Canadian Water Network

CONFIDENTIAL

Stormwater Capital Plan Prioritization Approaches

A Comparative Analysis for Toronto Water

April 2020

Contents

1. Introduction

1.1 Background

A core element of the City of Toronto's actions to manage the risk of urban flooding to homes and property is encompassed by its Basement Flooding Protection Program (BFPP) (City of Toronto, 2020). The BFPP currently utilizes a cost per benefitting property threshold of $32,000 to prioritize work. If a property is identified to be at risk of basement flooding based on the program criteria, infrastructure solutions are recommended to achieve the criteria, and this property is now a benefitting property. The cost per benefitting property is the estimated cost of the capital work divided by the total number of benefitting properties. Projects that meet this threshold are moved into Toronto Water's five-year capital plan, while those that do not meet this threshold are deferred to the program's "backlog." Projects in the "backlog" are not included in the five-year capital plan, and not funded.

In developing best options for next steps in evolving the structure and decision criteria used to implement in its stormwater management programs and projects, such as those approved through the BFPP, Toronto Water is interested in learning from peer communities across Canada how they address the issue of setting priorities to enable effective prioritization and selection of projects and investments for the goal of protection of homes from flooding.

This report provides a "snapshot" of the diversity of approaches taken to prioritize plans and actions related to stormwater management and urban flood prevention for 6 municipalities/utilities across Canada. For each of these municipalities, in order to obtain the kinds of insights desired by Toronto Water in understanding the nature of practices of different cities across Canada, this study takes a "deeper dive" into exploring the nature of how stormwater-related management units and programs are structured, how they evolved, and how they are currently being implemented in terms of prioritizing work and selecting projects, as well as key trends that might offer Toronto Water insights into best practices and elements to consider in designing options and plans to develop a customized prioritization approach.

1.2 Study Insight Objectives

In conducting a comparative analysis of stormwater project prioritization approaches for the prevention of flooding of homes, the elements for which Toronto Water indicated interest in gaining insights from this comparative analysis included:

- Identification of comparable capital programs and approaches used by other cities in Canada.
- A high-level understanding of the nature and positioning within local municipal governance and management of those capital programs (e.g., dollar value of the program, objectives, council direction) and the key technical elements employed in each approach.
- A comparison of the approaches, including their need for input from the municipality on its effectiveness, complexity of analysis, objectivity (requiring little in the way of staff judgement and minimizing political involvement), and other categories. Note, the main comparative tables presented in Section 2.2 present much of this information. Due to the fact that these factors are more nuanced, CWN has included comparative elements in the tables that capture the factors in an indirect way (e.g. governance structure at the municipality/utility or lead agency/department/unit responsible for developing and/or implementing the stormwater prioritization approach).

- Observations of successes/shortcomings of practices used, lessons learned and opportunities for improvement.
- Consideration of how other cities manage the transparency of sharing flood risk with the public (be it mapping or otherwise), and what disclaimers are used to obtain and share data.
- Consideration of practices, as available, on how municipalities coordinate/engage with the insurance industry, including facilitating the reinstatement of insurance for property owners. Note, this is a very current issue and a focus of discussions with the municipal sector and the insurance sector facilitated by CWN. In general, the municipalities/utilities interviewed for this study had not yet gotten to the point of structuring actions to engage with the insurance industry to facilitate the reinstatement of insurance for property owners.

1.3 Study Recommendations Objectives

The purpose of this comparative analysis is to provide best practices and considerations to Toronto Water that could assist them in designing their own prioritization options and plans. The intent of this analysis and the considerations resulting from this analysis are to provide a better awareness of best practices being employed or developed by other cities to enable Toronto Water to consider potential approaches to supplement their existing methodology, or possibly develop an alternative to the existing methodology.

2. Municipal Stormwater Prioritization Approaches

"Stormwater Management," is the terminology for the activity encompassing municipal flood protection of homes and buildings that is commonly used in the sector. It is inextricably linked with a significant number of other activities undertaken by utilities or local government departments, both in terms of city-wide goals and operational activities, investments and opportunities. Based on our background research, and this study's comparative analysis, we have found the following. Within the context of assessing how groups dealing with stormwater management and urban flooding prevention are structured and the best practices they undertake, the overall framing and approach to determining prioritization of investment decisions (including project selection and sequencing) comes down to three key issues:

1. Where **integration of overlapping goals/objectives** to be considered by the work happens (e.g., EPCOR and Halifax have Integrated Resource Plans for example that cross the whole water spectrum, City of Vancouver has an Integrated Water Management Group).
2. Where and how the overarching goals and specific operational objectives are identified; i.e., how intended or required **"Levels of Service (LoS)"** goals, or **risk-based objectives**, are set?
3. Where and how the main **"prioritization" criteria** that ultimately guide project selection and sequencing are applied.

The comparative analysis conducted for this study is presented in the following sections in a way that seeks to help better elucidate where the different considerations of particular interest to Toronto Water play out for the different municipalities/utilities considered.

2.1 Overview of Comparative Analysis Approach

CWN began by conducting comprehensive interviews with the 6 Canadian municipalities/utilities listed below.

- City of Vancouver (Vancouver, British Columbia)
- EPCOR Water Services Inc. (Edmonton, Alberta)
- Kitchener Utilities (Kitchener, Ontario)
- City of Ottawa (Ottawa, Ontario)
- City of Montreal (Montreal, Quebec)
- Halifax Water (Halifax, Nova Scotia)

CWN also included Toronto Water in the interview process in order to better assess considerations of best practices that would be most effective within the context of their BFPP program.

A structured questionnaire was developed to guide the interview process. The questionnaire is presented in Appendix A. Once the interview process was complete, CWN conducted a detailed analysis of each municipality's responses. Key elements of each municipality's prioritization approach were summarized in tables, which are presented in Section 2.2. Finally, a comparison and analysis of the interview results and the elements listed in the tables yielded the best practices listed in Section 2.3.

2.2 Comparison of Prioritization Approaches

The results of the interview and background analysis of the 6 municipalities/utilities considered in this study are summarized in Table 1 to assist in understanding how they compare, despite the difference in scope, maturity and approach. A comparison of the factors and criteria used in the prioritization process by each group is summarized in Table 2.

Table 1. Characterization of the different prioritization approaches used by municipalities/utilities to inform decision on stormwater actions and investments

Comparative Element	Municipality/Utility						
	City of Vancouver	**EPCOR (Edmonton)**	**City of Kitchener**	**Toronto Water**	**City of Ottawa**	**City of Montreal**	**Halifax Water**
Population (based on 2016 census rather than utility population served)	631,486	932,546	233,222	2,731,571	934,243	1,704,694	403,131
Approximate $ Size of the Capital Program(s) Specifically Related to Stormwater Management	No estimate available. Funding tied to Property taxes, which makes it very political. Currently considering development of a stormwater fee program. Also instituted a new Developer Cost Charge.	$50 million per year for stormwater. Will be increasing to $70 million per year in 2022.	$12.5 million per year.	Basement Flooding Protection Program (BFPP)-- $2.1 billion over 10 years.	$53.1 million per year (estimate based on 2019 capital spending on stormwater assets) This estimate is broken as follows: ▪ $1.1 million on non-linear stormwater management projects. ▪ $15.8 million on linear stormwater projects which include storm sewers and culverts but not combined sewers (combined sewers are typically managed as part of the sanitary assets). ▪ $36.2 million on the stormwater portion of integrated projects.	N/A (no specific stormwater capital programs identified – and integrated with sewage system issues) Note: Montreal does not have an approach that is as separate/ identifiable as the other municipalities. In general, recommended work elements have to be justified for funding.	$10 million per year.
Additional Context for Toronto Study: **Combined Sewers?** **Basement Flooding as Driver?**	Operating a Legacy combined system. City has 19 sewersheds that collect and convey to MetroVan (upper tier) who operate regional system and treatment. Still have many combined sewers– recognition that just completing sewer separation alone could cost $6-8 Billion was a driver in reorganizing the utility departments 2 years ago. Working with upper tier (Metro Vancouver) and province to eliminate CSO problem by 2050.	Have some combined sewers Home/basement flooding is a problem in some areas and degree to which that is a key risk for that particular sub-basin is factored into the risk framework – so captured rather than the primary driver. Flooding as a driver: ○ There was concern from the Climate Change Team at the City – flooding is now the highest risk event at the city but certainly in 10-years time once the risks are mostly addressed it	No Combined sewers Limited basement flooding – mostly resulting from high groundwater levels.	Have combined sewers Basement flooding has been a high-profile problem and resulted in BFPP.	From web site: 108 km of combined sewers 2,846km sanitary 2,700 km storm Basement flooding – yes – didn't pursue as to level of driver in interview.	Significant portion of the system is combined sewers. Basement flooding – Montreal has a fairly innovative inspection and information process for citizens to help them better protect themselves against basement flooding and, for example, to ensure that they have functional valves. As well, a municipal by-law has been in place for more than ten years to require the use of source control.	Have some combined sewers. Drainage fairly good – basement flooding not a major driver.

