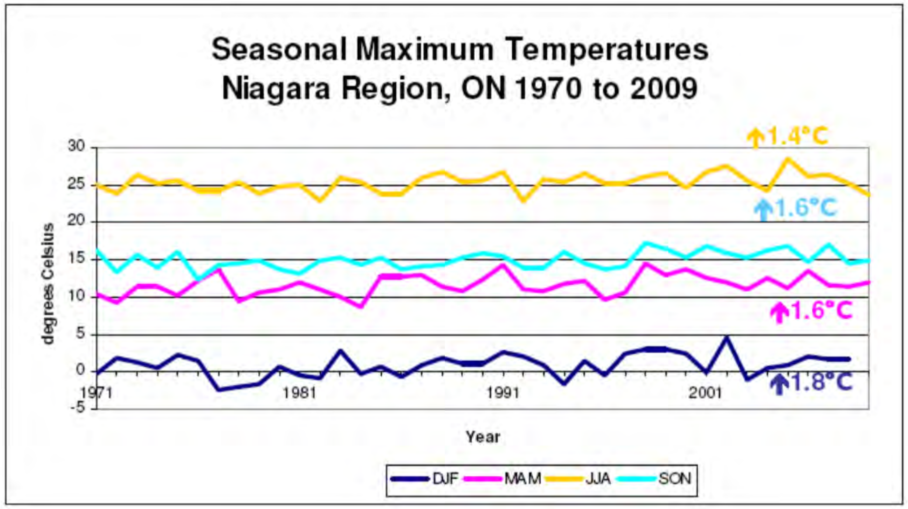
- High/Low Temperature
- Heat & Cold Waves
- Extreme Diurnal Temperature Variability
- Freeze Thaw Cycles
- Heavy Rain
- Daily Total Rainfall
- Winter Rain
- Freezing Rain
- Ice Storm
- Snow Accumulation
- Blowing Snow/Blizzard
- Lightning
- Hail Storm
- Hurricane/Tropical Storm
- High Winds
- Tornado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

6. Climate Variables



6. Climate Variables

- Definition - number of days with a maximum temperature > 35°C
- Historical Climate – based on historical record – 0.06 days per year
- Trends – literature review
- Climate Projections – literature review and analysis of occurrence using the WCRP CMIP3 database for 2020 and 2050 ... (World Climate Research Programme's Coupled Model Intercomparison Project Phase 3 multi-model dataset)



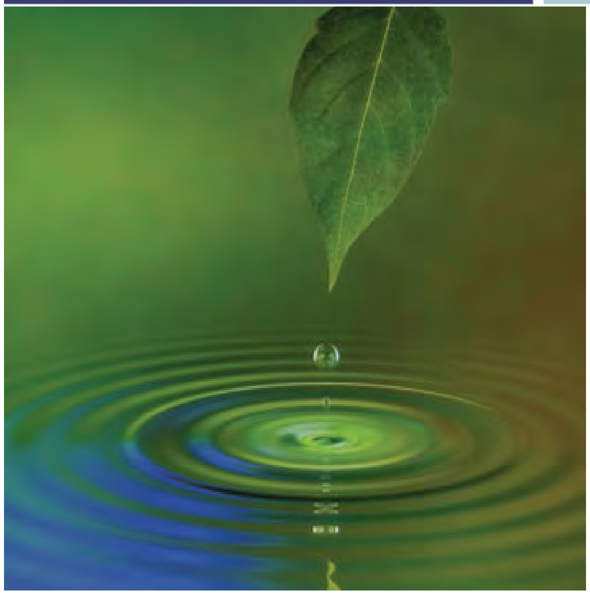
Description	Days/Year		
	Historic[1]	2020[2]	2050[2]
> 30°C	7	9	17
> 35°C	0.06	0.08	0.33
Probability Scale	2 remote	2 remote	4 Moderate / possible

