Edmonton Metropolitan Region Board

Regional Flood Risk Assessment

December 2023

PURPOSE

To develop a framework and model to assess flood risk across the Region

Stormwater Collaborative
Edmonton Metropolitan Region

1.0 Contents

1.0 Executive Summary

Flooding is a serious issue facing municipalities and poses a significant financial risk that does not recognize municipal boundaries. Increased pressure from growth and climate change, aging infrastructure, and outdated stormwater assets means that traditional engineering approaches to flood risk management are challenged to protect the Region from the effects of flooding. To help member municipalities of the Edmonton Metropolitan Region Board (EMRB) better understand, prepare for, and mitigate the risks associated with flooding, it is the consensus of the EMRB Stormwater Collaborative (Collaborative) that there is a greater need to understand flood risk.

By adopting a regional approach to flood risk assessment, this work takes advantage of expert knowledge from across the Region, economies of scale, and increased collaboration with other cross-municipal initiatives, projects, and data. In turn, all member municipalities benefit from a more comprehensive understanding of flood hazards and risks to their communities.

Building on work underlying EPCOR's award-winning Stormwater Integrated Resource Plan (SIRP)[1], the Regional Flood Risk Assessment provides an innovative and cost-effective method for identifying localized areas at the highest risk of flooding, while simultaneously establishing a regional model and framework to monitor and evaluate the evolution of flood risk over time. This work constitutes an essential first step required to assess the potential consequences of flooding and help prioritize future capital and operational investments in flood mitigation. The Regional Flood Risk Assessment provides the impetus for adopting an integrated approach towards stormwater management and can support each municipality in developing targeted flood mitigation strategies to improve flood readiness and resilience.

Results from the Regional Flood Risk Assessment are highly dependent on input data and risk tolerance, and they vary across the Region as a function of flood hazards, urban development patterns, and data availability. Preliminary results delivered to member municipalities alongside this report encourage investigation into quantified flood risk. At present, identified high-risk areas may be inaccurate due to data errors or incorrect risk tolerance assignment. Supplementary data and results support data exploration and validation. After validation results from the Regional Flood Risk Assessment can support numerous fundamental activities including:

- Prioritization of flood mitigation initiatives,
- External grant applications,
- Budgetary requests,
- Land use planning decisions,
- The communication of risk and stakeholder engagement, and
- The development of targeted public education programs.

With changing urban landscapes, climate, data availability, and municipal priorities, the flood risk environment is inherently dynamic. The Regional Flood Risk Framework and Model promote ongoing

[1] Additional information about EPCOR's Stormwater Integrated Resource Plan and flood mitigation activities can be found at: https://www.epcor.com/products-services/drainage/flood-mitigation/Pages/default.aspx.

reassessment to ensure that municipalities stay abreast of the continually changing flood risks affecting their assets and communities. Future considerations regarding future reassessment as well as long-term maintenance and reporting are summarized to facilitate the continuity and evolution of the efforts initiated by this Regional Flood Risk Assessment.

2.0 Organizational Context

The Edmonton Metropolitan Region Board's main functions, as defined by the Government of Alberta, are to plan for and enable future growth of the Region in a strategic, coordinated, and integrated way through the implementation of the Edmonton Metropolitan Region Growth Plan (EMRGP) and to create a Metropolitan Region Servicing Plan (MRSP) as a mechanism to support the implementation of the growth plan.

The EMRB initiated work on the inaugural MRSP in 2018. This work included an extensive environmental scan of high priority municipal servicing areas and recommended establishing regional collaboratives for key municipal servicing areas. Approved by the EMRB December 19, 2019, the MRSP represents the ongoing work of the Board toward fulfilment of its mandate and is an essential plan to support implementation of the EMRGP[2]. Moreover, it represents a commitment to working together with a focus on responsible growth.

2.1 Stormwater Collaborative

The Stormwater Collaborative (Collaborative) is one of four regional collaboratives established under the inaugural MRSP. Comprised of representatives from each of the 13 EMRB member municipalities (See Appendix A: Collaborative Members for a list of Collaborative members), it aims to leverage regional efforts and expertise, provide a supportive forum to foster research, share best practices, and enable evidence-based decisions and actions.

The important work of the Collaborative is guided by the MRSP Standing Committee (Committee), comprised of elected officials appointed from across the member municipalities. The Committee provides ongoing guidance and direction to the collaboratives and monitors development, opportunities, and challenges for each service area to ensure continued alignment with regional priorities and the growth plan.

The Collaborative is guided by a vision statement for stormwater management that reflects the desired future state and demonstrates alignment with the vision of the EMRGP and the MRSP Guiding Principles (See Appendix B: Growth Plan: 50 Year Vision and Appendix C: Metropolitan Region Servicing Plan Guiding Principles):

"The Edmonton Metropolitan Region will have protected natural assets while achieving resilience from stormwater impacts."

The Collaborative held its first bi-monthly meeting in March 2021, and the Board approved the first Stormwater Action Plan August 12, 2021. Since its initiation, the Collaborative has been focused on developing a foundational assessment of flood risk for the Region.

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[2] Edmonton Metropolitan Region Board. 2020. Edmonton Metropolitan Region Growth Plan: Re-Imagine. Plan. Build. Accessed June 21, 2021

3.0 Project Background

The Region's population is expected to grow by 1.0 million people reaching 2.2 million people by 2044. A growing population brings increasing demand for development, and our communities are facing rising pressures on municipal services and infrastructure. Development in flood prone areas and increases in impermeable surface areas may further stress existing infrastructure that is already experiencing reduced capacity due to age, a lack of maintenance, or outdated design.

At the same time, climate-induced shifts in precipitation patterns are expected to lead to increased flooding in the Region[3]. In turn, increased damage to municipal infrastructure, businesses, and homes as well as threats to public health and safety can be expected. The changing climate may further complicate stormwater management in the Region as the anticipated increase in storm intensity in the Region can also have significant impacts on our creeks, streams, and other natural water bodies that receive discharges.

Increasingly, communities across the globe are recognizing that with shifting demographics and climate patterns, aging infrastructure, and competing priorities for funding, traditional engineering approaches for infrastructure development strain to protect communities from flooding. Integrated stormwater management has emerged as a promising framework to integrate externalities, manage competing demands, improve cost-efficiency, and increase community engagement.

Approved in August 2021, the Stormwater Action Plan outlined a regional vision for stormwater management and proposed actions of regional significance, including a Regional Flood Risk Assessment. The Regional Flood Risk Assessment represents an opportunity to develop a shared understanding of the risks associated with flooding across the Region as a first step towards supporting the implementation of integrated stormwater management.

The urgency of this effort is underscored by the recent changes to available funding from Federal and Provincial disaster relief agencies, such as the Alberta Disaster Recovery Program, intended to help cover uninsurable losses resulting from natural disasters. Starting April 1, 2021, the Disaster Recovery Program introduced a 90:10 cost sharing agreement for disaster relief, leaving local governments and private-sector applicants responsible for 10% of eligible disaster costs. Changes to funding structures are being implemented to encourage municipalities and homeowners to take initiative to mitigate risk and reduce the financial and human costs of disasters.

3.1 Purpose

The development of a regional flood risk assessment is intended to help member municipalities better understand, prepare for, and mitigate the risks associated with flooding. The Regional Flood Risk Assessment represents an innovative and cost-effective method for identifying areas across the Region

[3] Kuo, C.-C. et al. (2021) *Future intensity–duration–frequency curves of Edmonton under climate warming and increased convective available potential energy*, Climatic Change, 168(3–4). doi:10.1007/s10584-021-03250-6.

that are at the highest risk of flooding to help prioritize future capital and operational investments in flood mitigation.

Capitalizing on data, experience, and expertise across the Region, the outcomes, and benefits of the Regional Flood Risk Assessment include:

- Highlights areas in each municipality that have the highest risk of impact from flooding to prioritize investigation and provides results in formats that facilitate data exploration at the municipal level.
- Coordinates with other provincial, regional, and municipal strategies and programs such as the EMRB's Climate Risk and Vulnerability Assessment and the provincial Flood Hazard Identification Program & Flood Damage Assessments (see Appendix D: Supporting Programs and Projects: Supporting Programs and Projects).
- Serves as a basis to transition towards an integrated management framework while supporting traditional stormwater planning methodologies.
- Provides an evidence-based model for requesting limited capital and operating dollars for highest-impact areas.
- Considers the non-financial aspects of flood risk (i.e., health & safety, social and environmental impacts) and accommodates detailed depth-damage curve information to accurately assess the financial impacts of flooding.
- Establishes a Risk Assessment Data Model for the Region that can be continuously improved over time with richer data such as detailed engineering studies, higher-resolution topographical maps, flood reduction controls, and/or property value data.
- Develops a tailored processing tool housed with the EMRB that can be used for continued re-evaluation of flood risk across the Region.
- Supports the monitoring and reporting of flood risk improvements and vulnerabilities.
- Establishes a base framework, tool and datasets that can be applied to other assess risk associated with other climate hazards (e.g., forest or grass fires).

3.2 Scope

The Regional Flood Risk Assessment is a granular GIS-based risk assessment that is tailored to the data and landscape of each member municipality. Where the EMRB's Climate Risk and Vulnerability Assessment (CRVA – see **Appendix D**: Supporting Programs and Projects: Supporting Programs and Projects) for more information) identifies the climate hazards that pose the greatest risk to the Region as a whole, the Regional Flood Risk Assessment looks at the building or parcel-level to identify localized areas within each municipality that are at the highest risk of flooding. To gain a holistic understanding of the flood risk landscape, **Figure 1** illustrates risk is quantified based on three flood hazards and according to four different risk perspectives.

Figure 1: Flood risk is assessed with respect to three flood hazards: river flooding, stormwater flooding, and sanitary surcharge; for each flood hazard, risks are assessed with respect to the health & safety, financial, environmental, and social consequences.

With an evolving physical landscape and rapidly expanding data availability, flood risk assessment should be considered an iterative process. The results delivered to member municipalities to accompany this report serve as proof of concept for the framework, data model, and processing tool and can be used to help identify and investigate high-risk areas. Future considerations and requirements for continued re-assessment, maintenance, and reporting are summarized.