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		may not be the highest risk event and Council will have to make the decision on whether they should start investing in wildfire mitigation or ice storms.					
Governance + Lead Agency/ Department/Unit (Including Additional Context Considerations)	Lower tier municipality No stormwater utility Change to the overall structure of stormwater: City used to have a separate Sewage and Drainage Utility. Two years ago, the City embarked on reorg where they separated the Sewage and Drainage Utility into 2 divisions: Design, construction and operations division (manages the current system and current level of assets) Planning division (centralizes the planning of all water services) In addition, they created a **One Water** governance structure; all water-related initiatives get reported through this structure (One Water Steering Committee) Note: Vancouver is a Charter City so they have full control over building by-laws and plumbing code.	Integrated regulated utility Approval of the stormwater plan happens within the **One Water** business unit Financial approval of the stormwater plan goes to the Utility Committee and ultimately to City Council after the Committee has endorses it Note: EPCOR sees themselves as a "partner" in the community and there's information that only they can potentially know – so EPCOR's role is helping the customer in interpreting and understanding their risk so they can make informed decisions	Lower tier municipality Stormwater utility (wrapped into Kitchener Utilities (gas, drinking water, wastewater, stormwater)	Single tier municipality No stormwater utility Pluvial flooding: The City of Toronto leads work on the reduction and elimination of adverse impacts of wet weather flow on Toronto's environment. Under its Wet Weather Flow Master Plan, Toronto addresses both quality and quantity. The WWFMP and its guidelines direct the management of on-site stormwater management associated with development. The city addresses extreme events impacts and basement flooding risk (BFPP). Toronto also has responsibility to maintain state of good repair to stormwater infrastructure Fluvial and Lake flooding: TRCA has mandate to manage riverine and Lake Ontario flood risk (TRCA collaborates with City of Toronto and the province of Ontario to deliver this mandate)	Single tier municipality No stormwater utility Governance and decisions distributed across two main types of departments: ▪ Asset ownership, operation and maintenance ▪ Planning and growth The Infrastructure Services department, which includes the Asset Management group, is where decisions on stormwater assets are made. **Additional Note:** Recently completed an important mapping of assets and assessment of levels of service that puts Ottawa in a much better position to do planning	Single tier municipality No stormwater utility The densely urbanized island of Montreal is served by an asset that has been designed and in place for over fifty years. Over the past 10-15 years, the first and main priority for water infrastructure investment has been the management of the maintenance deficit. This has monopolized most of the investment to date and little has been dedicated to the functional aspect of sewer systems. However, in recent years, Montreal has been investing significant efforts to **evaluate the level of service of the networks** and the need for upgrading.	Integrated regulated utility Stormwater utility within integrated Halifax Water Utility structure The Stormwater utility functions as a fully independent component within the overall structure. Water Rate Structure (2016) identifies 4 components: water, wastewater, stormwater and fire supply Implemented new charge for stormwater services for properties not previously paying for it. Fixed fee for all applicable properties (Was previously part of part of sewer surcharge rate. Appears as separate charge for those not on the water utility).
Programs, Plans or Strategies Driving Stormwater Actions and Investments	▪ Rain City Strategy (city-wide strategy that conducted watershed characterization for rainwater) – tied to: ▪ Integrated Stormwater Management Plan (integrates across	▪ SIRP Framework: Stormwater Integrated Resource Planning	▪ Kitchener adopted a Stormwater Management Policy – established high level (mostly environmental) objectives ▪ Stormwater Master Plan (2014) developed	▪ Wet Weather Flow Master Plan (2003) ▪ Basement Flooding Protection Program (BFPP) -- 2006 ▪ Don River and Waterfront Project Plan	No single city-wide stormwater-focused master plan. Many standards and policies guide decisions on stormwater to varying extents, including:	City of Montréal does not currently have an approved plan or strategy based on a specific method for prioritizing investments and actions with regard to stormwater flood risk management. However, Montreal has begun work on a	Integrated Resource Plan (IRP) with underlying Asset Management Plan

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	public, private and parks) ▪ Land Use Plan (some stormwater prioritization occurs in tandem with land use planning initiatives) ▪ The Vancouver Plan: separate 3-yr plan for vision of City, included funding for indigenous planners – reconciliation a major priority for Vancouver. ▪ Integrated Liquid Waste Resource Management Plan (commitment to reduce CSOs under this Plan is a guiding factor) ▪ Public Benefit Strategy (specifies ties to specific planning areas)		as part of Master Planning to address policy.		▪ Wet Weather Infrastructure Management Plan ▪ Water Environment Strategy ▪ Watershed plans ▪ Secondary Plans ▪ Master Drainage and Servicing Plans ▪ Asset Management Policy and Plans ▪ Flood Control Program ▪ Ottawa River Action Plan ▪ Retrofit Master Plans ▪ Official Plan ▪ Infrastructure Master Plans under Official Plan ▪ Pollution Prevention and Control Plan ▪ Air Quality and Climate Change Management Plan	master drainage and wastewater collection plan. There are relevant existing high-level plans within which elements could be situated: E.g. From web site: Sustainable Montreal 2016-2020? http://ville.montreal.qc.ca/pls/portal/docs/page/d_durable_en/media/documents/plan_de_dd_en_lr.pdf	
Prioritization Concept and Approach	The Integrated Water Management Group (within the Planning Division) are the integrators and prioritize using 2 main, sometimes combined, approaches: ▪ **Reactive approach:** This is a purely risk-based approach where prioritization is based on risk and knowing which watersheds are known to have operational issues ▪ **Proactive approach:** This approach is opportunistic and done in cooperation with land use planning (e.g. initiatives that leveraged public investment in Rapid Transit Expansion to assess land use in the	▪ The SIRP (Stormwater Integrated Resource Plan) strategy is the prioritization approach used by EPCOR ○ Basically they use the 5 themes to structure everything now. Even on their capital projects moving forward, they'll say if it's the **slow, move, secure, predict or respond** ▪ Previously, there were 4 separate stormwater strategies underway: one for pluvial flooding, one for river valley flooding, one for underpass flooding, and one for	▪ The Stormwater Master Plan (SMP) identifies priority sub-watersheds and individual stream reaches (within each of these sub-watersheds) that require actions/ investments to improve based on a priority scale ▪ **Step 1:** Review the SMP, which allows the City to see where the big environmental risks are in their sub-watersheds ▪ **Step 2:** Once the SMP is reviewed and the priority sub-watersheds are known, the City uses this baseline information to layer on other prioritization factors (e.g. socioeconomic factors;	▪ **Step 1:** Under the BFPP, determine necessary projects by studying if locations are at risk of basement flooding against an enhanced level of service ▪ **Step 2:** If projects do not meet the enhanced level of service during existing conditions, solutions/ upgrades are recommended to achieve the level of service ○ Benefiting property: A property that does not meet the BFPP enhanced level of service during existing conditions, and proposed upgrades achieve the level of service	▪ Prioritization is a multi-tiered approach at the City – not only about what is highest risk, but also about opportunities and constraints ▪ More recently, the City is trying to leverage the databases and systems they have to identify projects for implementation ▪ **Main prioritization process:** Multiple factors could trigger a project (e.g. structural/ condition issue; performance issue; opportunities for asset renewal that coincide with other construction works)	▪ Over the last 20 years, the City has conducted ad hoc network study and investigation activities following major flooding episodes and for repeated flooding episodes ▪ More recently, the City of **Montreal is now piloting a major initiative to analyze areas at risk of flooding**, which is being funded by provincial authorities ▪ The initiative is focused on analyzing **riverine/fluvial flood risk** and involves the following tasks:	• Follows predominantly a proactive approach based on the asset management plan, with a reactive component, based on complaints and unforeseen critical failures. • **Proactive Plan:** The IRP includes a 30-year planning horizon that gets updated every 5-7 years. • The underlying asset management plan which informs the IRP and 5 year capital plan, is updated as new information on location and condition of assets, service levels,