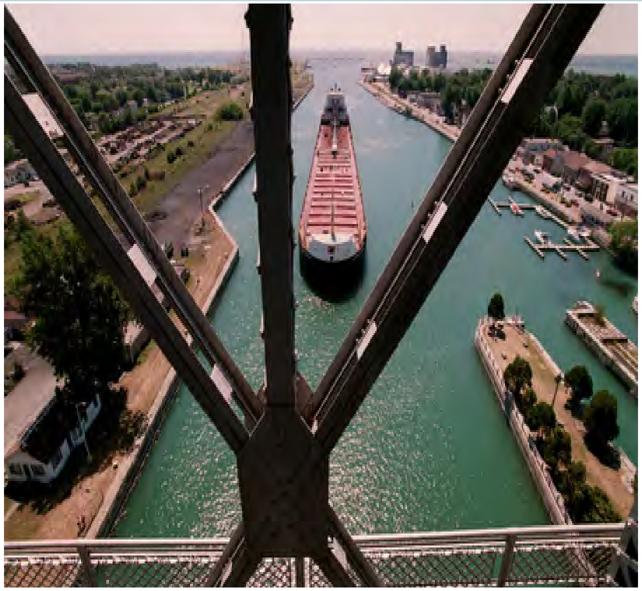
6. Climate Variables

General Outcomes

- PIEVC protocol, premise based on two future time frames 2020 & 2050
- Number of days/yr with temp. exceeding 35 deg C to remain same through 2020 but 4 times through 2050
- Number of days/yr with temp. 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
- 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





7. Intensity – Duration – Frequency Rainfall Relationship Update

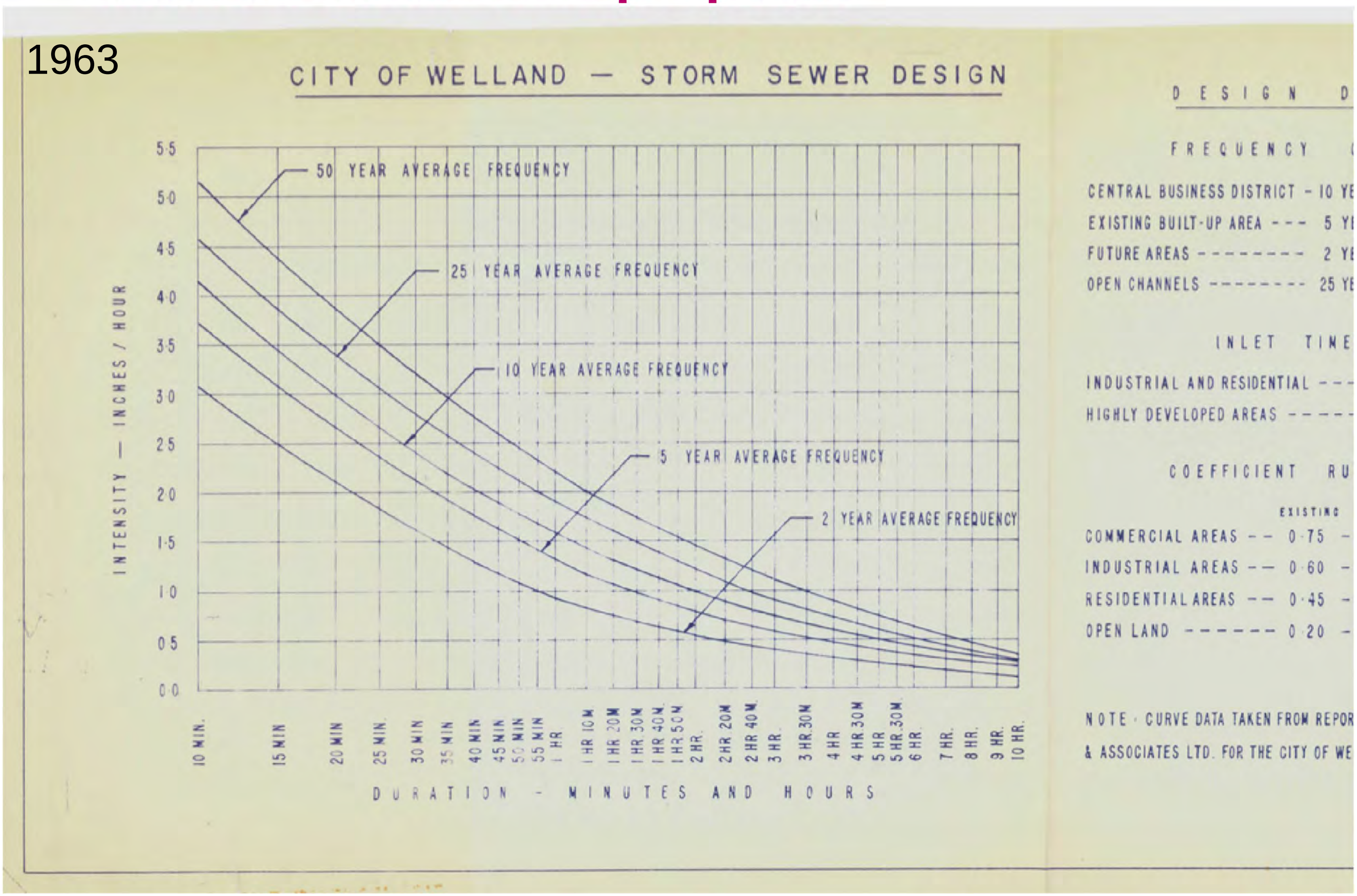
IDF curves are used to determine storm sewer sizes.