Stormwater planning for the City of Edmonton is largely directed by EPCOR's SIRP (**Appendix D**: Supporting Programs and Projects: Supporting Programs and Projects), under which lies the award-winning flood risk assessment framework that provides the foundations for this regional project. The City of Edmonton's flood risk assessment is currently being updated by EPCOR. Consequently, flood risk in the City of Edmonton is not included in this Regional Flood Risk Assessment. All other EMRB member municipalities and any other hamlets, municipalities or First Nations located within or bordering their geographic extents have been included.

Note that cost-benefit analysis and mitigation recommendations for high-risk areas are out of the scope of this project.

3.3 Approach

The Regional Flood Risk Assessment Project Charter was approved by the Board on April 14, 2022.

The first deliverable of this project was to complete a study on the adoption of regional Intensity, Duration, and Frequency (IDF) curves[4]. IDF curves describe the likelihood of a range of extreme rainfall events for a given location and are a central element for stormwater management system design. In municipalities throughout the Region, four different sets of IDF curves are currently in use. These curves vary in the number and location of rain gauges that they reference as well as the period of record and the statistical methodologies used to derive them. The synthetic design storms that use these IDF curves to design stormwater infrastructure are also inconsistently referenced across municipal standards. The primary objectives of this work were to:

1. Review how IDF curves and their application to stormwater infrastructure design differs across the Region,
2. Describe the implications of these differences for the design of stormwater management systems,
3. Determine whether there is value in having all municipalities align their standards to a single, consistent set of IDF curves.

Working with subject matter expert Dr. Thian Yew Gan a professor with the Faculty of Engineering at the University of Alberta - this highly technical report recommends best practices for IDF curve derivation and their application in the Region. Findings from the review indicated that the derivation method used by EPCOR to update their IDF curves in 2020 aligns with best practices; the other three sets of curves used in the Region did not. The final report proposed municipalities using other IDF curves may wish to align their design and construction standards with the most up-to-date EPCOR IDF curves, as is feasible.

The report also reviews projected climate trends for the Region. While recognizing that rainfall intensity – and consequently flood hazards – are expected to increase in the Region, the report concludes that uncertainty in climate modeling and associated processes is too large to recommend the incorporation of climate-projected IDF curves into design standards. It suggests alternative climate mitigation and adaptation strategies be prioritized. One such measure favored under an integrated planning framework is the adoption of a risk-based management approach. The larger Regional Flood Risk Assessment project is foundational to this effort and is the subject of the rest of this report.

Building on the risk assessment framework underlying EPCOR's SIRP, the Regional Flood Risk Assessment integrates local knowledge, information and data from other initiatives in the Region including: EMRB's Climate CRVA, Alberta Environment and Park's (AEP) Flood Hazard Identification Program (FHIP), flood hazard mapping products used by the insurance industry, the Government of Canada's Flood Damage Estimation Guidelines, the Government of Canada's Flood Damage Assessment Studies, as well as municipal and intermunicipal studies and programs (See Appendix D: Supporting Programs and Projects: Supporting Programs and Projects) for more details on each program). Where available, open-source data was used to fill data gaps. Members from EPCOR's Stormwater Planning team and the Collaborative provided guidance throughout development of the Regional Risk Assessment. The resulting risk assessment framework is tailored to the Region as a whole, while the data model and assessment results are adapted to each municipality's data and landscape. The key components of the Regional Flood Risk Assessment are as follows:

Risk Assessment Framework: Adopted from EPCOR, the risk assessment framework defines the components that determine flood risk and describes the analysis structure. The framework characterizes

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[4] Regional Approach to Intensity Duration Frequency Curves (EMRB, March 2022)

flood risk according to four perspectives: health and safety, financial, environmental, and social. A risk matrix approach is used to define risk as a function of flood likelihood, flood consequence and modifying factors.

Data Model: Tailored to the member municipalities covered in this assessment, the data model details exactly which metrics are calculated and which data are required to assess risk.

Thirteen indicators are defined to quantify flood risk across the four risk perspectives defined in the risk assessment framework. The indicators and risk tolerances were established with reference to the flood risk assessment literature, ongoing programs in the Region (Appendix D: Supporting Programs and Projects: Supporting Programs and Projects), available data, and the wider regional context. Discussions in the CRVA workshops and among the Collaborative were used to confirm these preliminary indicators and risk tolerances. The data model should be dynamic and is expected to evolve as the physical landscape, data, and priorities in the Region change over time.

Processing Tool: Developed specifically for the Regional Flood Risk Assessment, a scripted GIS-based tool automates model processing and considers the spatial overlap between flood likelihood, flood consequence, and modifying factors to quantify flood risk across the thirteen indicators defined in the data model. The tool aggregates flood risk scores to the sub-basin level, and risk maps are generated for each municipality. Summary tables and other supporting results are also calculated.

This automated tool aims to facilitate the continued reevaluation of flood risk across the Region as assessment inputs and priorities shift.

Risk Assessment Results: The primary results from the Regional Flood Risk Assessment are unique to each member municipality and include a set of tailored flood risk maps as well as supplementary summary data designed to facilitate interpretation. These results are considered preliminary. While they highlight areas and assets with the greatest flood risk and provide important information to direct further investigation, the input data and established risk tolerances must be validated by member municipalities before we can determine how best to incorporate the insights into future planning.

4.0 Methodology

4.1 Flood Risk Framework

When assessing the potential damage from any natural disaster, risk is traditionally considered as the intersection of three factors: hazard, exposure, and vulnerability shown in Figure 2. Where hazard is the potential to experience a particular destructive physical phenomenon – for this risk assessment river flooding, stormwater flooding, and sanitary surcharge are considered. Exposure represents the stock of property, infrastructure, and population exposed to the hazard, and vulnerability relates to the differing susceptibility to damage among exposed elements (e.g., the

Figure 2: Flood risk is defined as the intersection between flood hazards, exposed assets and populations, and vulnerabilities.

young or elderly, old buildings and infrastructure, ecologically sensitive areas).

Building on this foundation, the Regional Risk Assessment adopts the risk assessment framework underlying EPCOR's SIRP and employs a matrix-based approach to quantify risk. Following this methodology, flood risk is expressed as the cross product of the likelihood of flooding and the consequence of flooding, as illustrated in the risk matrix illustrated in Figure 3: A flood risk matrix qualifies flood risk from very low (green) to very high (red) risk as a function of flood likelihood and flood consequence.:

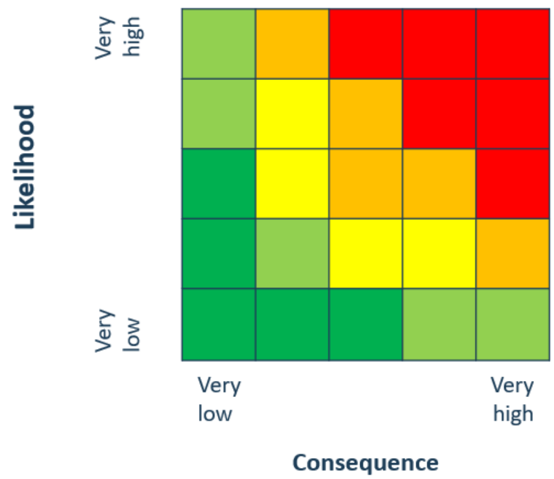


Figure 3: A flood risk matrix qualifies flood risk from very low (green) to very high (red) risk as a function of flood likelihood and flood consequence.

The consequence of flooding scales along the x-axis with the severity of consequences to exposed elements. For example, the financial impact of flooding in 100 homes would be greater than only a single home; similarly, the wider community would be significantly more affected by the closure of a hospital due to flooding than if a single pharmacy had to close.

The likelihood of flooding considers the probability that a particular hazard will occur. After consulting with the insurance industry to understand how flood hazard is evaluated in insurance risk models, EPCOR adopted a similar approach. Flood likelihood is determined by the probability of a property being affected *by a range of flood events with respect to a property's lifetime* shown in Table 1. The following storm events are considered for stormwater and river flooding (and for sanitary surcharge where available):

Table 1: Flood likelihood scores are determined with reference to the most frequent modeled storm event that an area, asset, or population is exposed to.

Storm Event	Percent Likelihood over Time			Flood Likelihood Category	Flood Likelihood Score
	1-year	30-years	100-years		
1:20 year	5.00%	78.54%	99.41%	Very High	4.5
1:50 year	2.00%	45.45%	86.74%	High	4.0
1:75 year	1.33%	33.15%	73.88%	Moderate	3.5

1:100 year	1.00%	26.03%	63.40%	Low	3.0
1:200 year	0.50%	13.96%	39.42%	Very Low	2.0

Addressing flood likelihood in this manner enables the introduction of a service level component into the risk model. In general, an asset exposed to flooding at 1:20 year flood event is at higher risk than if it was not exposed until a 1:200-year event. If that asset has a 30-year lifetime, the probability of flooding from a 1:200-year event is 13.96% - this could be deemed tolerable. A base likelihood score of 2.0 would be appropriate. But if the asset is costly to remediate and has a 100-year lifetime, a 39.42% likelihood of flooding may not be acceptable, and the flood likelihood score could be increased from the base score reported in Table 1.

Vulnerability to flooding is addressed through the introduction of modifiers, which can shift flood risk along the positive or negative directions on either the consequence or likelihood axes of the risk matrix. For example, undersized or poorly maintained stormwater infrastructure could increase the likelihood of flooding, while a well-maintained storm pond could reduce flood likelihood throughout the sub-basin simultaneously reducing flood risk. Along the consequence axis: residents in a retirement home might be more vulnerable to the effects of flooding, shifting flood risk up; on the other hand, a well-developed emergency management plan could reduce the consequences of flooding.

The final component of the flood risk assessment framework is the definition of flood risk perspectives. Project prioritization is often driven by traditional cost-benefit analysis that fails to adequately capture the non-financial externalities of flooding. Through the addition of three other perspectives – health and safety, environment, and social – a more comprehensive understanding of flood risk can be evaluated.