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	impacted areas and work to support drivers such as affordable housing; various servicing scenarios are then developed for each initiative) ○ Within the proactive approach, they developed a **Decision Support Tool (DST)** with a number of different categories and criteria ○ The **DST matrix** is used to evaluate the different servicing tools that could be used to replace currently deficient systems ○ The servicing tools could be green or grey interventions ○ DST factors and criteria (see Table 2) are weighted; this process was the result of a survey that involved 12 agencies (e.g. health authority; regional government) ▪ Over time, they will continue refining the initiatives within each approach and recalibrating investments as needed ▪ Note: The Design, Construction and Operations Division prioritize through condition assessment and use their own algorithm for selecting candidates for replacement (using	environmental aspects of flooding. In addition, the two treatment plants had their own strategies ▪ During the development of the SIRP strategy, EPCOR was able to incorporate all of the above strategies into a single risk framework ▪ **The SIRP strategy segments Edmonton into sub-basins, which are a way to capture a large amount of data at a geospatial level for a particular sub-basin (Approx. 1300 sub-basins)** ○ Each sub-basin may have different datasets that are available to it, so EPCOR takes the best available data within each dataset and assess it within the sub-basin to define risk ▪ **The SIRP strategy used the City of Edmonton's risk grid** to inform it approach. The City's risk grid looked at 4 dimensions of risk: Health and safety, social, financial, and environmental (note, EPCOR had to downscale the risk dimensions in the City's grid so that they applied to individual sub-basins as opposed to the whole City level) ▪ To inform how each of the risk dimensions would be weighted in the overall risk grid, EPCOR engaged Edmonton residents in a	alignment with corporate strategies) ▪ Overall, step 1 applies the environmental lens which then allows the City to focus on applying other prioritization lenses in step 2. (Note: risk of flooding is not an explicit factor considered but costs/impacts from it considered in step 2 **SMP's Approach in Determining Priority Areas:** ▪ To identify priority sub-watersheds in the SMP, the City assessed the individual reaches within each sub-watershed based on five ***environmental factors***: ○ Stormwater management (i.e., assess whether there is sufficient stormwater management practice in place in each of the sub-watersheds) ○ Water quality ○ Stream health ○ Aquatics ecology ○ Terrestrial ecology ▪ Each of the above factors is scored individually from 1 to 5 ▪ Each score is assigned a specific definition within each factor (e.g. for stream health, a score of 1 indicates good quality stream health, while a score of 5 indicates poor quality stream health) ▪ Once each stream reach is scored on all 5 factors, the scores are added and	○ Note: This approach is absolute – proposed infrastructure upgrades must meet the full enhanced level of service (no flexibility for a reduced level of service) ▪ **Step 3:** The prioritization approach is applied. This involves calculating a cost per benefiting property and comparing this cost to the cost ceiling/ threshold of $32,000 per benefiting property (2011) ▪ **Step 4:** Properties that have a cost per benefiting property which are below the ceiling/threshold are added to the end of Toronto Water's 5-year capital plan and assigned for preliminary design. Project Prioritization Within 5-yr Capital Plan: Per August 2011 City Council Directives - the prioritization of Basement Flooding Protection Program projects be consistent with the principle that the greatest number of properties are protected as soon as possible within approved funding envelopes and coordinated with other City capital programs. ▪ The prioritization approach was developed through internal strategic planning and consultation, and was approved by Council ▪ The $32,000 cost threshold is based on 1) household water rates	▪ **Additional prioritization lens:** The financial process, including budgets, tax and rate, and budget envelopes – all of which play a role in the prioritization of projects ▪ **In addition, different departments have their own prioritization approaches** that layer onto the above approaches ○ For example, the Asset Management group applies the Capital Project Valuation Assessment to certain projects, which provides a consistent approach to project prioritization across asset classes ○ The **recently completed City-wide Flood Risk Profile (FRP)** provides the Asset Management group with a way to prioritize that is transparent and evidence-based; the FRP provides more level of service information on every house and every pipe in the City	○ Review and optimization of emergency measures to be implemented to protect citizens residing near the shoreline during water level rise around the island of Montreal (led by fire department) ○ Diagnosis of the network of outfalls and the development of corrective measures when watercourse water levels may generate flood risk ○ Development of intervention plans at the local level to better protect flood-prone areas along the riverbank ▪ A prioritization of interventions may be developed once the results of this initiative are finalized and provincial policies are specified Pluvial Flooding focus: ▪ In parallel with the above initiative, the City has begun an initial analysis of prioritization that considers the **prioritization of drainage basins** based on a simplified analysis of the collection network capacity and a statistical analysis of claims and rainfall history	replacement value, etc. is collected. • The levels of service is a key metric to determine upgrades are needed, and are in most cases based on industry accepted design standards for minor systems, combined systems, major systems, pre- and post development flows, etc. • Based on a risk matrix in the asset management plan, they identify and prioritize which assets require renewal. **The risk matrix includes regulatory, performance, health and safety, environmental, and financial factors,** in order to prioritize consequence of failure • Based on the asset management plan, approximately 10 million is allocated each year for asset renewal based on ranking of higher risk assets • **Reactive approach:** complaints are also captured within the plan to guide prioritization • Note, if complaints are related to the level of service, this doesn't trigger an upgrade or change in prioritization; they only update if the established level of service is not being met. • For example, combined sewers have a low level of service, but currently

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	information from their customer complaint system and video inspections of the sewer system)	comprehensive survey where residents were presented with scenario statements and asked to pair-match what they would protect most versus protect least ○ There was a total of 7 statements for each of the 4 risk dimensions and for 3 levels of risk ▪ A unique approach that EPCOR took is the step-wise identification of flooding solutions through a *desegregated risk analysis* ○ Instead of grouping all the assessment factors together when defining risk or solutions, EPCOR assesses each factor individually through its own lens; the top score in any one of the individual factors is what drives the risk ranking ○ This approach to risk analysis allows EPCOR to undertake incremental improvements (e.g. if the highest risk component in a particular sub-basin is the risk of drowning, then mitigating this risk will drop the risk level for the whole sub-basin – even if other, lower-risk components still remain such as the risk of infrastructure damage) ▪ EPCOR conducted the desegregated risk analysis then gave the Utility Committee 3 options on how to combine the risks:	it is then placed into one of 4 priority scales (e.g. any stream reach that exceeds a score of 20 is automatically in Priority 1) ▪ Finally, the City starts working to address each stream reach starting from the highest priority (Priority 1) to the lowest priority (Priority 4) ▪ Environmental risk is a significant component in identifying priority areas that would require stormwater management actions. However, decisions on which actions/ investments are implemented follow a different prioritization process ▪ Within each priority level, the highest scored (i.e., most environmentally at-risk) stream reach is not necessarily the one the City addresses first. Stormwater actions and investments are driven by a different prioritization process or layer of factors/ considerations, including financial and strategic factors Climate change lens becoming a bigger priority in considerations	and 2) a reasonable return on investment or payback period per benefiting property ▪ The cost threshold test is applied twice: First using cost estimate generated at the end of the study phase; Second at the completion of the preliminary design phase ▪ Projects that exceed the cost threshold are entered into the BFPP's backlog for future consideration on an opportunistic basis; they are not entered into the 5-year capital plan and not funded)		▪ The City is also working on a Drainage and Wastewater Collection Master Plan – with the aim of evaluating level of service of the current networks and assessing the need for upgrades **Notes on justifications/ rationale for capital investments to date in collection system repair/upgrades**: Based on recommendations from analyses over recent years, some upgrading work has been or is being carried out. To date, four main factors or cases have made it possible to justify and implement interventions: • High cost-effectiveness of relatively minor intervention that eliminates localized cases of repeated flooding (often in connection with a location with low point topography); • opportunity resulting from the redevelopment/ development of an urban sector instead of an intervention –could justify the implementation of this intervention in the short or medium term; • In the case of recommendations to install large underground retention structures to reduce the risk of flooding, the advisability of adapting the management of the	they mainly separate them opportunistically when other road works are being undertaken. • Revisiting the definition of levels of service would happen at the IRP planning stage.

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		○ Option 1: All 4 risk dimensions are weighted equally ○ Option 2: Financial risk is weighted more than all other risk dimensions ○ Option 3: Health and safety and social risks are weighted more (this option was based on the public survey results) ▪ The Utility Committee picked Option 3 ▪ For the overall prioritization approach, Council approves the methodology for prioritization but it's up to EPCOR to manage the projects that qualify within that prioritization approach ○ So if many projects qualify, then there's a discussion with Council about the funding envelope and which projects should be undertaken first ○ These risk categories shown are used by EPCOR and City Council to assess whether they should move down the list of categories or spend longer on a given category ○ Within each category, it is important to note that not all high risk or medium risk areas are the same in the way their risk is mitigated; solutions are tailored based on the specific conditions and needs of each area	Council can have a strong influence on the types of projects that get selected			structure to reduce the overflowing of the combined sewer system during frequent rainfall was a justification for financing its construction in the short term; • Also, the case of portions of sewer networks in a state of advanced degradation or the case of significant road repair work offered an opportunity for intervention and upgrading of the local network (resizing of pipes).	

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Drivers for Developing Prioritization Approach	▪ Risk mitigation ▪ Finding opportunities with other departments (starting with the reorganization and integration that the City embarked on 2 years ago)	▪ The main driver was a mandate from their City Council to complete this work (Council Directive); Council was concerned about the increased insurance risk, increased occurrence of flooding, and were generally focused on climate change adaptation ▪ Another driver for undertaking the SIRP process is that this approach was part of bringing the Drainage department from the City over to EPCOR	▪ The City developed a Stormwater Management Policy that informed the development of the Stormwater Master Plan and its approach to identifying priority sub-watersheds ▪ The Stormwater Management Policy articulated several environmental objectives that the City incorporated into the Master Plan, such as: ○ Meeting water quality targets ○ Reducing contaminant loading to surface waters ○ Improving stream and riparian habitat ○ Maximizing use of source control with pollution prevention and infiltration (e.g. LID practices)	▪ Prioritizing City of Toronto funds based on benefiting the largest number of properties ▪ Ensuring cost certainty – the cost threshold enables the City to maintain annual capital costs and limit costly projects	▪ Asset Management ▪ Financial sustainability ▪ Risk Management ▪ Pollution prevention and control ▪ Flood control ▪ Extraneous flow control ▪ Erosion control ▪ Water quality control ▪ Regulatory compliance	**Fluvial flooding**: major spring flooding episodes occurred in 2017 and 2019 bringing significant attention to the need for intervention, but for a relatively small, but sensitive area. These episodes also raised awareness/concern provincially as they caused flooding conditions for many municipalities in Quebec, many of which were much more affected than the City of Montreal. -- has led to a major, provincially led and funded exercise to analyze flood risk along waterways. Montreal is developing some activities in response to this work. **Pluvial/storm flooding:** See above – this work beginning to be larger component of Montreal's work; mainly more of reactive and catch-up on deferred maintenance.	• Halifax Water was asked in 2007 to take on drainage and stormwater needs, along with wastewater. Stormwater needs were integrated into the utility. • One of key drivers is intergenerational equity – through investment in the asset management program, to maintain system assets to target service levels • Has a role in maintaining clear lines between the utility and the municipality – e.g. prioritization process is clearly laid out and defensible, and any upgrades outside of that process go through the Utility Review Board and a discussion with HRM, particularly as it relates to covering costs to system upgrades and renewal.