Current City standards based on 1963 curve & 2 year return frequency.

Original 1963 Curve was based on Buffalo weather data

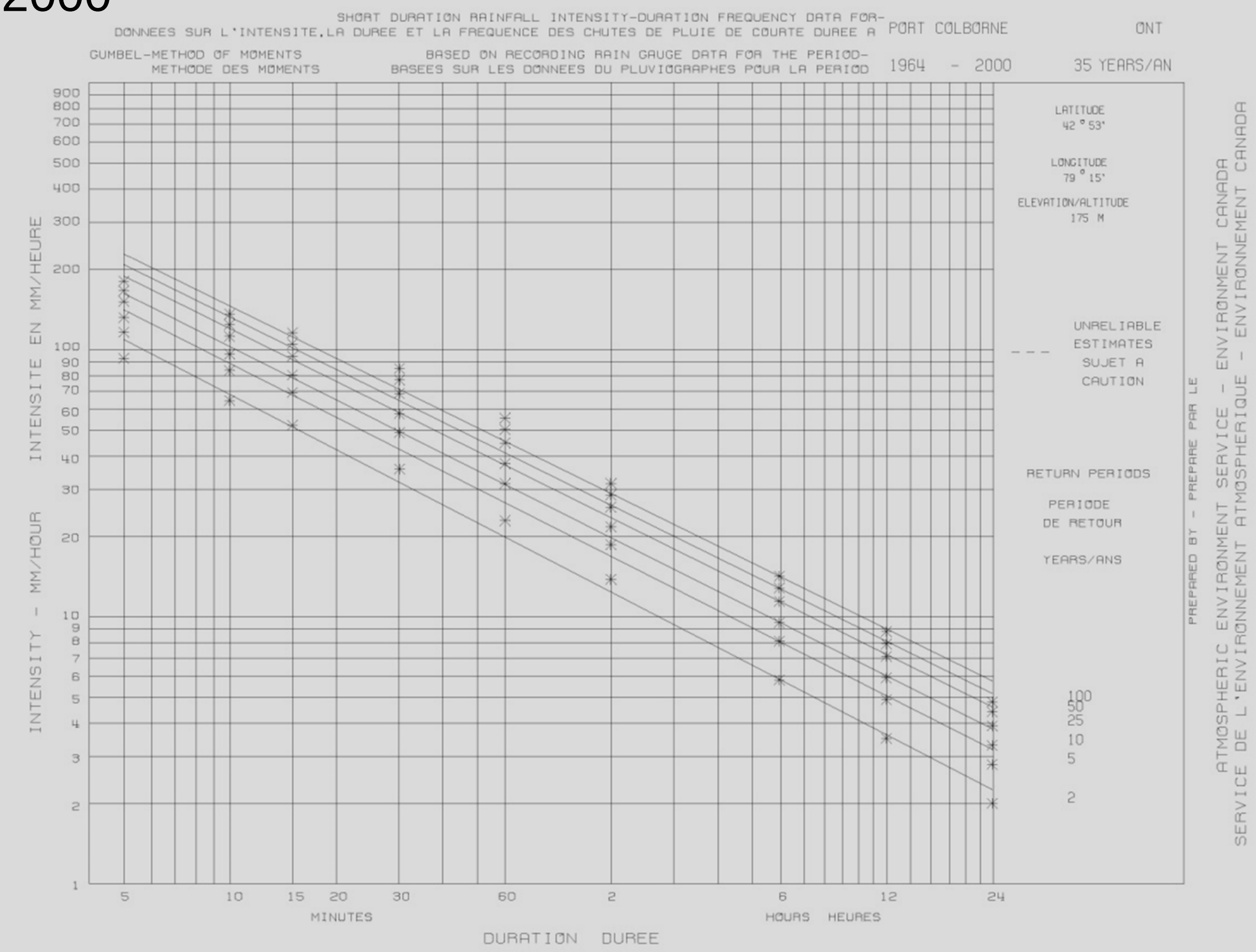
New curves based on Environment Canada data from Port Colborne weather station up to year 2000