For the City of Edmonton, this perspective-based approach also created an opportunity for residents to influence the direction of stormwater management. Through a multi-phased public engagement process, participating Edmontonians provided feedback and responded to surveys aimed to understand which infrastructures should be prioritized in flood mitigation planning. The results informed infrastructure-specific risk tolerance and were used to assign a representative weight to each perspective to calculate a final, comprehensive flood risk score. Key findings from the public engagement campaign are summarized in Appendix E: Results from EPCORs Public Engagement on Flood Mitigation Prioritization: Results from EPCOR's Public Engagement on Flood Mitigation Prioritization. The diagram in Figure 4: Conceptual diagram illustrates how the likelihood of flooding, consequences of flooding, and modifiers are connected in order to calculate perspective-based flood risk scores as well as a comprehensive final flood risk score.: is conceptual and illustrates how the likelihood of flooding, consequences of flooding, and modifiers are connected in order to calculate perspective-based flood risk scores as well as a comprehensive final flood risk score.

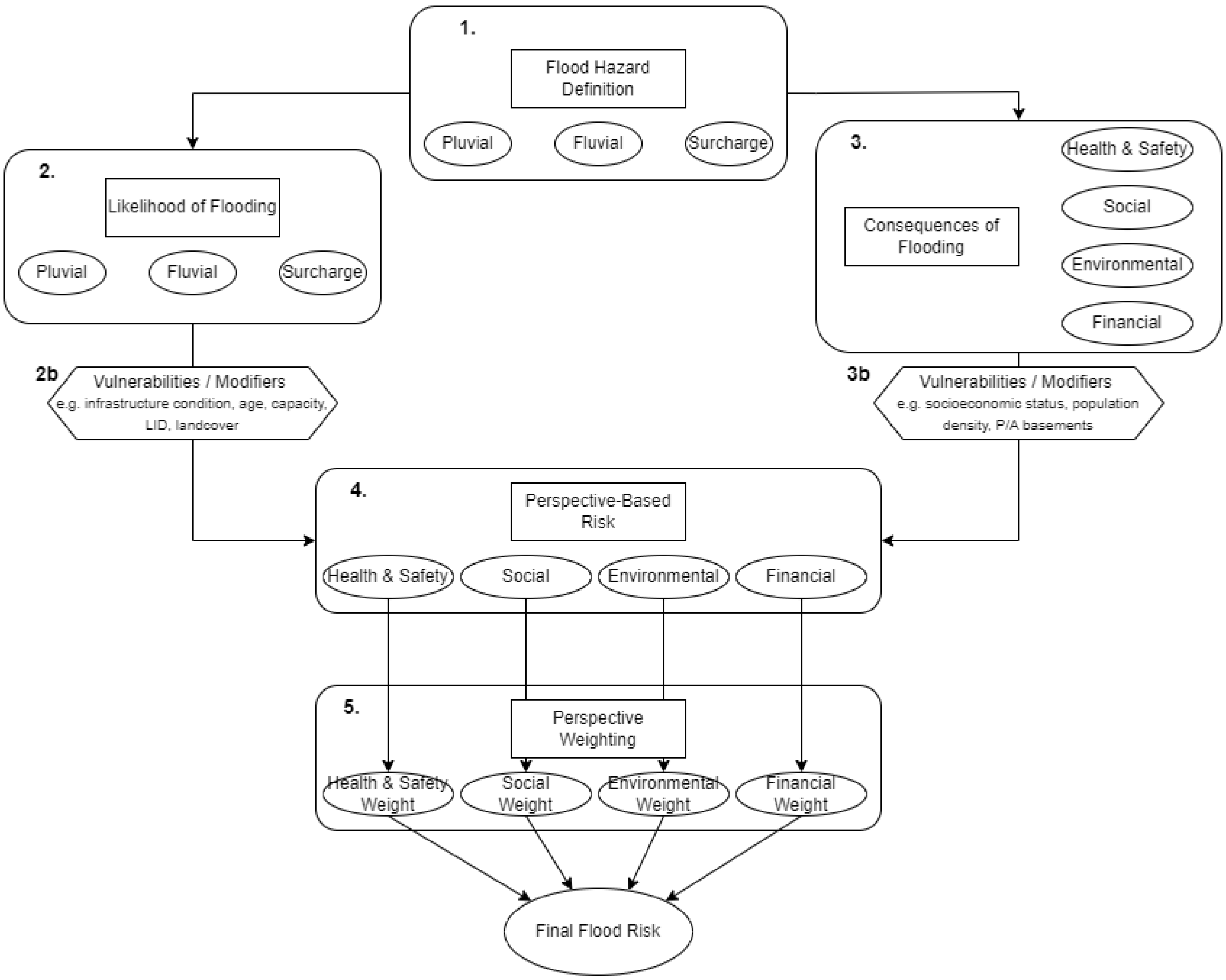


Figure 4: Conceptual diagram illustrates how the likelihood of flooding, consequences of flooding, and modifiers are connected in order to calculate perspective-based flood risk scores as well as a comprehensive final flood risk score.

4.2 Data Model

The data model underlying to Regional Flood Risk Assessment describes which data are used to quantify risk and how. Where the flood risk framework described above is fixed, the data model should be dynamic. As more and better data become available, the data model should evolve. Data described in the current model can be replaced, supplemented, or removed completely as it becomes outdated or no longer applicable.

The model is structured such that flood risk is quantified at three levels for each location:

1. TOTAL FLOOD RISK: a single comprehensive flood risk score calculated by weighing the perspective-based flood risks[5].
2. PERSPECTIVE-BASED FLOOD RISK: an aggregate score summarizing flood risk according to each of the four flood risk perspectives: health & safety, financial, environmental, and social.
3. INDICATOR-SPECIFIC FLOOD RISK: a risk score calculated to quantify the risk associated with a specific effect of flooding.

4.2.1 Flood Risk Indicators

Building upon EPCOR's risk assessment data model, experience from across the scientific literature, as well as from discussions among Collaborative members and CRVA workshop participants, the thirteen flood risk indicators outlined in **Figure 5**: Thirteen flood risk indicators evaluated in the Regional Flood Risk Assessment organized according to constituting flood risk perspective..

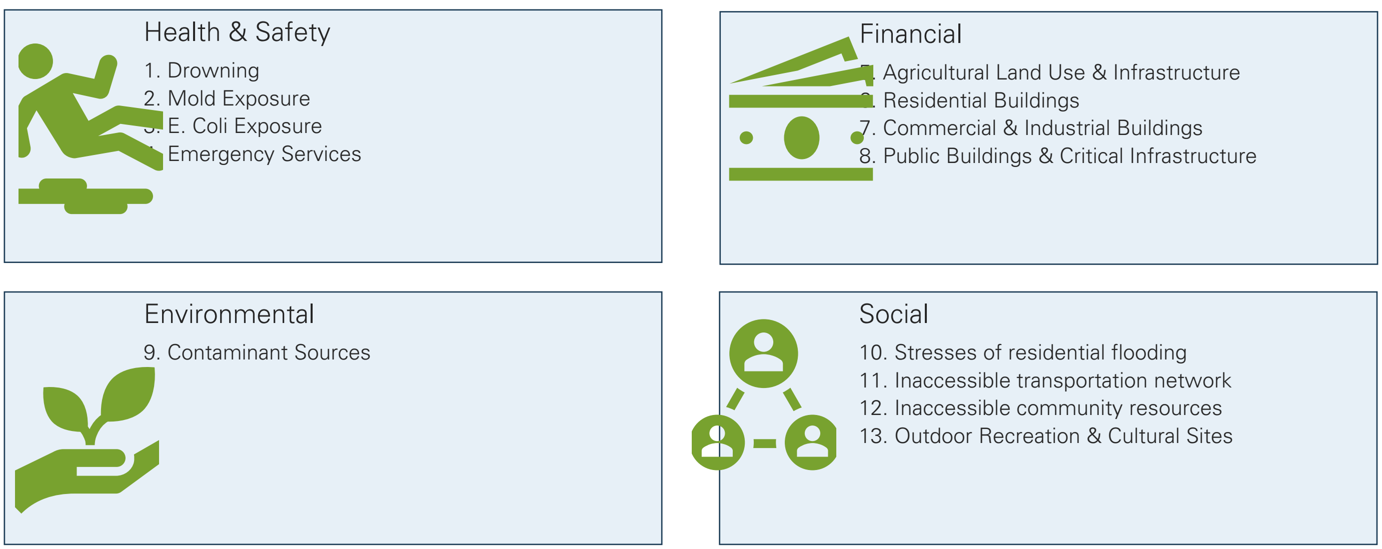


Figure 5: Thirteen flood risk indicators evaluated in the Regional Flood Risk Assessment organized according to constituting flood risk perspective.

In its evaluation, each indicator considers:

1. At least one or more **flood hazards**: stormwater flooding, river flooding, or sanitary surcharge.
2. At least one or more **receptors**: the physical element that is exposed to flooding, for example, commercial buildings, industrial parks, the road network, or a resident population.
3. Optional **likelihood modifiers**: factors that increase or decrease the likelihood of a flood hazard affecting exposed receptors; for example, a stormwater management facility (decrease likelihood), or a damaged storm pipe (increase likelihood).
4. Optional **consequence modifiers**: factors that increase or decrease the severity of consequences when receptors are exposed to a flood hazard; for example, vulnerable populations (increase

[5] The weighting scheme used in this preliminary assessment is adopted from EPCORs perspective weighting. See **Appendix E**: Results from EPCORs Public Engagement on Flood Mitigation Prioritization: Results from EPCOR's Public Engagement on Flood Mitigation for more information.

consequence), ecologically sensitive areas (increase consequence), existing emergency management plan (decrease consequence).

A simplified conceptual diagram of the data model is provided in

Appendix F: Regional Flood Risk Data Model: Regional Flood Risk Data Model. summaries of each of the thirteen indicators are also provided. Limitations, assumptions, data sources, and an estimate of the indicator confidence are included in each summary.

4.2.2 Variability Across the Region

The data model is generally consistent across municipalities with differences primarily due to:

1) Data availability: The comprehensiveness of spatial data catalogues is highly variable across the Region. Consequently, for some municipalities, the risk assessment may rely entirely on open data; for others a combination of municipal and open data was used. This results in an inconsistency in the quality of input data between municipalities and, in some cases, it may have been impossible to calculate specific indicators (e.g. Outdoor Recreation).