Table 2. Factors and criteria assessed within the prioritization approach used by each municipality/utility

Factor Considered to Prioritize Stormwater Actions & Investments (i.e., Prioritization Factors)	**Municipality/Utility**						
	City of Vancouver	**EPCOR (Edmonton)**	**City of Kitchener**	**Toronto Water**	**City of Ottawa**	**City of Montreal**	**Halifax Water**
Physical Flood Risk		✓ *Size of area affected by flooding impacts *Frequency of flooding	✓	✓ *Flood risk for each area assessed against enhanced level of service	✓ *Size of area affected by flooding impacts *Frequency of flooding	✓ *Frequency of flooding and insurance claims the only criteria used to date	✓
Cost Ceilings	✓ *Capital and operating cost (cost effectiveness and efficiency)			✓ *Cost ceiling/threshold per benefiting property of $32,000	✓		
Property Type/ Basement Apartment Location		✓			✓		
Population Density		✓	✓				✓ *Size of benefitting area, if there are two competing projects
Socioeconomic Factors	✓ *Community benefits (community health and accessibility/active mobility)	✓ *Socioeconomic equity impacts (used IPCC recommended categories) *Socioeconomic service impacts	✓ *Socioeconomic service impacts		✓ *Socioeconomic equity impacts *Socioeconomic service impacts		✓ *Health and safety is a criteria in the risk matrix for prioritization, including impacts to emergency services and critical customers, but otherwise don't explicitly consider these factors, e.g. low-income neighbourhoods, etc.
Municipal Assets	✓ *Reliability of the servicing intervention *Feasibility (constructability and implementation ease) *Resiliency	✓			✓ *Level of service		

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	City of Vancouver	**EPCOR (Edmonton)**	**City of Kitchener**	**Toronto Water**	**City of Ottawa**	**City of Montreal**	**Halifax Water**
Critical Infrastructure		✓ *Used IPCC recommended categories			✓		✓
Historical Flood Report Location and/or Density		✓			✓		✓
More Sophisticated Risk Calculations (e.g. Cost-Benefit Analyses; Return on Investment Calculations)		✓ *Considered when funding released for each project (to assess alternatives to achieving project objectives)			✓		✓ *Cost-benefit analysis to ensure overall affordability
Political and/or Legal Considerations		✓			✓		
Alignment with Current Corporate Programs, Policies and Strategies			✓				✓ *Implicit in the prioritization approach guided by the Integrated Resource Plan (IRP)
Ability to Leverage Government Grants			✓				
Other	✓ *Reconciliation *Environmental benefits *Ecosystem health	✓ *Health and safety benefits *Environmental impact of flooding *Cost to homeowners and/or the municipality	✓ *Health and safety benefits *Alignment with current corporate programs, policies and strategies *Ability to leverage government grants		✓ *Cost to homeowners and/or the municipality *Health and safety benefits *Environmental impact of flooding		✓ *Environmental benefits *Regulatory considerations

One of the goals of this comparative study was to collect and compare best practices used by the different cities in applying criteria to prioritize their work, project selections and investments. The study results made it clear that not only do different cities use different criteria and at different levels of objective formula vs staff decision-making approaches, but they also apply them at different stages of the process as illustrated in Figure 1, below. A comment repeated by a number of the interviewees was that they use many/all of the factors and criteria presented as options in questionnaire, but they apply them to differing degrees in different parts of their decision-making process and not always as formal criteria or considerations. Those who shared specific decision matrices, generally shared risk-based ranking frameworks. Table 2 (above) provides an attempt to capture where each of the utilities/cities indicated the use of the individual criteria featured significantly within their project prioritization process.

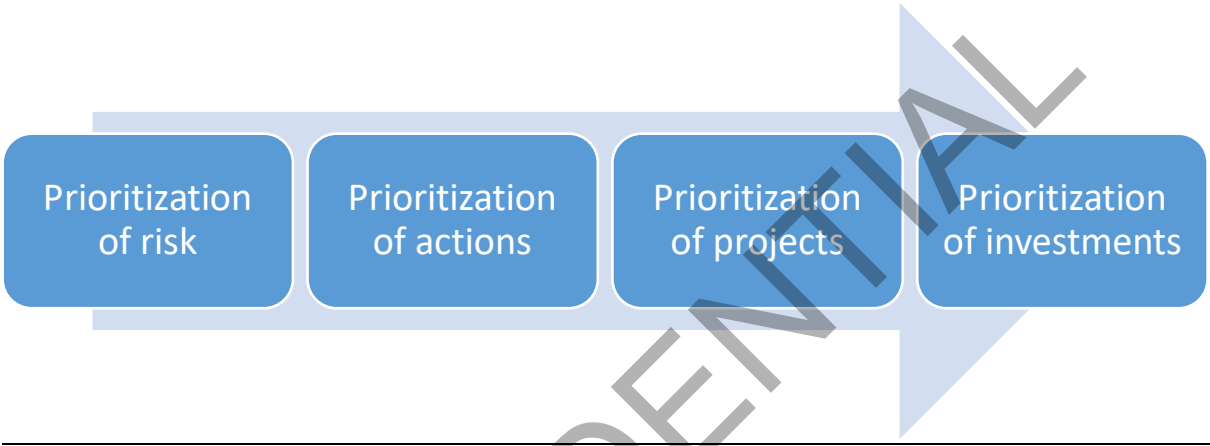

Figure 1. The different stages at which prioritization factors and criteria are applied within the municipalities/utilities that were interviewed for this project

A summary of the key challenges or lessons learned by each of the 6 municipalities/utilities in developing and implementing their prioritization approaches is captured in Table 3.

Table 3. Observations of key challenges or lessons learned in the development and implementation of each prioritization approach

Key Challenges and Lessons Learned	Municipality/Utility						
	City of Vancouver	**EPCOR (Edmonton)**	**City of Kitchener**	**Toronto Water**	**City of Ottawa**	**City of Montreal**	**Halifax Water**
Challenges/Lessons Learned in Program Development	There were some challenges – especially in the early phases of the Rain City Strategy: ▪ Because of how far-reaching the impacts would be to manage rainwater (changing land use, changing building forms, changing the amount of pervious areas), this impacted the private realm quite significantly – so had to work with their private realm partners ▪ For parks realm, Vancouver is very parks deficient in the City – so the challenge encountered by the parks partners was how to create parks in a developed environment → so, to manage rainwater, they have less space to work with to implement the program ▪ Response: To manage that across the City, they created a One Water governance structure	○ It was challenging to get everyone comfortable with the benefits of achieving incremental risk reduction and moving away from system component-based design storm standards (i.e., understanding that it's okay to aim for what's reasonable from a risk perspective) ○ Storms are not perfect circles of intensity when they manifest locally. Understanding how storms manifest at the local level is critical for the effective design of prioritization approaches and solutions	○ N/A	○ Political pressure to implement the rule (i.e., $32,000 cost threshold) and ongoing political pressure to change the rule	○ An ongoing task is the coordination of policies, strategies and departments – a tough challenge, but successful coordination is where the opportunities and optimization could be found	○ The City does not currently have a prioritization approach in place – this is primarily because the past 10-15 years have been focused on the management of the maintenance deficit for water infrastructure. In recent years, the City has been investing in evaluating the level of service of networks and the need for upgrades	• **Clarifying responsibility:** Due to Halifax Water's utility model, contractual responsibility is more clearly defined, e.g. in establishing the expectations for the what the utility is responsible for, vs what the municipality is responsible for. • **Establishing System Targets:** Based on goals set in IRP –Integrated Resource Plan -- (influenced by both internal and external factors), the program is funded adequately. However, if consider new goals or higher level of service, such as fully separating combined sewers, this would be a financial challenge.

Key Challenges and Lessons Learned	Municipality/Utility						
	City of Vancouver	**EPCOR (Edmonton)**	**City of Kitchener**	**Toronto Water**	**City of Ottawa**	**City of Montreal**	**Halifax Water**
Challenges/Lessons Learned in Program Implementation	○ N/A	○ Accepting that crossing the public-private divide could be uncomfortable, but that it could yield significant benefits – it's important to recognize that utilities can invest in assets which are on private property and this could be done on a case-by-case basis with a right-of-way covenant (to specify who maintains the asset, etc.)	○ The potential for clashing priorities between stormwater management initiatives and other initiatives (e.g. cross-topic areas or cross-divisional policies) – this is an ongoing challenge for the prioritization of stormwater infrastructure solutions that need to be implemented	○ Updating the $32,000 cost threshold for the BFPP while maintaining equity is an ongoing challenge ○ The cost threshold treats all properties the same way and is therefore ill-suited for downtown Toronto due to the high density of buildings and multi-unit dwellings ○ The cost threshold is simplistic and does not take into account the greatest impact based on highest hazard risk, greatest return on investment, or factors such as population density	○ Same as above	○ N/A	• **Public Communication:** The challenge has been related to public understanding of the established service levels. For example, from the utility's point of view, some street flooding is acceptable. • Overall, Halifax doesn't have major flooding issues, so no major operational challenges.