7. Intensity – Duration – Frequency Rainfall Relationship Update



7. Intensity – Duration – Frequency Rainfall Relationship Update

2000



7. Intensity – Duration – Frequency Rainfall Relationship Update

- 40 years of data available
- 112 Global Climate Models (GCM) run, output used to predict 2020 & 2050 IDF curves
- Comparison between 1963 Buffalo and the projected 2020 and 2050 climate projections 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.

7. Intensity – Duration – Frequency Rainfall Relationship Update

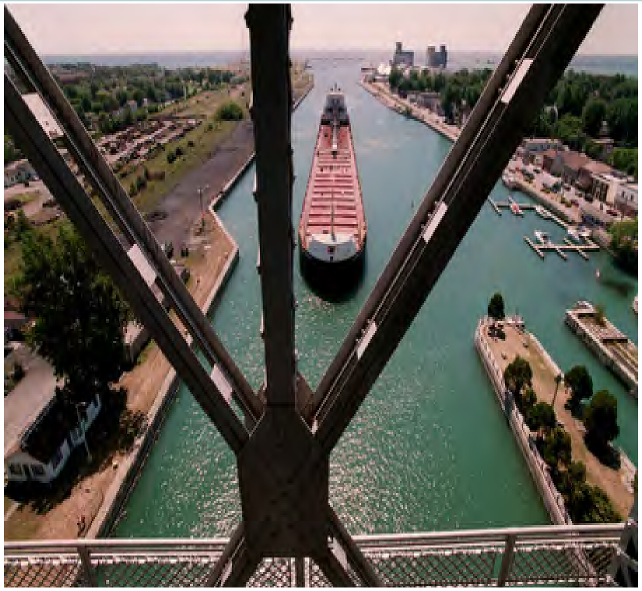
Source of uncertainty

- GCM uncertainty
- Downscaling method
- IDF model structure
- Emissions scenarios
- Observed data

Consider uncertainty when applying projected IDF curves

- Top 10% of projections show large increases in precipitation
- Mean might be appropriate for short-lived infrastructure
- 90^{th} percentile might be appropriate for longer-lived infrastructure
- Consider all sources of information
- Use your judgement!
- Adjust current IDF curve by climate sensitivity ratio

8. Risk Assessment



8. Risk Assessment

Risk workshop amongst a team of Specialists to evaluate various factors and system response functions to predict qualitatively the risks related to climate change.

- Engineers (Civil, Wastewater & Structural)
- Climate Specialists
- Operations
- Resource Managers

8. Risk Assessment

The focus is a qualitative assessment in which professional judgment and experience are used to determine the likely effect of individual climate events on individual components of the infrastructure.