   Due to this heterogenous data, model accuracy can vary significantly by municipality.

2) Assigned risk tolerance: acknowledging the differing contexts and development intensities across the Region, consequence thresholds could not be uniformly assigned across all municipalities. For example, in a densely developed area, if 75 residences were at risk of flooding, the consequences could be rated as "Very High". However, in a rural area, due to the lower development density, 75 residences may never exist within a single basin, and 25 may be a more suitable threshold for a "Very High" consequence. As a result, for indicators where consequence thresholds were determined with absolute values, they are based on receptor density patterns specific to each municipality.

   Risk tolerances for certain indicators are consistent across municipalities, particularly where risk tolerance is determined with respect to relative values (i.e., percent of assets exposed) or specific infrastructure (e.g., flooding of a fire hall elicits a consequence score of 5 in all municipalities).

The Regional Flood Risk Assessment data model differs from that underlying EPCOR's flood risk assessment in the following ways:

1. Combined sewer overflow (CSO)-associated flood risk is not considered in the Regional data model. Flood risk in parking garages and underpasses is also less significant in the wider Region and not evaluated.
2. In alignment with the EMRGP, flood risk to the transportation network and agriculture are explicitly evaluated with their own indicators.
3. Data is structured to support analysis through widely used ESRI GIS products and open source processing software.
4. Outputs are structured to encourage investigation and data exploration rather than a succinct list of locations where flood mitigation should be prioritized.
5. Limited data availability across the Region makes it unrealistic to assess certain flood risk indicators at this time (e.g., creek erosion or total suspended solid release).

4.2.3 Unit of Analysis

The Regional Flood Risk Assessment evaluates flood risk across different types of buildings, infrastructure, land use, and populations that are all expressed at different spatial scales. To summarize all this information into a concise value that enables comparison across receptors and effectively communicates total risk, a spatial unit of analysis is defined. The final, comprehensive, total risk score is calculated as an aggregation of risk to the different elements located within the defined spatial unit.

The boundaries of the unit of analysis will influence the resulting risk score. While different spatial units can be used, sub-basins derived from topography and the stormwater network (**Figure 6** illustrates an example of sub-basins (in red) from the Region shown over cadastral data (black). Sub-basins are the unit of analysis used for this assessment. from the Region shown over cadastral data (black). Sub-basins are the unit of analysis used for the assessment and are preferred for the Regional Flood Risk Assessment for the following reasons[6]:

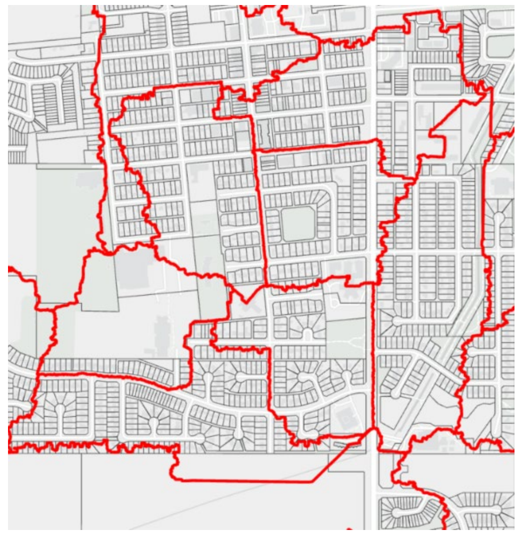


Figure 6 illustrates an example of sub-basins (in red) from the Region shown over cadastral data (black). Sub-basins are the unit of analysis used for this assessment.

- Sub-basin boundaries enclose areas with similar hydraulic and hydrologic conditions.
- It is a reasonable approximation of an area of influence for a mitigation measure (e.g., a storm pond could reduce flood risk throughout the entire sub-basin).
- Many municipalities already have sub-basins delineated increasing overlap with other municipal initiatives.
- Results from the risk assessment can be easily linked to past or future drainage assessments.
- Results can be easily scaled-up to understand risk at a drainage basin level.

4.3 Flood Risk Assessment Processing Tool

All processing for the Regional Flood Risk Assessment is accomplished using a GIS-based tool scripted specifically for this assessment. The tool requires three specific inputs:

1. FLOOD HAZARD MAPPING: this includes depth grids for all river and stormwater flood mapping. Results presented in this assessment are based on the 20-, 50-, 75-, 100-, and 200-year stormwater and river hazard flooding events.
2. RECEPTOR DATA: specific to each indicator, receptor data outlines the physical element that is exposed to flooding (e.g., land parcel, grocery store) and any associated consequence or likelihood modifiers (e.g., multi-family unit has higher flood consequence). Reference
3.

[6] Sub-basin geometry was not available for Beaumont, Fort Saskatchewan, or Leduc County. Results are aggregated to a regular hexagon grid. Hexagon areas are determined as a function of mean development density.

4. Appendix F: Regional Flood Risk Data Model: Regional Flood Risk Data Model for details on data sources for each indicator.
5. SUB-BASIN GEOMETRY: the spatial representation of the unit of analysis and any associated consequence or likelihood modifiers (e.g., modifying score associated with the presence of a storm pond).

By evaluating the spatial overlap between these three datasets, the flood likelihood and flood consequence are calculated for each indicator, in each sub-basin. Indicator-specific flood risk is then calculated for each sub-basin as a product of the calculated flood likelihood and consequence. Perspective-based risk is then calculated for each sub-basin by aggregating the constituting indicators (Figure 5: Thirteen flood risk indicators evaluated in the Regional Flood Risk Assessment organized according to constituting flood risk perspective.: Thirteen flood risk indictors evaluated in the Regional Flood Risk Assessment organized according to constituting flood risk perspective), and total risk is calculated as a weighted average of perspective-based risk (Appendix E: Results from EPCORs Public Engagement on Flood Mitigation Prioritization. Data permitting, 18 preliminary risk maps are produced for each municipality: 13 indicator-specific maps, four perspective-based maps, and one final risk map.

In addition to the mapped sub-basin risk, the tool also generates a series of additional summary outputs in table and graphical format to help municipalities interpret risk assessment results.

The processing tool requires ESRI's ArcPro and Spatial Analyst extension, which are widely in use in GIS departments across the Region. Additional processing is scripted using Python and R. The use of these free and open-source programming languages ensures that future use of the tool won't be limited by software availability. Additional advantages of an automated processing tool over ad-hoc processing include:

- Ease of repeatability facilitates assessment re-run; this can speed up sensitivity testing for risk tolerances and modifying values, make the incorporation of new data much quicker, and facilitate updates as flood mitigation projects are implemented.
- Results are calculated much more quickly,
- Less opportunity for human error,
- Increased transparency around processing,
- Transfers processing protocols to the EMRB upon completion of the project enabling the continuation of the Regional Flood Risk Assessment.
- The tool requires a standard data structure and schema ;these can be shared with municipalities to facilitate data sharing and subsequent reassessment.

5.0 Results & Considerations

5.1 Flood Hazard Mapping

The primary sources for river and stormwater flood hazard mapping were sourced from either AEP's FHIP or JBA Risk Management – flood hazard maps used by the insurance industry (Appendix D: Supporting Programs and Projects: Supporting Programs and Projects). The provincial mapping is derived at a much higher resolution and produces more accurate results. However, coverage is limited to only three study reaches along major watercourses in the Region: North Saskatchewan River, Big Lake, and

Blackmud Creek. In addition, only river flooding is assessed. Elsewhere the JBA flood hazard mapping is used for both stormwater and river hazard mapping.

The JBA mapping methodology is proprietary, and no accuracy estimates are provided. To ensure that the flood hazard maps were appropriate for use across the entire Region, the hazard maps were compared with other available model results and areas with a known history of flooding. Visual inspection confirmed that JBA hazard mapping coincided well with other sources making them an acceptable source for the Regional Flood Risk Assessment. However, due to the comparatively low resolution of the JBA data, mapped flood extents are less accurate in areas with flat topography or very steep slopes (i.e., along steep river or creek banks. Compared with other high resolution studies (e.g., AEP FHIP and draft modeling from the City of Leduc's Drainage Master Plan), the JBA mapping seems to overpredict wet; this leads to a more conservative evaluation of flood likelihood and is acceptable for a risk assessment.

5.2 Consequence and Likelihood of Flooding

Risk assessment results have been calculated independently for each municipality based on adapted risk tolerances and available data. Compiled from municipal, provincial, federal, and open sources, the receptor data used to quantify the consequences of flooding can supplement existing spatial data maintained at each municipality. An example area is illustrated in Figure 7: Example of receptor data used to quantify the consequences of flooding in one sample area in the Region. Note that certain building footprints may be considered in multiple indicators and thus duplicated in multiple receptor classes (e.g., a health centre could appear in the Emergency Service, Community Centre, and Public Building classes shown)..

For municipalities that do not have significant GIS resources, these spatial data can support future projects or serve as a basis for supporting the development of a GIS program or future GIS-based projects. These data also support the re-iteration of the Regional Flood Risk Assessment as municipalities can directly edit the input data before delivering it back to the EMRB for reassessment.