2.3 Best Practices and Key Considerations for Stormwater Prioritization

The following subsections highlight the best practices that emerged from the interview process. They also present key considerations in the development and implementation of stormwater prioritization approaches.

Risk-Based Approach to Prioritization

Most of the interviewed municipalities use an overarching risk-based approach to prioritize stormwater actions and investments. The way in which each municipality's risk-based approach is applied to a prioritization process varies; some municipalities use it to prioritize flood protection activities, while others use it to prioritize areas in need of work or to select and sequence flood mitigation projects. In addition, the municipalities vary significantly in the extent to which their risk-based approach is explicit and codified.

Each municipality is at a different stage in their development of a risk-based approach. For example, EPCOR's recently developed Stormwater Integrated Resource Plan (SIRP) is a progressive model in North America and represents the most mature and comprehensive prioritization approach explored in this project. Meanwhile, Montreal is actively in the early stages of developing a proactive stormwater management prioritization approach. Below is a summary of the key elements of the risk-based approaches undertaken by the municipalities interviewed for this project.

In developing the SIRP framework, EPCOR took a unique, stepwise approach in the identification of flood mitigation options. This approach involved conducting a desegregated risk analysis whereby flood risk factors are assessed individually instead of being grouped together when defining risk or mitigation options. Then, using this individual assessment, the top score in any one of the individual risk factors is the one that drives the risk ranking for the entire sub-basin. This approach of assessing flood risk factors individually and through their own lens allows EPCOR to undertake incremental improvements in sub-basins so that the highest risk factors are prioritized in the identification of mitigation options for each sub-basin. For example, if the highest risk factor in a given sub-basin is the risk of drowning, then mitigating this risk would drop the risk level for the whole sub-basin even if other, lower-risk factors still remain (e.g. the risk of infrastructure damage).

EPCOR's risk-based approach goes further by characterizing all SIRP projects using the five major themes listed below. Each of the themes has a specific budget allocated to it, with the *slow* theme making up about 50% of stormwater investments and *move* making up about 25%. Note, projects could be characterized under one or multiple themes depending on the mitigation objectives that they achieve.

- **Slow:** Projects that focus on slowing the entry of stormwater into the drainage system by absorbing it using green infrastructure and holding it in ponds. This creates space in the collection system during storm events.
- **Move:** Projects that move excess stormwater safely away from areas at risk, ensuring that this is done quickly and efficiently.
- **Secure:** Projects that secure individual properties in higher risk areas against sewer backups, pluvial flooding and fluvial flooding.
- **Predict:** Projects that integrate smart sensors and technologies into the collection system to predict and manage the movement of stormwater.

- **Respond:** Projects that focus on providing emergency response equipment to ensure the fast rollout of flood barriers, traffic diversions and public communications to protect life, safety and property.

For the SIRP framework to function fully and effectively, EPCOR is ensuring that it invests in all five of the major themes. Susan Ancel, Director of One Water Planning at EPCOR, stated that *slow* projects typically represent green infrastructure solutions and *move* projects represent pipe-based solutions, but that the SIRP framework does not work unless EPCOR also invests projects under the *secure*, *predict* and *respond* themes.

The City of Ottawa has recently developed a city-wide Flood Risk Profile (FRP) that enables transparent, evidence-based prioritization of future needs in areas that are at risk of flooding. The development of the FRP was driven by a recognition that the completeness of flood risk information varies considerably for different events and different locations, which results in an incomplete understanding of public-side flood hazards across the City. Recognizing that the completion of a storm, sanitary and major system flood hazard study via computer models would be prohibitive in terms of time and resources, the City sought to create a method for 'filling in the blanks' with respect to flood risks. They leveraged knowledge from completed flood studies and GIS techniques developed by the City's water resources engineers to calculate the flood risk for public-side flood hazards for each building in the city. This resulted in the creation of a profile of risks for each building in the city. In order to develop a profile of risks for each building in a reasonable amount of time, the City developed proxies for real flood risk. The proxies were developed using the City's knowledge of how homes flood and how municipal infrastructure behaves. This approach uses just enough factors to get a fit-for-purpose estimate of flood risk without requiring detailed studies. It is fundamentally risk-based; the approach is driven by a need to assess risk in a reasonable amount of time when "one does not know the answer for sure but when doing nothing is not an option". The FRP provides the City with better information on the current level of service and wet-weather performance of every building and every pipe. It will continue to be improved as more and better information becomes available, but it allows the City to start prioritizing actions and investments now in a transparent, evidence-based way.

The City of Kitchener emphasized in their interview that although they apply all the benefit/impact criteria listed in the questionnaire to some extent, they primarily focus on applying a 'risk lens' to guide decision-making for stormwater actions and investments. The City's key consideration is how much risk they could reduce or pull out of the system.

Halifax Water's stormwater prioritization approach is integrated into their Asset Management Plan. When prioritizing actions and investments, Halifax Water uses a risk matrix to prioritize the consequence of failure of specific assets. This includes assessing factors such as asset condition, cost to replace and the impact of upcoming regulation. Overall, the approach is shaped by the risk of asset failure.

The City of Montreal is in the early stages of piloting an initiative to analyze areas at risk of flooding. The initiative is assessing fluvial flood risk through the review and optimization of emergency measures to protect citizens, diagnosis of the pipe network and development of corrective measures in areas at risk of fluvial flooding, and the development of local level intervention plans to better protect flood prone areas. The City anticipates that an approach for prioritizing actions may be developed once this assessment is complete.

Increasing Trend in the Use of Integrated Plans to Inform Capital Program Objectives

In general, municipal practice and/or structure in Canada is trending toward more integrated plans that frame the development of capital program objectives. In general, the degree to which municipalities participate in this trend varies. However, integration is increasingly taking place at the upper levels of municipal governance structures or within planning units to determine approaches to proactive asset management and clarify required levels of service.

There is an overall increase in integration at the planning stage. However, once the objectives are set through municipal plans, there can be a pivot in terms of how solutions are identified at the operational level, depending on which operational group is leading project implementation. Below are a few examples from the interviewed municipalities that highlight how they have adopted integrated planning within their governance structures.

EPCOR's SIRP framework is driven by an integrated approach to decision-making. Prior to the development of the SIRP, there were four separate stormwater strategies underway: A pluvial flooding strategy, a river valley flooding strategy, an underpass flooding strategy and a strategy for managing the environmental impacts of flooding. Additionally, each of the two wastewater treatment plants in Edmonton had their own stormwater strategies. During the development of the SIRP framework, EPCOR incorporated each of these individual strategies into a single, integrated risk framework.

The City of Vancouver has created a One Water governance structure, led by a steering committee, through which all water-related initiatives get reported. In addition, the City's Planning Division centralizes the planning of all water services. Within the Planning Division, the Integrated Water Management Group prioritize using the two approaches listed below.

- **Reactive approach:** Risk-based approach where prioritization is based on risk and knowledge of watersheds with historical operational issues.
- **Proactive approach:** Opportunistic approach involving cooperation with the Land Use Planning Unit where a Decision Support Tool is used to prioritize options for providing water services (note, both green and grey interventions are considered).

These approaches ensure that, as growth and rehabilitation occur in a given watershed, they would be guided by an integrated water management plan that is unique to the watershed. Ultimately, the integrated One Water structure that the City recently implemented has enabled them to find more opportunities and synergies with other departments.

The City of Kitchener used integrated planning in its development of the Integrated Stormwater Management Master Plan. The Plan provides an initial lens in the prioritization of stormwater actions and investments. The elements of the Plan were developed with an emphasis on integration. This emphasis ensured that City goals – such as increasing urban tree canopy, constructing new trails and cycle lanes, improving transit and rehabilitating parks – could also serve to improve stormwater management through improved coordination and the leveraging of economies of scale (City of Kitchener, 2016). The Plan's integrated approach resulted in the identification of priority sub-watersheds and individual stream reaches that require actions and investments.

Halifax Water has an Integrated Resource Plan (IRP) which, in combination with their asset management plan, guide their stormwater actions and investments. The IRP outlines the assets owned by Halifax Water,

as well as the condition of each asset and the requirements for maintaining its condition to deliver a target level of service. It defines asset classes, replacement value and targets for a 30-year planning horizon. The IRP is also updated every 5-7 years and the updates are informed by the latest information from Halifax Water's Asset Management Plan.

Using Impact Reduction and Benefit Objectives to Determine Levels of Service

There are two differing approaches to the structure and operation of municipal systems that impact how the prioritization of stormwater actions and investments is conducted. The first approach involves the use of traditional engineering methods to attain clearly articulated design standards for system components where industry-established standards comprise clear level of service objectives. Using this approach, an example of a design standard would be that storm pipes have to provide protection from a 1:100-year storm. The second approach involves the use of risk and impact considerations to implement incremental risk-reduction measures. This approach uses impact reduction and benefit objectives, rather than system component design standards, to determine program objectives and levels of service. In general, there is an inherent tension between these two approaches when it comes to the structure and operation of municipal systems. Municipalities across Canada are at different stages in addressing these differing approaches in their structure and operation. EPCOR's use of impact reduction and benefit objectives to determine levels of service is highlighted below.