	Performance Response											Climate Parameters																					
Infrastructure Component	Structural Dersign	Functionality	Watershed, Surface Water and Groundwater	Operations, Maintenance, Materials Performance	Emergency Response	Insurance Considerations	Policy Considerations	Social Effects	Water Quality	Economic Considerations	Other	High Temperature	Heat Wave	Heavy Rain	5 day Total Rain	Freezing Rain	Ice Storm	Hurricane / Tropical Storm	Drought / Dry Period	Heavy Snow	Snow Accumulation	Freeze Thaw Cycles	Winter Rain	Blowing Snow / Blizzard	Lightning	Hailstorm	High Winds	Tornado	Heavy Fog	Low Temperature	Cold Wave	Extreme Diurnal Temperature	Flooding (100 year) (aka Regulatory)
Administration																																	
Personnel		Y		Y	Y	Y	Y	Y				16	16	20	10	15	12	8		25	6	6	10		20	12	12						
Storm Collection System																																	
Catchbasins	Y	Y	Y	Y		Y		Y	Y					20	15	10	6	10					10					2					1
Manholes	Y	Y	Y	Y		Y		Y						10	10	10	6	4					5					2					1
Pipes	Y	Y	Y	Y			Y							15	15			6					15							3			
Outfalls	Y	Y	Y	Y			Y	Y						25	25			10					25							3			
SWM Ponds	Y	Y	Y	Y	Y	Y	Y	Y				16	20	25							6							12					
Oil Grit Separator	Y	Y	Y	Y			Y							15	20																		
Major System - Old	Y	Y		Y	Y	Y	Y	Y				12	16	20	10	10	9	10		10	6		25					10					
Major System - New	Y	Y		Y	Y	Y	Y	Y				12	16	20		5	6	8		10	6		25					10					
Sanitary Collection System																																	
Manholes	Y	Y		Y	Y	Y		Y						20	15	10				10	4	4	20					6					
Pipes	Y	Y		Y	Y	Y	Y	Y						20	20			8					20										
Forcemains	Y	Y					Y																										
Inverted Syphons	Y	Y		Y					Y					25	25			10															
Reservoirs		Y			Y		Y	Y						10	15			6															
Pump Stations		Y			Y			Y						25	20			10							28								
Flow Control Structures	Y	Y	Y	Y	Y		Y	Y	Y					25	25			10					10				4						3
CSO's	Y	Y	Y	Y	Y		Y	Y	Y					25	25			10					5				4						3
WWTP																																	
Main Pumping Station	Y	Y		Y	Y	Y	Y	Y				16	16	15	10		9	10						8	12			14	8	2			
Screening, Grit Removal, Flow Splitter	Y	Y		Y	Y			Y		Y			12	20	20		6	8					15					14		2	4		
Plant Systems	Y	Y	Y	Y					Y									6										10					7
Outfall to Welland River		Y																															2
BioSolids Management		Y		Y			Y	Y						15	15	10	6	14		10	4		15	8				10	8				
Electric Power																																	
Transmission Lines	Y	Y		Y	Y							8	8	10		5	15	12							12		12	12					
Standby Generators		Y		Y	Y	Y			Y																								5
Transportation																																	
Supplies Delivery		Y		Y	Y	Y			Y					10	10	15	21	12		10	4							14	8				
Communications																																	
Telephone, Telemetry	Y	Y		Y	Y											5	9	12							8			8					