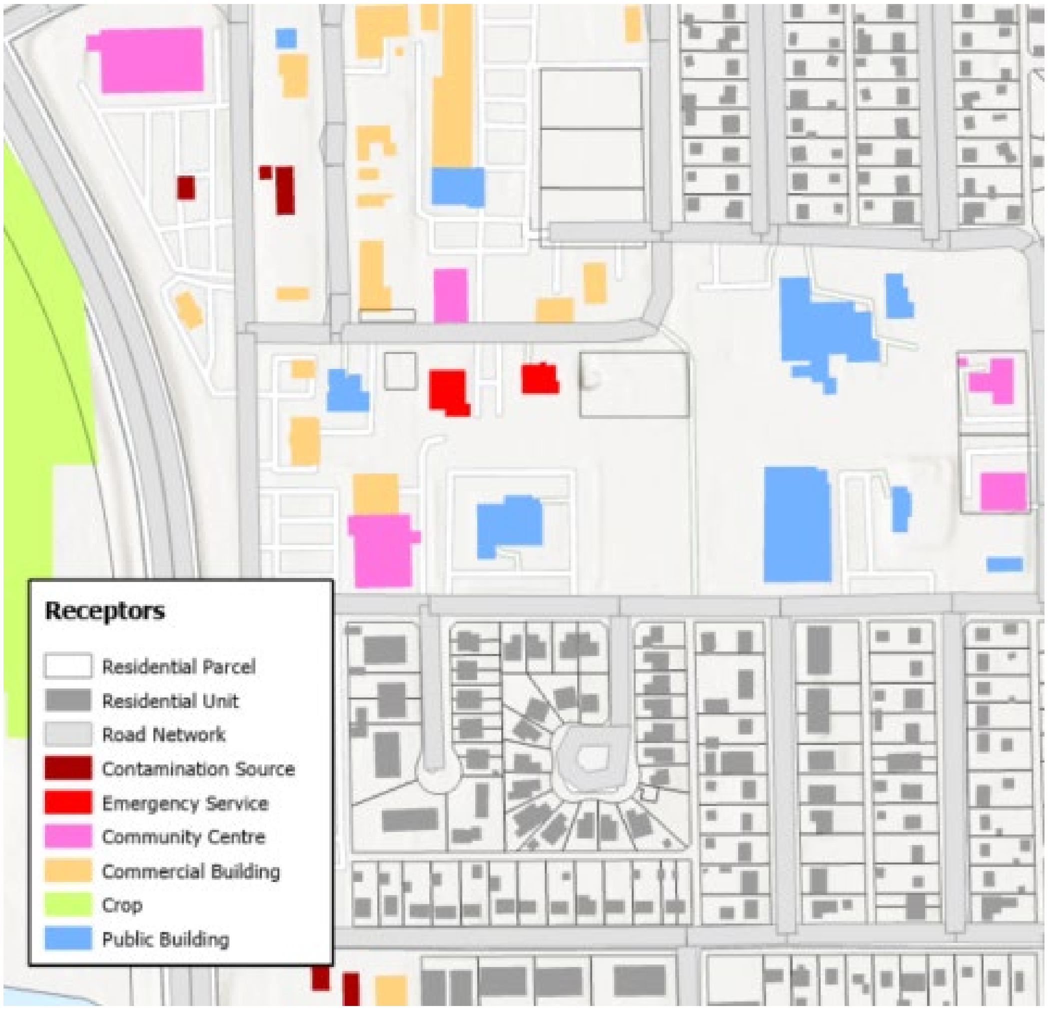


Figure 7: Example of receptor data used to quantify the consequences of flooding in one sample area in the Region. Note that certain building footprints may be considered in multiple indicators and thus duplicated in multiple receptor classes (e.g., a health centre could appear in the Emergency Service, Community Centre, and Public Building classes shown).

Municipalities can also refer to flood likelihood maps delivered alongside results (see example in Figure 8: Example of flood hazard data used to quantify flood likelihood in the Region. Both stormwater and river flood hazards are shown; cadastral data are outlined in black to facilitate interpretation. of flood hazard data used to quantify flood likelihood in the Region. Both stormwater and river flood hazards are shown, cadastral data are outlined in black to facilitate interpretation) to visually assess flood hazards where mapping has not previously been conducted.

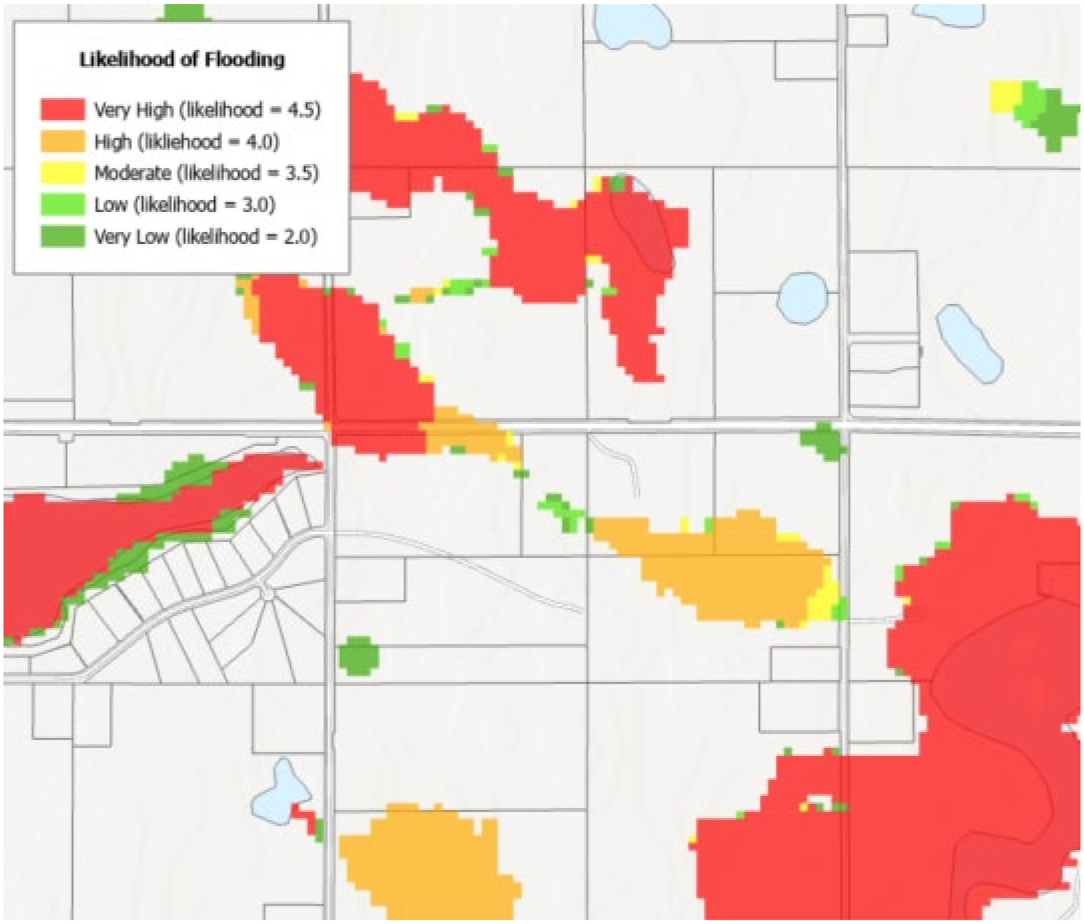


Figure 8: Example of flood hazard data used to quantify flood likelihood in the Region. Both stormwater and river flood hazards are shown; cadastral data are outlined in black to facilitate interpretation.

5.3 Regional Flood Risk Assessment Results:

The preliminary results produced for each member municipality can be used to identify areas at high risk of flooding, and, with their comprehensive definition of flood risk, they can also support traditional stormwater planning. Results are considered preliminary because they have been derived based on available data and information that have not been reviewed by the municipalities and include assumptions that must be validated. As required, adjustments can be made to input data, modifying values, and risk tolerances to produce more accurate and representative results.

To promote further review and to facilitate validation and general data exploration, a series of outputs are generated by the risk assessment processing tool:

1. **Preliminary risk maps** are provided to quantify flood risk at the sub-basin level. Risk is summarized according to three levels:
    a. **Indicator-specific risk** – where data availability permits, 13 independent risk scores that correspond to the flood risk indicators included in the data model are calculated for each sub-basin

b. **Perspective-based risk** – represents the aggregation of indicator-specific flood risk according to the pre-defined flood risk perspectives: health & safety, financial, environmental, and social.

c. **Total flood risk** – provides a single flood risk score for each sub-basin that illustrates the comprehensive flood risk across each municipality by weighting perspective-based flood risk according to findings from the City of Edmonton's public engagement survey (**Appendix E**: Results from EPCORs Public Engagement on Flood Mitigation Prioritization: Results from EPCOR's Public Engagement and Flood Mitigation Prioritization).

Figure 9: Example of sub-basin flood risk ratings for a sample area in the Region. Red sub-basins represent areas with a very high flood risk; the darker green sub-basins have a very low flood risk. Note that for simplicity, only four of the thirteen indicators are illustrated in the first column.provides an example of sub-basin flood ratings for a sample area in the Region.

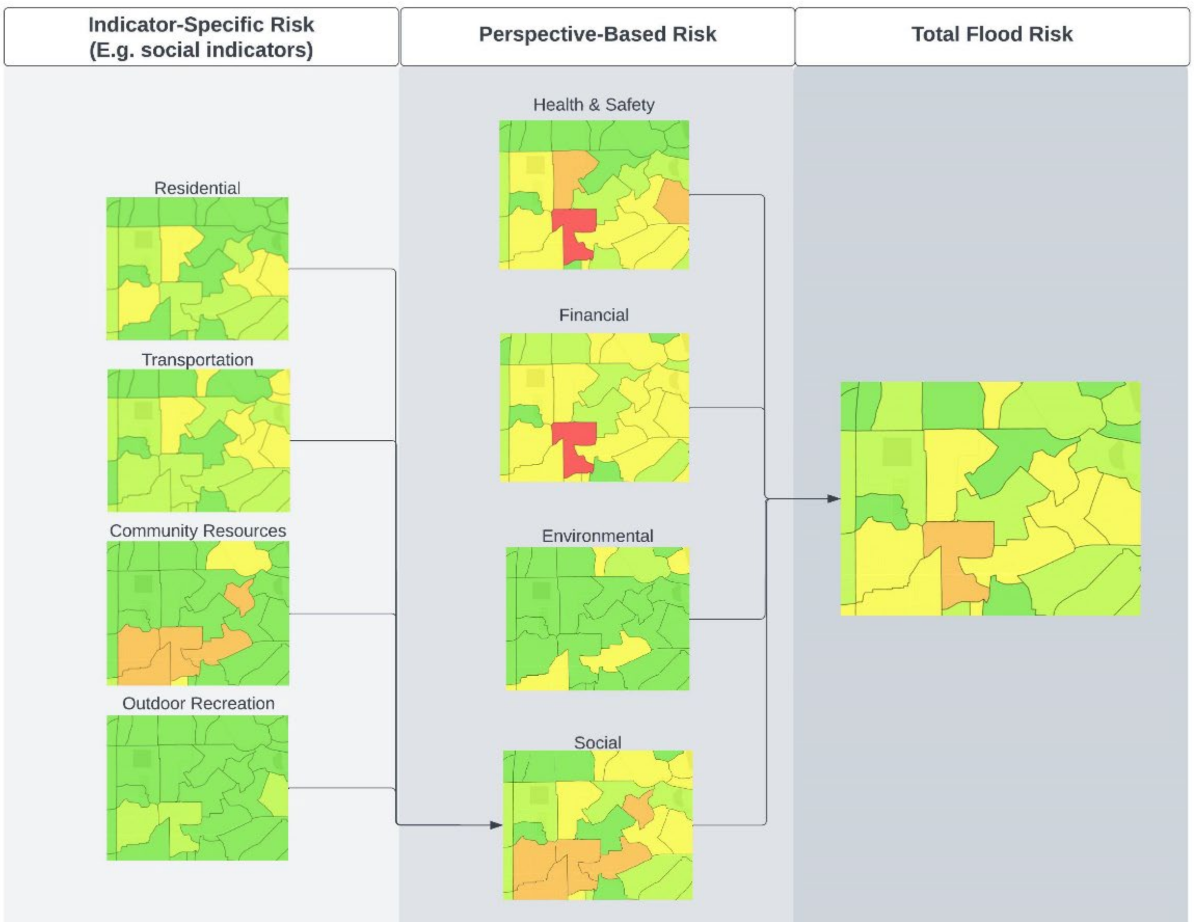


Figure 9: Example of sub-basin flood risk ratings for a sample area in the Region. Red sub-basins represent areas with a very high flood risk; the darker green sub-basins have a very low flood risk. Note that for simplicity, only four of the thirteen indicators are illustrated in the first column.