One of EPCOR's key findings in developing the SIRP framework was the importance of considering a range of design storms in determining levels of service instead of basing level of service objectives on a single design storm. Figure 2 depicts EPCOR's approach to assessing design storms. Instead of focusing on bringing a single design storm (represented by a given dot in Figure 2) to the point where it becomes zero-risk, EPCOR's approach focuses on shifting ranges of design storms (i.e., clusters of dots) such that there is an incremental decrease in risk. This approach is driven by impact reduction, using it to determine level of service objectives. The approach also allows EPCOR to focus on incremental risk reduction, an approach which fundamentally recognizes that not all risk can be mitigated right away; given that there is a limit to the number of mitigative actions and investments, this approach focuses on the reduction of the highest component of risk within each sub-basin and then incrementally reducing the risk posed by lower-risk components. The approach allows EPCOR to provide immediate risk reduction for each sub-basin rather than focus on reducing all risk for a few sub-basins at a time.

In addition, EPCOR has found that considering a range of design storms yields a better understanding of risk exposure over the lifetime of a property, which is the key factor considered by property owners and insurers. EPCOR has found that assessing the likelihood of occurrence over a spectrum of storms and over time leads to more targeted flood mitigation solutions (i.e., solutions which go beyond pipe-based options). Table 4 presents how the range of design storms is incorporated into the SIRP framework through a likelihood scale.

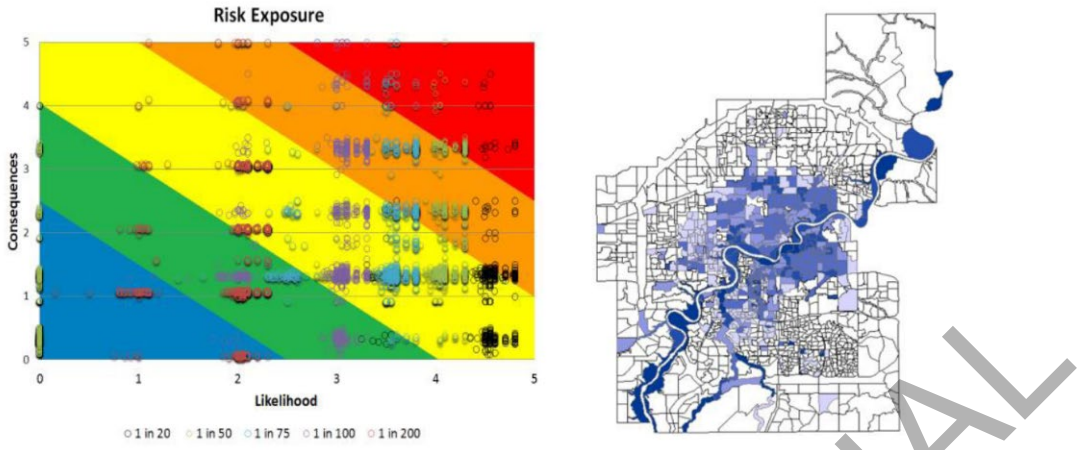

Figure 2. The range of design storms assessed in EPCOR's SIRP framework. This approach was undertaken for each of the four risk dimensions: Health and safety risk; environmental risk; financial risk; social risk. The map on the right highlights the sub-basins which are at risk over multiple design storms for the health and safety risk factor

Table 4. The range of design storms considered in the development of EPCOR's SIRP framework. The SIRP likelihood scale is developed by considering both the design storm and the respective likelihood of its occurrence over time

Storm Scenario	Percent Likelihood Over Time			SIRP Likelihood Scale
	In One Year	Over 30 years	Over 100 years	
1:20	5.00%	78.54%	99.41%	4.5
1:50	2.00%	45.45%	86.74%	4
1:75	1.33%	33.15%	73.88%	3.5
1:100	1.00%	26.03%	63.40%	3
1:200	0.50%	13.96%	39.42%	2

Identifying Low-Lying Areas and Basins

Of the municipalities interviewed, several have found that the identification of low-lying/sag areas or basins in their systems was helpful in prioritizing stormwater actions and investments. Specifically, they have found that the identification of low-lying areas resulted in a high correlation with areas that had experienced priority problems, complaints and/or risks. Ultimately, regardless of the prioritization approach used, areas around homes and buildings which are prone to the pooling of floodwaters typically posed the biggest issues for built environments.

EPCOR's SIRP framework has fully incorporated the assessment and identification of low-lying areas. EPCOR identified approximately 1,300 unique stormwater sub-basins across Edmonton, each of which is analyzed and risk ranked based on the characteristics of the sub-basin. Initially, EPCOR identified 1,200 sub-basins but the number has since increased due to the additional segmentation of sub-basins with surface topography that results in a portion of the sub-basin having a trapped low area where water could pool after a storm. These trapped low areas are now identified as unique sub-basins under the SIRP framework. The additional segmentation of sub-basins to identify low-lying areas was done to reflect the greater risk of flooding to adjacent properties that could be caused by the pooling of water after a storm (EPCOR Water Services Inc., 2018). Additionally, EPCOR reviewed flood hazard maps generated by the insurance sector and found that there is a high correlation between the insurance map indications of risk and the utility's known basement flooding problem areas. These problem areas tend to be located where development has occurred over old creeks and lake beds.

Increase in Direct Engagement of Customers

Increasingly, municipal planning and programs are involving direct engagement of the public/customers in determining priorities. In general, ranking or weighting exercises involving public engagement tended to reveal public support for the prioritization of health and safety risks. This approach provides for better public and council support of budget and project selection that is guided by the public's input. Below are a few examples of the use of customer engagement in municipal prioritization approaches.

EPCOR views their utility as a partner in the community. They see a key aspect of their role being to help customers interpret and understand their risk to flooding in order to be able to make informed decisions. When developing the SIRP framework, EPCOR used the City of Edmonton's risk grid to inform the dimensions of risk on which prioritization of actions and investments is based. A total of four risk dimensions were used to assess risk for each sub-basin: Health and safety risk; social risk; financial risk; environmental risk. In terms of informing how each of the risk dimensions is weighted in the overall risk grid, EPCOR engaged Edmonton residents in a comprehensive survey about flood impacts in August 2018. The survey presented residents with scenario statements and asked them to pair-match what they would protect most versus what they would protect least. The survey and its results are presented in Appendix A of EPCOR's October 2018 report to the Utility Committee (EPCOR Water Services Inc., 2018).

Once EPCOR conducted their desegregated risk analysis, they provided their Utility Committee with three options for combining the risk dimensions into an overall risk score:

- Option 1 – All four risk dimensions are weighted equally
- Option 2 – Financial risk is weighted more heavily than the other risk dimensions
- Option 3 – Health and safety risk and social risk are weighted more heavily than other risk dimensions

Option 3 represents the weighting scheme that was informed by the results of the public survey. The Utility Committee ultimately picked Option 3 and this weighting scheme now guides all sub-basin risk rankings.

In terms of sharing flood risk information with the public, EPCOR is the only utility of those interviewed that is sharing its assessment of flood risk with the public, including publishing the flood risk maps for each risk category and for each of the five assessed storm scenarios (see Appendix B in EPCOR Water Services Inc., 2018). Currently, EPCOR is not using disclaimers to obtain and share data.

The City of Kitchener's development of its Integrated Stormwater Management Master Plan involved a comprehensive consultation plan which focused on obtaining public input and improving citizen participation. The intent of the Plan was to move public engagement beyond a process of presentation and feedback. As such, public engagement focused on community visioning and used interactive approaches to secure valuable insights and ideas. Public Open Houses featured zones which offered the public an opportunity to share vision and ideas as to how stormwater management could be improved in their neighborhoods, on their property and in their community. Local stakeholders, agencies and the development community were also invited to participate in the Public Advisory Committee and through the City's Environmental Advisory Committee (City of Kitchener, 2016).

Increase in Actions and Investments that Cross the Public-Private Divide

The majority of actions and investments considered by municipal prioritization programs deal with municipally owned or publicly owned land and assets. However, some programs are beginning to look at how and when explicitly coordinating actions and investments on privately-owned property provides a more effective risk-reduction solution. EPCOR is the only utility of those interviewed that has explicitly included the consideration of actions and investments on privately-owned property in its 5 major themes that classify flood mitigation actions. The *secure* theme involves securing individual properties in higher risk areas against sewer backups, pluvial flooding and fluvial flooding – which sometimes involves undertaking projects on privately-owned property. EPCOR has stated that if flood proofing individual properties was a more economical means of protection for a sub-basin than utility infrastructure, then the utility may propose investments on private property in the future (EPCOR Water Services Inc., 2018).

So far, the majority of investments that fall under EPCOR's *secure* theme involve maintenance rehabilitation, inflow and infiltration (I/I) reduction, and enhanced building flood proofing. Enhanced building floodproofing is the main investment category which may involve actions on privately-owned property. This category includes funding to upgrade public-side lot grading in conjunction with private-side improvements and is available to residential, multi-family and commercial properties. Private-side improvements are focused on the properties which EPCOR has identified as being at increased risk of basement flooding due to surface ponding (i.e., the properties falling in low-lying/sag areas). For these properties, EPCOR is undertaking floodproofing through a 2-step *secure* investment by (1) installing backwater valves at these properties and (2) undertaking I/I reduction adjacent to these properties, including sealing manhole barrels and ensuring catch basins are connecting directly to the storm sewer system.