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

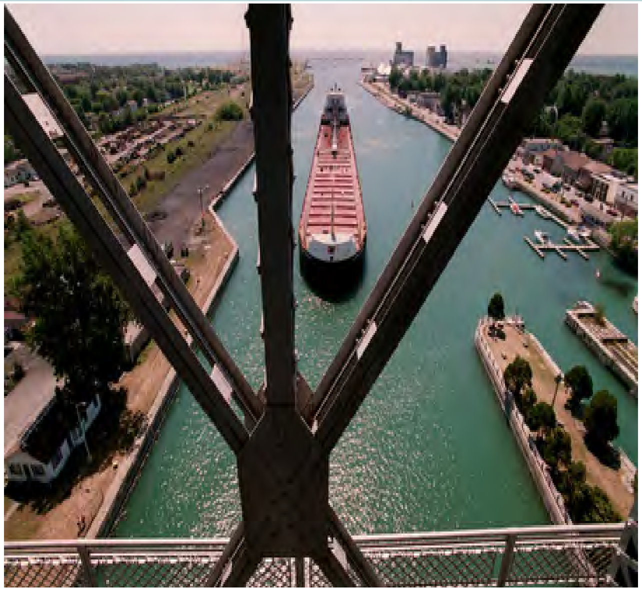
From this assessment

Vulnerability exists when Total Load > Total Capacity

Adaptive Capacity exists when Total Load < Total Capacity

Parameter	Notation	Value
existing load	L_E	100
anticipated climate change load	L_C	20
other change loads	L_O	0
total load	L_T	120
existing capacity	C_E	64
projected change in existing capacity from aging/use	C_M	15
additional capacity	C_A	26
project total capacity	C_T	75
vulnerability ratio	V_R	1.6
capacity deficit	C_D	45

9. Action Plan – Recommendations


9. Action Plan – Recommendations

Categories

1. Remedial engineering or operations action required
2. Management action required
3. Additional study or data required
4. No further action required

9. Action Plan – Recommendations

Action Classifications	# of recommendations
Additional Study as a prerequisite for Management Action	1
Additional Study as a prerequisite for Management and/or Operational Action	6
Additional Study as a prerequisite for Remedial Action	2
Additional Study as a prerequisite for Remedial Action and/or Management Action	21
Management Action	12
Management and/or Operational Action	2

Recommendation Cost Range	# of recommendations
< $ 100,000	33
$ 100,000 to $ 500,000	11
$ 500,000 +	0

Implementation Time Frame	# of recommendations
ASAP	12
Short	13
Medium	19

Recommended Action by	# of recommendations
City	12
Region	8
City & Region	24

9. Action Plan – Recommendations

Infrastructure Component	Climate Variable / (Priority of Climate Effect)	Recommendation Category	Comments on Recommendations	Performance Responses: Design	Functionality	Environment	Performance	Emergencies	Insurance	Policies	Social Effects	Water Quality	Economic	Cost Range	Implementation Time Frame	Recommended Action By
Wastewater / Combined Collection System																
General	General	Management Action	It is recommended that the City of Welland continue to work with the Regional Municipality of Niagara to determine the effect of climate change on achievable flow reduction through sewer separation and inflow and infiltration reduction programs.	Y	Y					Y	Y	Y		$$	Short	City & Region
		Management Action	Many of the recommendations in this study would be most effective if completed in conjunction with ongoing and new Municipal and Regional initiatives, continued co-ordination and dialogue required.							Y				$	ASAP	City & Region
		Management Action	Infrastructure funding to complete the sewer separation program is constrained resulting in implementation delays. Welland should work with all levels of government to establish a consistent funding program for the sewer separation program.	Y	Y					Y		Y		$	ASAP	City & Region
		Management Action	Infrastructure funding to maintain the existing collection system and replacing aging components of the system is required. Welland should work with all levels of government to establish a consistent funding program for the sewer maintenance program.	Y	Y		Y			Y	Y	Y		$	ASAP	City & Region
		Additional Study as a prerequisite for Remedial Action and/or Management Action	An assessment of the impact of a change in the Ministry of Environment Procedure F-5-5 and/or the impact of compliance with Ministry of Environment Procedure F-5-1 should be completed.	Y	Y		Y			Y		Y		$	Short	City & Region
		Additional Study as a prerequisite for Remedial Action and/or Management Action	Infrastructure vulnerability exists to increased rain as a trigger for increased frequency of CSO's. Mitigation is possible through on-going and currently planned sewer separation. Beyond this, the extent of the impact is partially dependent on the design standard of the separated sewer systems and the allowance for inflow and infiltration. Further study is required to identify the relationship between increased rainfall and inflow and infiltration rates in the collection systems.	Y	Y							Y		$$	Short	City
		Additional Study as a prerequisite for Remedial Action and/or Management Action	City of Welland programs aimed at reducing wet weather flow in the collection systems are on-going. These should be continued and actively promoted to residents perhaps through increased educational opportunities. An assessment of the applicability of green infrastructure, as an additional tool to increase resiliency in adapting to climate change, should be completed.	Y	Y					Y	Y			$	Short	City

$$$ Range of Anticipated Cost for Implementation of Recommendation		
	$	< $100,000
	$$	to $500,000
	$$$	$500,000+