2. **Summary tables:** have been developed to support interpretation of the risk maps and to facilitate data exploration; these include:

a. A list of priority buildings and infrastructure with an indication of the modeled maximum flood depth, the proportion of the asset footprint at risk of flooding, and the associated sub-basin-level flood risk score.
b. For each flood risk indicator, a summary of the number of sub-basins at each risk level (i.e., very high, high, moderate, low, very low).
c. For each flood risk indicator and each affected sub-basin, the calculated flood risk score for each flood hazard scenario (e.g., 20-year river, 20-year stormwater) along with the final indicator-specific flood risk score for each sub-basin.

3. **Graphical flood exposure summaries:** For each municipality, a number of graphical summaries are produced to illustrate the proportion of a particular asset or land use at-risk from river and stormwater flooding. These figures are for informational purposes and provide a high-level overview of how flood risk is partitioned across a few of the assets and landcovers assessed in the Regional Flood Risk Assessment. An example illustrating the proportion of emergency route exposed to a flood hazard is provided in **Figure 10** Example of a bar graph illustrating percent of asset at-risk from flooding..

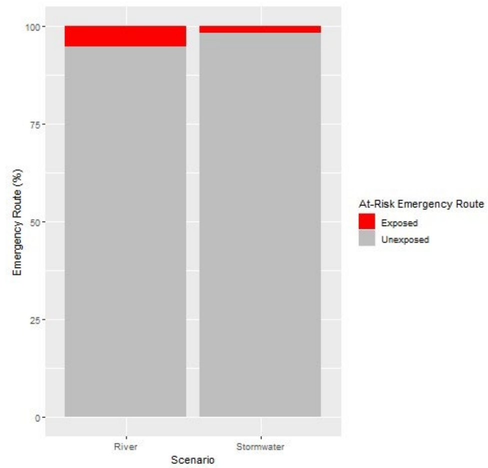


Figure 10 Example of a bar graph illustrating percent of asset at-risk from flooding.

5.4 Municipal Implications

Preliminary results from the Regional Flood Risk Assessment have been delivered to each municipality through their Stormwater Collaborative representative. Validation of consequence data and established risk thresholds are required before results can be shared publicly or solely relied upon to prioritize intervention. However, paired with the provided likelihood and consequence mapping, the results from the Regional Flood Risk Assessment are designed to facilitate data exploration to help municipalities attain a more comprehensive understanding of their flood risk. The derived risk maps provide a clear indication of where available data and preliminary model parameters characterize risk to be the highest. Supplementary results as well as the provided consequence and likelihood mapping enable municipalities to explore these high risk areas to determine whether:

a) The calculated risk is invalid, and the model parameters or input data need to be adjusted; or
b) The calculated risk seems appropriate, and intervention should be prioritized in the highlighted area.

When interpreting the risk assessment results, it is important to note that all assets located in a high-risk sub-basin are not necessarily at risk of flooding. When considering the flood risk to a specific building or asset, only pertinent indicators should be considered, relevant local knowledge and previous work in the area should be relied upon, and supporting information delivered alongside this report should be referenced.

The results of the risk assessment prioritize spatial assessment, but additional insights can be gleaned by plotting each sub-basin on the risk matrix, as shown in the example in Figure 11: For a sample area in the Region, sub-basin risk scores are plotted on risk matrices for each of the four flood risk perspectives.

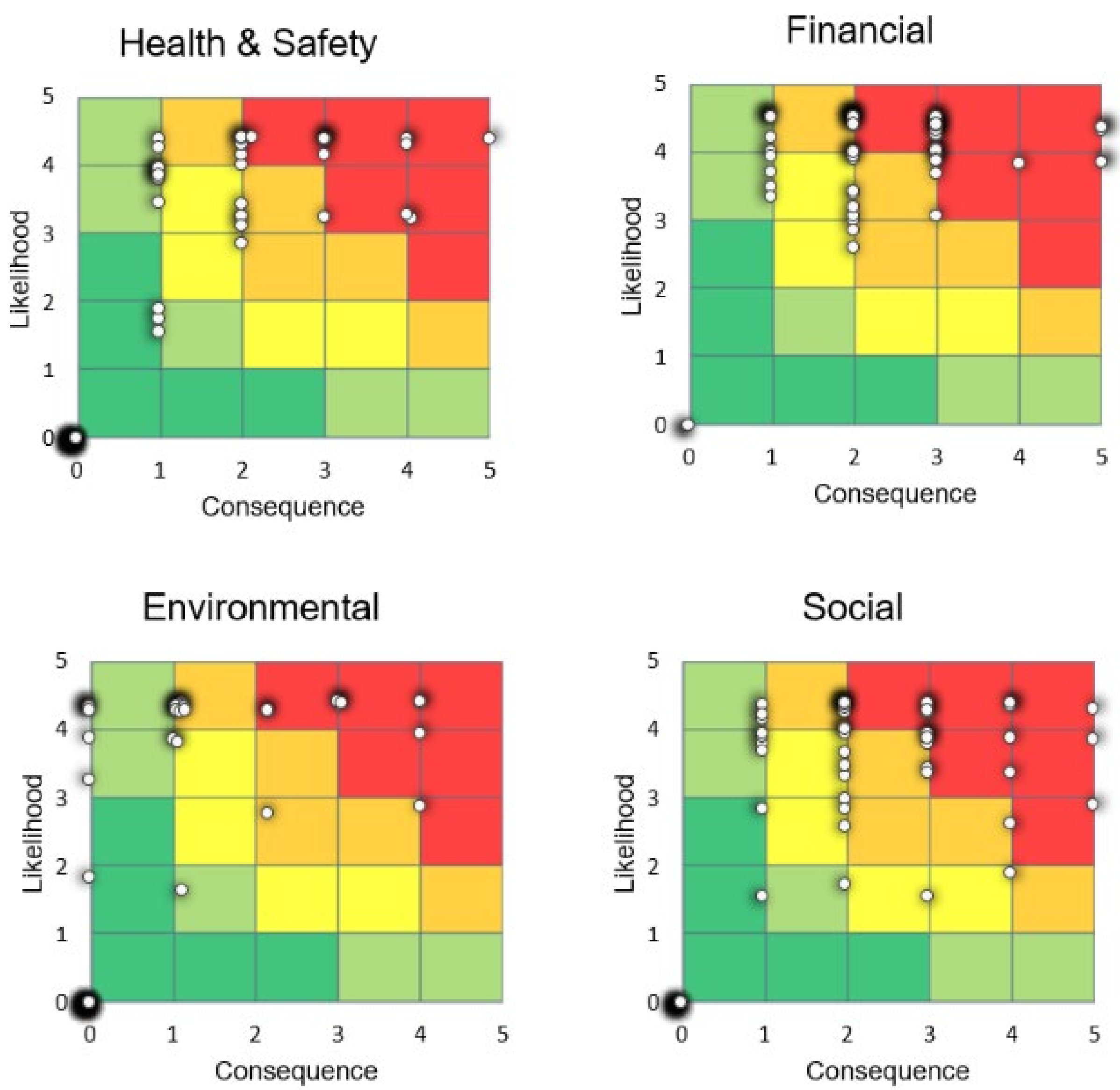


Figure 11: For a sample area in the Region, sub-basin risk scores are plotted on risk matrices for each of the four flood risk perspectives.

Visualizing flood risk according to the constituting flood likelihood and consequence scores as above can be helpful when determining an appropriate intervention for each sub-basin. Other utilities that have used this technique typically define the zones of the risk grid as follows[7]:

- **High Consequence & High Likelihood:** Intolerable risk requires immediate intervention.
- **Low Consequence & High Likelihood:** Requires increased monitoring.
- **High Consequence & Low Likelihood:** Requires increased contingency planning.
- **Low Consequence & Low Likelihood:** Requires continuous review to confirm risk ranking.

Once input data has been validated and sensitivity testing has been completed, municipalities may choose to establish appropriate risk tolerances to support future budgetary requests.

In addition, as the risk model considers the health and safety, environmental, and social components of flood risk as well as the financial aspect, these results can support municipalities when applying for external grants or funding that require a more holistic consideration of flood risk.