3. Summary of Best Practices and Considerations for Toronto Water

3.1 Summary of Analysis of Best Practices for Prioritizing Stormwater Investments

- Most cities use an **overarching "risk-based framing" approach** to prioritize flood protection activities, prioritize areas in need of work, and select or sequence projects. They vary significantly in how explicit and codified those approaches are and the 7 cities considered in this study are at differing stages in their development. EPCOR's recently-developed Stormwater Integrated Resource Plan (SIRP) is being referenced as a leading model for North America and likely represents the most mature and comprehensive of the Canadian examples (i.e., works from city-determined risk-grid and vulnerability frame right down to project sequencing and selection). Montreal is actively in the earliest stages of developing an approach among the 7 cities considered and is very interested in sharing peer results to help them advance.

- There is an overall national trend in practice and/or structure of water utilities and city departments toward **more integrated plans** that frame development of the objectives driving capital programs. Practical response to/involvement in this trend varies considerably among cities, but increasingly, this integration takes place at the upper level or within planning units to determine required approaches to proactive asset management and to clarify required levels of service for the programs' operational levels. In general, there is increasing integration at the planning/goals stage, but, once the objectives are set through the plans, there can be a pivot to divergence in the various solutions identified at the operational level, depending on which operational group is implementing projects.

- There exists an **inherent "tension" in the structure and operation of municipal/utility systems** between a) traditional engineering approaches driven by attainment of clearly articulated, design standards for system components (e.g., pipes provide protection from 1:100 flood) where industry-established standards comprise clear level-of-service (LoS) objectives, and b) incremental risk-reduction approaches driven by risk and impact considerations, where impact reduction and benefit objectives, rather than system component design standards, determine program objectives and levels of service (LoS). The second approach to determining LoS objectives –i.e., **using equity of impact, rather than equality of investments** –represents a newer approach for municipal water utilities and represents the general trend of where the sector is heading. Until there is more familiarity and clarity in how equity of risk and impact is determined, this approach may be challenging for some as it may be seen to be less equal/objective in levels of service provided to different customers. However, it is, by definition, more equitable in the way it prioritizes risk and recognizes impact and more suited to an overall resilient city approach as a result. It is also an approach that is likely to be better supported by explicitly engaging the public in determining the approach and/or formula determining how risks and impacts should be prioritized. For example, when designing and implementing its new SIRP, EPCOR found that engaging the public in determining the weighting of risk categories resulted in greater buy-in from their Utility Council and City Council. Note: in our discussions at CWN, we find the use of "Levels of Service" terminology can mean different things to different people within the water sector. Cities across Canada are at different stages, often reflecting different overall management cultures, in addressing this difference in approaches and operation.

- At its most basic, several urban flood prevention schemes have found that identifying **low-lying areas, basins, "soup bowls" or "sags"** in their systems that contained significant development or infrastructure was helpful and had a high correlation with a large proportion of the priority problems, complaints, risks. That is, regardless of mechanism, areas prone to periods of standing flood waters around homes/buildings typically had the biggest issues for built environments (including basement flooding). Example: for Edmonton, there is a high correlation of insurance map indications of risk and the utility's known basement flooding problem areas where development has occurred over old creeks and lake beds. (Note: groundwater levels, regardless of surface/standing water, was also a suspected issue for basement flooding)

- Approaches to utility planning and programs are increasingly involving **direct engagement of the public/customers** – rather than this input being delivered solely through council direction and approvals – in determining priorities. Ranking and "weighting" exercises involving public engagement and input tended to reveal public support for health and safety (and not necessarily personal financial) risks and provide for better public and council support of budget and project selection that reflects that input. Public/customers are increasingly looking to utilities to provide them with information related to their property risks and insurance needs.

- **Crossing the Public-Private Divide**: Whereas, the majority of actions and investments covered by these municipal utility programs dealt with utility-owned or publicly-owned land and assets, the programs are beginning to look at how and when explicitly co-ordinating (voluntary, subsidized, or regulated) actions and investments on privately-owned property (e.g., floodproofing, such as installation of backwater flow valves) provides a better risk-reduction solution. We are seeing this movement on the drinking water side (e.g., lead (Pb) in drinking water) and, with more integrated municipal approaches, are starting to see it emerge more in areas such a resilience and adaptation measures. In the EPCOR approach, it is the *secure* element of the 5-pronged approach that most often involves actions on private property. For more information on the *secure* approach, please refer to the section titled Increase in Actions and Investments that Cross the Public-Private Divide.

3.2 Study Findings Relative to Project Selection Best Practices and Toronto's BFPP

Based on this study of other Canadian municipal approaches to stormwater, there is no obvious set of short-list prioritization/decision criteria or objectives that can be readily adopted by Toronto as established project selection criteria to apply to sequencing within the BFPP. Rather, best practice suggests that City of Toronto develop its own risk-based framework and set of prioritization criteria. In developing a risk-framework, a list of risk factors that are used in several of the approaches taken by other cities include: health & safety, environmental, social, financial, regulatory and performance risks (the last two may be considered more "corporate" than municipal/system risks.

- Toronto uses a core **"cost-ceiling"** ($/benefitting property) to assess eligibility of projects for funding within its BFPP. Whereas, other municipalities take cost-benefit into account among other factors in making decisions on project selection and sequencing within approved funding envelopes, **none of those we interviewed used a cost-ceiling or explicit cost/benefit trigger**. Even in the more systematized approach taken by EPCOR, when there are multiple qualifying projects, there is a discussion with Council about funding envelopes and sequencing of projects.

- For the cities studied, the **framing of priority needs/areas** – i.e., where to focus decisions about best projects to undertake is **more explicit or formulaic** (clearer criteria and/or risk identification process) **than selection or sequencing of projects** within programs or approved budgets/funding envelopes – where the criteria used may be explicit, but their application or use is less formulaic. Different cities employ different Decision Support Tools, Algorithms, or Matrices, but **these do not provide good "apples to apples" comparisons** as they address different elements, often in a more or less "lumped" comparison (though EPCOR uses a "desegregated risk analysis that drives actions by single highest risk in a sub-basin).

- Most of the different approaches to project prioritization, in some way, help narrow or frame project selection, rather than make an explicit ranking for project selection or sequencing (i.e., they are **decision "support" tools, not decision "making" tools**). The peer conversations with several people in this study underscored the importance of recognizing that the maps and risk-ranking frameworks and models are simply decision guiding/support tools that make approaches to solution identification more transparent. They cautioned against trying to "math" or "model" your way out – rather, best solution approaches must be informed by consideration of what these maps and ranking are more clearly pointing at.

- For **selection and sequencing of projects**, given the significant cost nature of the challenges and strong interconnection of stormwater activities with other utility and municipal priorities and programs/spending, **"opportunistic"** considerations (that are not as easily "scored"/ made "formulaic" or "objective") feature significantly in project selection (e.g., roads being ripped up for other reasons, grant availability etc., as well as emergence of council/government priority interests) for many of the cities studied. (Example: Vancouver: "There's a huge push from Council to "daylight" or re-establish urban waterways and there's a prime opportunity at Hastings.")

- Several interviewees indicated that the realities of project selection/sequencing/ implementation involved a **combination** of **"reactive"** (purely issue and risk-based, response to identified problems, system failures/emergencies, and where systems were not meeting established LOS) and **"proactive"** (planned asset management renewal and upgrades, opportunistic investments when complementary priorities arise, such as other surface or pipe work being done).

3.3 Study Conclusions and Elements for Consideration by Toronto Water

The scope of work for this study indicated that the report conclusion should discuss the analysis, as well as suggest best practices, and identify a preferred approach. Based on the experience and best practices of other Canadian cities who have been evolving their approaches to prioritizing stormwater investments, there does not currently exist a standardized set of criteria for use in project selection. Rather, the best practice approaches comprise customizing either throughout the full scope of operation, or within identified program elements –a more formal, risk-based framework to guide project selection. The following provides some elements for consideration by Toronto Water in any decision to design its own options and plans to develop a customized risk-based approach.

Toronto's current use of a simple cost threshold/benefitting property to assess projects has served the city well in its initial development/delivery of its BFPP work, and provided clarity and a level of objectivity for investment decisions. However, it may lack the flexibility Toronto Water is seeking to equitably

consider differing land use and flooding contexts and impacts, or to shape future selection and prioritization of projects eligible for consideration within the existing Capital Projects funding envelope.

The nature of the BFPP program is inherently risk-mitigation based, lending itself to a more explicit risk-based decision process. An alternative to developing an explicit risk-based decision framing is to imbed such project selection/prioritization decisions directly within a proactive stormwater asset management program by establishing their preferred LoS for the program based on their own risk-based goals. The program could then use these locally relevant, risk-based LoS and focus on assessing where projects bring actual LoS in accord with the desired LoS. This may provide a more familiar setting for the engineering community and better match the culture for Toronto Water group (e.g., Ottawa 2017 Asset Management Plan, Figure 8: Capital Investment Prioritisation Process).

Public engagement represents another emerging element of best practices for Canadian utilities engaged in risk management. This may represent a consideration for future work for Toronto, involving public engagement in the development of the risk-based system and criteria to achieve buy-in and support for the final criteria and approach and to ensure that equity is built into the assessments.

Based on a consideration of how learnings from best practices of other cities might inform an approach designed and developed by Toronto Water, the following comprise some elements that Toronto Water could consider in that development. The considerations are not offered as a complete or sequenced plan. Rather they are meant to provide a spectrum of approaches from high level to more immediate activities from which Toronto Water may wish to draw on in developing a made-for-Toronto plan.