Time Frame		
	ASAP	as soon as possible
	Short	implementation should be initiated within 5 years
	Medium	implementation should be initiated within 10 years

Priority of Climate Effect This value represents the Response Severity Scale Factor (P) multiplied by the Climate Probability Scale Factor (S) and is used to determine how the interaction will be assessed in the context of the PIEVC Protocol. The Climate Probability Scale Factor reflects the expectation of a change in a climate variable under the influence of climate change. The Response Severity Scale Factor reflects the expected severity of the interaction between the climate phenomena and the infrastructure component. As such, different climate phenomena may lead to varying response severities.

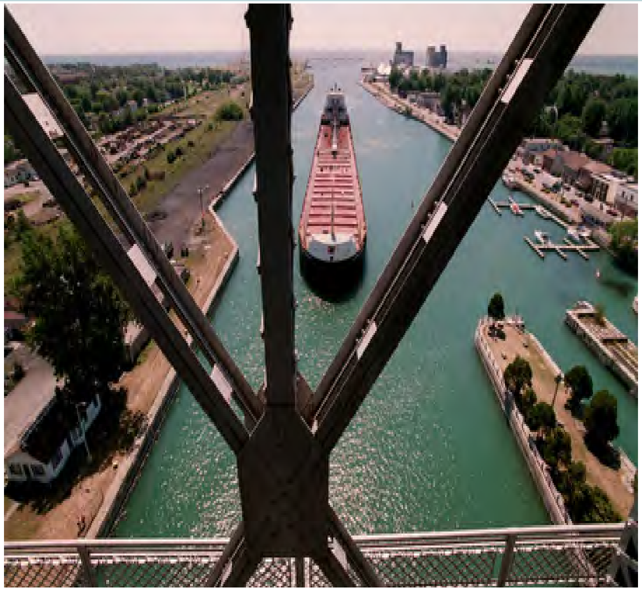
9. Action Plan – Recommendations

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. Engineers Canada added Welland Study results to the national database of case studies. Also have developed a triple bottom line (economic, social & environmental) costing module.

3. MOE, profile study in annual "Climate Ready: Ontario's Adaptation Strategy & Action Plan" report

10. Next Steps Continued

4. WaterSmart, study referred to in the "Adapting to Climate Change: Challenges for Niagara" report.

5. City of Welland to advance higher priority 'ASAP' & 'Short Term' recommendations, starting with,

   - Evaluating the implications of using revised IDF curves for storm sewer design, 1963 vs. P.C. 2000 and projected 2020 & 2050.
   - Evaluating implications of revising storm design standard from the current 2 year to 5 or 10 year.
   - PCP Update & City wide sanitary sewer model

Contact Information

Ron Scheckenberger
AMEC Environment & Infrastructure
3215 North Service Rd
Burlington, ON
Canada L7N 3G2
Phone: (905) 335-2353
Email: ron.scheckenberger@amec.com

Peter Nimmrichter
AMEC Environment & Infrastructure
160 Traders Blvd E., Suite 110
Mississauga, ON
Canada L4Z 3K7
Phone: 905-568-2929
Email: peter.nimmrichter@amec.com

Marvin Ingebrigtsen
Technical Analyst - Infrastructure Programs
Infrastructure Services - Engineering Division
Corporation of the City of Welland
60 East Main Street, Welland, ON
Canada L3B 3X4
Phone: (905) 735-1700 ext. 2209
Email: marvin.ingebrigtsen@welland.ca

Erik Nickel
Technical Services Supervisor
Infrastructure Services - Engineering Division
Corporation of the City of Welland
60 East Main Street, Welland, ON
Canada L3B 3X4
Phone: (905) 735-1700 ext. 2138
Email: erik.nickel@welland.ca