5.5 Regional Observations and Implications

Results from the Regional Flood Risk Assessment are highly dependent on assigned risk tolerances and vary by municipality according to flood hazards, development patterns, and data availability. Consequently, regional statistics are not meaningful, and results cannot be directly compared across municipalities. Below are some general observations from across the Region:

- Essential services, like health centres, fire halls, RCMP detachments, and utility stations, are represented under multiple indicators and flag certain sub-basins as high risk across multiple perspectives.
- Generally, the highest health and safety risks are typically associated with fire halls, health centres, or RCMP detachments. Otherwise, health and safety risk are predominantly driven by mold exposure in high density neighbourhoods. The risk of drowning is comparatively negligible.
- Flooding in industrial areas typically poses the greatest environmental risk.
- Essential services are also common in sub-basins with high financial risk. This is largely due to the way each financial indicator evaluates risk. The agricultural, residential, and commercial indicators assess risk relative to the exposed area; these indicators act as a proxy for direct financial flood damages. For the public services indicator, the indirect and intangible financial consequences are accounted for by qualitatively assigning financial consequences scores to specific infrastructure.
- Flooding of essential services and other community resources like grocery stores, churches, or community centres are important from a social perspective. In rural areas where residential development (Indicator 10) and the transportation network (Indicator 11) are less dense, a small number of assets exposed to flooding can lead to a higher social flood risk score. Apart from campgrounds exposed to widespread flood hazards, the Outdoor Recreation indicator has a small associated flood risk.

[7] https://www.epcor.com/products-services/drainage/Documents/EPCOR_SIRP_Feb2018_Report.pdf

While it is not meaningful to compare at-risk sub-basins between municipalities, it is worthwhile to consider how flood hazards are expressed across the Region. By area, more land in the Region is at-risk from river flooding than from stormwater. Across the study area 1,259 km^2 and 390 km^2 of land is at risk from a 1:200-year storm event from river and stormwater flooding, respectively. However, slightly more buildings are at-risk from stormwater than river flooding, 13,299 and 13,083, respectively.

River-related flood hazards are generally more well-understood; flooding is typically constrained to flood plains and adjacent low-lying areas, and many municipalities are actively working to limit development in these flood prone areas through policy action. At the same time, documented historical floods and the ongoing FHIP continue to further a regional understanding of exactly where river flooding hazards could pose the highest risks. Generally, hazards from stormwater flooding are often more localized requiring targeted intervention. Whereas the cumulative effects of stormwater flooding can be significant, yet insurance coverage for overland flooding is often offered as a policy add-on. Without the same widespread understanding of stormwater hazards and support from higher levels of government, an integrated approach is particularly well-adapted for stormwater management. Complimented by traditional stormwater planning, the risk model and preliminary results can serve as a basis to support a more integrated approach to stormwater management across the Region.

Another important regional implication for this work is its connection with the EMRB's ongoing Climate Risk and Vulnerability Assessment. The workflow, climate scenario risk ranking results, and discussions that occurred through the CRVA workshops informed this Regional Flood Risk Assessment to ensure alignment between the two studies. Where the CRVA takes a large-scale view of climate risk in the Region, the flood risk model provides a highly granular assessment of two high risk climate scenarios considered in the CRVA – stormwater and river flooding. The overlap between these two projects can provide increased support for projects seeking funding from council to address flood risk mitigation and adaptation measures proposed by the CRVA could be locally implemented with reference to results from the Regional Flood Risk Assessment. In addition, the risk model and consequence data underlying the Regional Flood Risk Assessment could be adapted to other high risk climate scenarios identified in the CRVA. For example, fire hazard mapping could be easily input into the model to identify areas at high-risk from forest fires across the Region.

6.0 Future Considerations

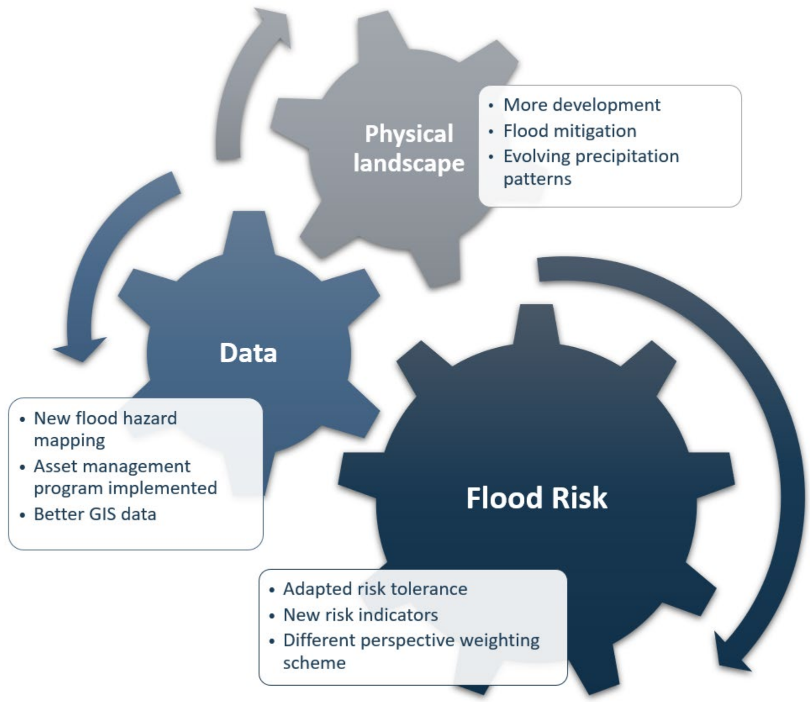


Figure 12: Conceptual diagram illustrating the dynamic, multifaceted environment captured in the Regional Flood Risk Model.

As illustrated in Figure 12: Conceptual diagram illustrating the dynamic, multifaceted environment captured in the Regional Flood Risk Model.the flood risk environment is complex and inherently dynamic. This dynamicity is engendered by evolving physical landscapes, data, and social contexts. Municipalities are dynamic entities; new areas are being developed, land uses are changing, and urban areas are densifying. These shifts significantly influence flood risk by impacting both the likelihood and consequence of flooding events. At the same time, effective implementation of flood mitigation measures reduce risk. Of note is that climate-projected rainfall trends indicate an increase in rainfall intensity in our Region, potentially leading to a shift in flood likelihood and risk. Therefore, as new data becomes available the model should be updated to enhance the accuracy and comprehensiveness of data describing public and private assets. Finally, municipal priorities inevitably shift, in the Flood Risk model, this translates into evolving risk tolerances, indicators, and perspective weighting schemes. The EMR Flood Risk Assessment Data Model is designed to evolve, incorporate these updates, enabling the generation of more accurate, comprehensive, and representative flood risk assessment results over time. The framework, data model, and processing tool have been designed, implemented, and evaluated for the Region, with the intent of promoting the iterative assessment of flood risk.

6.1 Reassessment Interval

The data collection and pre-processing required for reassessment can be very time and resource intensive. As such, it is recommended that every two years each municipality consider the evolution of their flood risk environment to determine whether a reassessment is required. The following list provides examples of factors that could result in a change in flood risk scoring:

Physical Landscape:

- Change in local precipitation patterns.
- Upstream development influencing local drainage patterns.
- Flood mitigation measures implemented in high risk areas.

- New neighbourhood development.
- Infill leading to significantly changed residential or commercial densities.
- Land use changes.
- Construction or demolition of buildings for important local services (e.g., hospital, correctional facility, school),

MUNICIPAL CONTEXT:

- Altered risk tolerance (e.g., flooding of an ambulance bay should be reflected by a consequence of 5; flooding from a 1:200-year stormwater event should be reflected by a likelihood of 3)
- Flood risk indicators that are not currently included in the assessment are identified and relevant data is made available (e.g., creek erosion)
- Perspective weighting used in preliminary analysis is determined to not reflect citizen's (e.g., environmental perspective should form 10% of total flood risk)
- Change in municipal policy or bylaw that impact risk framework or data model (e.g., changing from a 1:100-year event as a design standard to a 1:200 year event).
- Change in provincial guidelines that impact risk framework or data model (e.g., introduction of water quality guidelines)
- Development of complimentary policies or programs (e.g., climate adaptation plan)

DATA AVAILABILITY:

- Higher accuracy or more comprehensive data describing any of the factors described above becomes available.
- Improved flood hazard modeling is conducted through municipal studies, the provincial flood hazard identification program, updated JBA flood risk mapping, and other initiatives.
- Data describing current flood risk becomes available (e.g., data on inflow/infiltration, sanitary surcharge, water quality, stormwater asset condition, better flood consequence data – building footprints or attribution, transportation network, population density metrics)

As the data model and assessment results are unique to each municipality, there is no value added by running the model for the entire Region if certain municipalities have not undergone appreciable change.

6.2 Long-term Maintenance

The Regional Flood Risk Assessment tool and preliminary input data reside with the EMRB. The processing tool has been developed with widely used ESRI GIS software (ArcPro) and other open-source tools to ensure that future use is not limited by software availability. The model's structure and underlying assumptions are concisely documented in a technical document delivered alongside this report so that the tool can be directly altered or re-built in a different program that better aligns with the technical expertise of EMRB staff. Future re-assessment costs could vary significantly depending on how the EMRB decides to adapt the tool in the future; possible options include: contract a developer to code a tool with a graphical user interface that can be used by EMRB staff, engage a consulting firm to re-run the assessment through their own proprietary script-based format, or hire permanent technical staff capable of altering the existing tool.

In addition to the long-term maintenance and utility of the processing tool, data storage must also be considered. As the EMRB is currently developing their organizational data strategy and data storage framework, data used in this preliminary assessment is housed outside of any organizational data structure in project-specific spatial databases. However, many of the datasets used in this assessment are useful for other EMRB initiatives (e.g., zoning information, building footprints, agricultural land use, transportation network, landfill transfer stations). When a data storage solution is eventually developed, it would be more efficient for the flood risk assessment tool to connect directly to a regional database and all relevant data could be directly accessed for processing. It is essential that the EMRB considers spatial data storage and processing requirements when eventually developing their data storage solutions. Use of an ETL (extract, transform, and load) software program such as FME would increase interoperability and ensure database integrity throughout processing.

Once data storage solutions have been established protocols for updating input data must be established. It should be the responsibility of municipalities to identify if sufficient change has occurred to warrant a reassessment (Section 6.1) and to also identify data for subsequent reassessment. In most circumstances, the municipality should be responsible for providing updated data. If regionally relevant products become available, for example high-resolution JBA flood hazard modeling, it may be beneficial to acquire data as a Region.

Note that in most cases significant pre-processing will be required to convert data into the required formats for use in the processing tool. Depending on the type and structure of input data, the time commitment and technical expertise required to conduct the necessary pre-processing could be significant. Technical and budgetary limitations at the municipal level could be prohibitive, and it would be up to the EMRB staff and member municipalities to determine whether this pre-processing will be conducted by the municipality or by a GIS expert on staff at the EMRB.