- **High-level/Future-Planning Level:** Create a made-for-Toronto "One Water" Governance structure or develop an Integrated Water Management Plan (see Vancouver example).
- **Mid-range – Planning Level**: Propose (if not already in the works) development of a risk-based Integrated Resource Plan for Toronto Water (or Integrated Stormwater Resource Plan if more in keeping with structural realities) that would encompass and help more effectively position value/expected outcomes and project sequencing for existing programs like the BFPP (several peer examples in the report).
- **Medium Term – Organizational Approach** : Consider the value of adopting a proactive stormwater strategy/frame like EPCOR's *Slow, Move, Predict, Secure and Respond* to assessing solution options, classifying and generating funding, and sequencing recommendations for stormwater work (e.g., as opposed to more silo-ed or trade-off "grey vs green/LID" considerations. This better positions the role of various complementary solutions – Tunnels/pipes = *move*; green infra = *slow*, but all solutions must include *secure, predict* and *respond* steps to be effective – this approach makes the relative need for these clearer to council/public and adds to rationale for business cases about sequencing work).
- **Medium-Term – Public Engagement in Risk Criteria Development**: Select a short list of the various benefits/impacts criteria used for prioritizing risk and action by cities across the country at different levels of their decision processes and conduct a Toronto-based public-engagement exercise to gain insights and buy-in to the key priorities and/or weightings to use to guide project selection.

- **Near-Term – Internal Toronto Water Initiative:** Take steps to create a first cut at a risk-based approach by identifying the highest-risk sag/low-lying basin areas; validating the findings of the risk analysis against claims/complaints data and assessing the known factors within them (e.g., number of homes and businesses, past complaints, past costs etc., public and critical infrastructure locations, etc.). This could create a first cut at assessing/building a risk assessment approach for Toronto. To better build towards connection to customer issues in matching municipally determined risks, with insurance questions, it may be beneficial to compare the probabilistic analysis approach used by the insurance sector to the deterministic modelling approaches that Toronto currently employs to see how they compare and might complement each other. This might include purchasing the maps generated by the probabilistic analyses undertaken on behalf of the insurance industry, and comparing them with the data and maps produced with Toronto Water information. Such an analysis may help reveal how well the two approaches identify overall hot-spots or high risk areas and whether or how the information could be combined to generate high-level "first cut" maps that identify key areas at high risk under different storm conditions (different magnitude storms and different storm centre locations). (i.e., taking a first cut at more of a GIS/mapping for decision support/frame than establishing a predictive hydraulic modelling system).
- **Near-Term – Internal Toronto Water Initiative:** Continue/expand compilation of diverse data sources already achieved through basement flooding EAs and other activities for each of sub-basins/regions across the city (they may be disparate kinds of info/source) to 1) help support (ongoing/evolving) development of risk rankings and 2) to support decision-making in selecting solutions by deepening understanding of risk drivers for that sub-basin. (see City of Ottawa – recently completed Flood Risk Profile).

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Appendix A: Interview Questionnaire

Stormwater Investment Prioritization Project

Introduction

Canadian Water Network (CWN) is undertaking a project for Toronto Water. The project involves conducting a comparative analysis of stormwater project prioritization approaches for the prevention of flooding of homes, best practices used in other jurisdictions and a recommended methodology to be considered for Toronto Water practices. This is intended to enable Toronto Water to either select an approach to supplement their existing methodology or an alternative to the existing methodology (see *Project Description* section below for more information).

Project Description

The City of Toronto's Basement Flooding Protection Program is a multi-year program aimed at reducing the risk of basement and surface flooding during extreme storm events. To achieve this goal, the City has identified a number of chronic basement flooding study areas by completing city-wide Basement Flooding Environmental Assessment (EA) studies. For the identified areas, the City upgrades service level standards for sanitary sewers and upgrades storm drainage systems, where feasible, to provide for a 1:100-year storm. The program currently utilizes a cost per benefitting property threshold of $32,000 to prioritize work. If a property is identified to be at risk of basement flooding based on the Basement Flooding EA study, infrastructure solutions are recommended to mitigate the risk of basement flooding, and this property is now a benefitting property. The cost per benefitting property is the estimated cost of the capital work divided by the total number of benefitting properties. Projects that meet this threshold are moved into Toronto Water's five-year capital plan, while those that do not meet this threshold are deferred to the program's "backlog."

Toronto Water is exploring options for approaches to prioritizing work on those capital projects that have been identified to fall within the five-year capital plan based on this threshold of $32,000 per benefiting property. The prioritization approach identified through the current project could be an approach to supplement their existing process, or an alternative to the existing process.

For this project, CWN is conducting a comparative analysis to determine current approaches undertaken in other jurisdictions across Canada to identify and prioritize urban flooding (i.e., pluvial/surface/overland/ inland/flash flooding) capital projects.

A critical part of the comparative analysis is an interview process with representatives from members of the Consortium Leadership Group of the Canadian Municipal Water Consortium, as well as other municipalities who have developed stormwater investment prioritization approaches.

Thank you for agreeing to participate in an interview.

In preparation for this conversation, we kindly ask that you review the interview questions in advance (see next section).

Interview Questions

1. **Can you provide us with a high-level overview of your utility's approach to stormwater management? That is, where do decisions about stormwater management fit within your utility structure? Does the utility have a strategy or plan (past/present) that speaks to your stormwater goals, and where does the prioritization of investments and actions fit within that strategy/plan?**
   - In your response, please note whether the utility has a distinct strategy/plan for different types of flooding (pluvial/fluvial/coastal) and how this impacts the way investments and actions are prioritized.

Note: For the following questions, CWN will be asking about your utility's approach to prioritizing investments and actions, and its elements. In order to conduct a comparative analysis of the various prioritization approaches that are used by each municipality/utility being interviewed, CWN has assumed that each prioritization approach contains: (1) factors (variables and/or formulas) that help inform its implementation, and (2) criteria that are used to assess or measure each of these factors. See Figure 1 for a visual representation of these elements and how each fits within the broader prioritization approach.

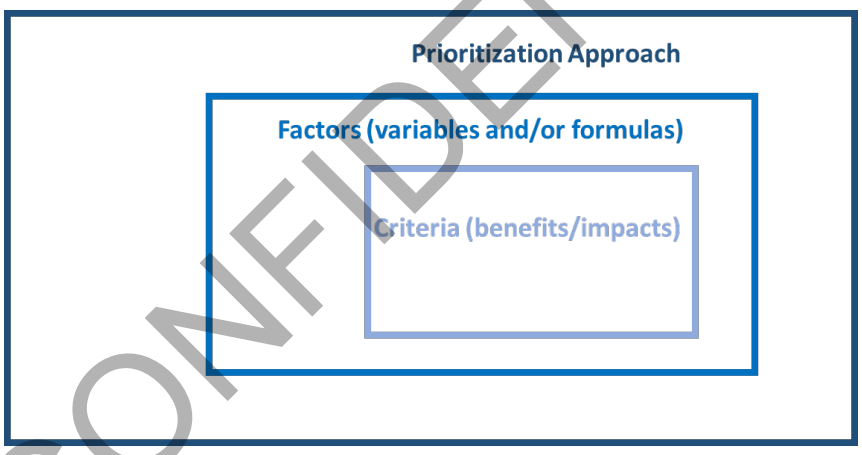

Figure 3. The elements of the prioritization approach that will be examined by CWN in the interview.

2. **What prioritization approach do you use at your municipality/utility? Please provide a broad description of the approach (keeping in mind that we will delve deeper into the approach in the upcoming questions).**
   - In your description, please note whether the development of the approach was influenced by an enterprise or community-determined risk prioritization standard.

3. **What were the drivers for developing your prioritization approach for investing in, or sequencing, stormwater projects?**

4. **What factors inform your prioritization approach? That is, what factors do you measure/assess and/or consider as input to your prioritization deliberations?**
   - Factors might include (but not be limited to):
     - Physical flood risk (topography only; including infrastructure; riverine flood risk)
     - Cost ceilings
     - Property type/basement apartment location
     - Population density
     - Socioeconomic factors
     - Municipal assets
     - Critical infrastructure
     - Historical flood report location and/or density
     - More sophisticated risk calculations, including elaborate cost-benefit analyses and/or return on investment calculations
     - Political and/or legal considerations

5. **What criteria (benefits/impacts) does your approach use/assess that to enable you to prioritize projects/investments?**
   - Criteria may include (but not be limited to) the following benefits or impacts:
     - Size of area directly affected by flooding impacts
     - Cost to homeowners and/or the municipality
     - Health and safety benefits
     - Socio-economic equity impacts
     - Socio-economic service impacts
     - Frequency of flooding
     - Environmental impacts of flooding

6. **How did you develop the benefit/impact criteria above?**
   - Examples may include (but not be limited to):
     - Using regulations/policies/guidelines
     - Conducting internal/external (e.g. consulting firm; public) consultation

7. **How are the criteria applied within the prioritization approach? For example:**
   - Are criteria staged (i.e., applied in a particular sequence)?
   - Are criteria assigned a weight based on priority/importance?

8. **What have been the key challenges in the *development* of the prioritization approach? What have been the challenges in the *implementation* of the approach?**
   - In your response, please indicate whether your municipality/utility uses different approval mechanisms – from a design standard perspective – for stormwater infrastructure projects (i.e., different mechanisms for the approval of greenfield projects versus existing system rehabilitation).