6.3 Reporting and Key Performance Indicators

Findings from the Flood Risk Assessment can be extremely sensitive and require validation of the input data, and risk tolerances by member municipalities before making the results public. In making the results public, will require the municipality to:

a) Explain the risk assessment results at a more granular level.
   - For example, if a particular sub-basin is high risk, municipalities must be able to explain the results and implications to the assets and populations in that sub-basin.
   - In support of this: the supplementary results generated by the risk assessment processing tool are designed to encourage exploration of the results and facilitate a greater understanding of flood risk at a granular scale.

b) Be prepared to address questions around how flood risk will be mitigated in any high-ranking area/sub-basins.
   - Respond with mitigation solutions based on existing policies and bylaws, level of service, budgetary limitations, and other factors.
   - Discussions, knowledge sharing, and future projects undertaken by the Stormwater Collaborative could provide extra support for municipalities as they attempt to address identified high risk areas.

The objective of sharing results publicly is to provide information and tools to educate citizens about their specific flood-associated risks, so that they can make informed choices about how to protect themselves. This is a key aspect of integrated stormwater management.

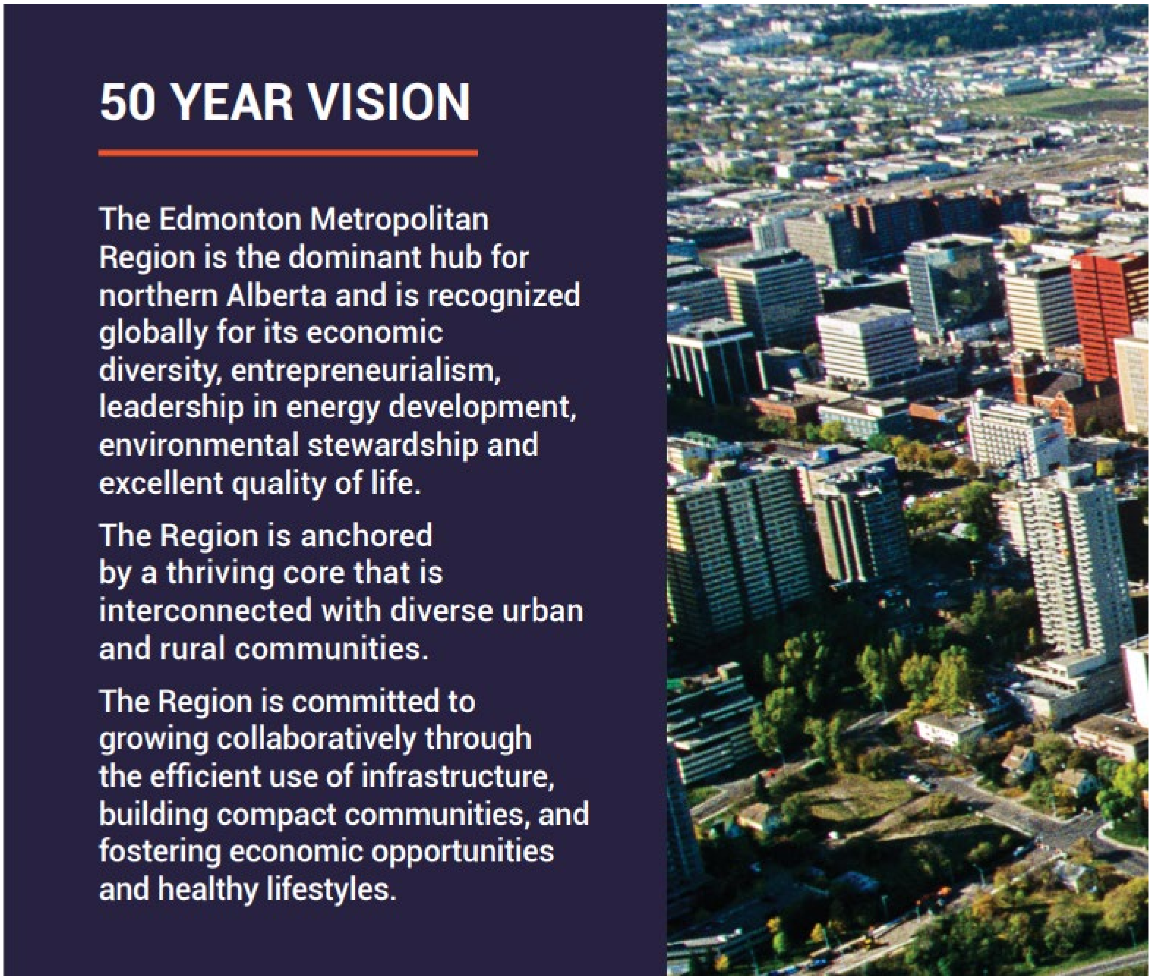
Due to the dynamic nature of the model, flood risk indicators developed and calculated as part of the risk assessment should not be considered as Key Performance Indicators (KPIs). Results are highly dependent on the quality and comprehensiveness of model input data, and, at this early stage, changes in flood risk scores are just as likely to reflect improvements in data quality as they are to reflect flood risk reduction.

However, model input data as well as public and stakeholder engagement around model results can help to inform the KPIs needed to monitor and measure stormwater management in the Region. In combination with information from past regional projects (e.g., the Blackmud/Whitemud Surface Water Management Study), regional data and climate initiatives currently underway can provide additional guidance on KPIs. Collectively, these initiatives contribute to the development of a common framework to monitor and measure stormwater management across the Region, but additional work is needed to identify well-defined, attainable objectives for stormwater management in the Region and in turn relevant, quantifiable KPIs.

Appendix A: Collaborative Members

- Beaumont – **Ryan Orlovsky**, Manager, Utility and Facility Operations (Member); **Aaron Lewicki**, Director, Infrastructure (Alternate)
- Devon – **Sean Goin (Co-Chair)**, Manager of Infrastructure (Member); **Paresh Dhariya**, General Manager of Planning and Operations (Alternate)
- Edmonton – **Mathew Langford (Co-Chair)**, Manager of Stormwater Planning, EPCOR (Member); **Susan Ancel**, Director, One Water Planning, EPCOR (Alternate)
- Fort Saskatchewan – **Brad McDonald**, Manager, Infrastructure Strategies (Member); **Janel Smith-Duguid**, General Manager of Infrastructure and Planning Services (Alternate)
- Leduc – **Ryan Graham**, Manager, Infrastructure (Member); **Shawn Olson**, Director, Engineering and Environment Planning (Alternate)
- Leduc County - **Des Mryglod,** Director of Engineering and Utilities (Member); **Shailesh Modak**, Manager of Utilities (Alternate)
- Morinville – **Jordan Betteridge**, Manager, Infrastructure Services (Member)
- Parkland County – **Matthew Good**, Land Development Engineering (Member)
- Spruce Grove – **Mark Hussey**, Director of Engineering (Member); **Rae-Lynne Spila**, Municipal Engineer (Alternate)
- St. Albert – **Regan Lefebvre**, Senior Manager, Utilities (Member)
- Strathcona County – **Jessica Dalton**, Manager, Land Development Engineering (Member)
- Sturgeon County - **Jeff Yanew**, Manager of Utility Services (Member)

Appendix B: Growth Plan: 50 Year Vision



Source: *Edmonton Metropolitan Growth Plan: Re-Imagine. Plan. Build.*

Appendix C: Metropolitan Region Servicing Plan Guiding Principles

Creating common understanding of the shared servicing challenges is vital to creating an environment where municipalities can think and act in the best interest of the Region. The Metropolitan Region Servicing Plan[8] (MRSP) Principles reflect the regional imperative for working together and will provide critical guidance for the planning, investment, and coordination of the delivery of metropolitan services. The MRSP Principles are aligned with the guiding principles of the growth plan.

The MRSP Principles are to:

- Lead with a metropolitan mindset for the greater good.
- Pursue leading and innovative research, technology, and best practices.
- Build, collect, and share regionally relevant data, information, and knowledge.
- Prioritize regionally scaled service investments informed by evidence.
- Leverage sub-regional service initiatives to benefit the Region.
- Recognize the unique municipal service contexts.
- Guarantee the safety and wellness of citizens.
- Act in a regional manner with a unified voice.

[8] Edmonton Metropolitan Region Board. 2019. Metropolitan Region Servicing Plan. Accessed June 2021.

Appendix D: Supporting Programs and Projects

EPCOR's Stormwater Integrated Resource Plan (SIRP)

A combination of strained municipal budgets, changing weather patterns, as well as expanding and intensifying development demands a shift in the way water is valued, managed, and planned. In the Region, EPCOR is leading the transition towards integrated water resource management through their Stormwater Integrated Resource Plan. By adopting a holistic, iterative planning framework that integrates externalities; accounts for operational, planning and infrastructure responses; is informed by risk as well as financial analysis; and is underlain by an open participatory process, EPCOR has demonstrated that a practical, evidence-based program can save money and increase community engagement.

The EMR benefits from access to existing expertise in Integrated Flood Risk Management. In its 2021 Report: Climate Change and the Preparedness of 16 Major Canadian Cities to Limit Flood Risk[9], the Intact Centre gave Edmonton top marks for its Flood Risk Assessment as it considers health, safety, environmental, and social/services, as well as financial impacts. Developed, and managed by EPCOR, the Flood Risk Assessment framework supports SIRP and was a driving factor behind a much-improved flood resiliency grade from 2015 and helped Edmonton earn one of the highest scores of any Canadian city.

EPCOR's Flood Risk Assessment Framework was adopted for the Regional Flood Risk Assessment, and members of the SIRP team provided valuable feedback throughout the development of the Regional Flood Risk Data Model.

Climate Risk Vulnerability Assessment (CRVA)

The Climate Risk and Vulnerability Assessment is a separate EMRB-led project run in parallel to this Flood Risk Assessment. The CRVA is a comprehensive evaluation that identifies and analyzes the risks and vulnerabilities in the Region resulting from climate change. Where the EMR Flood Risk Assessment identifies localized areas of high-flood risk, the CRVA works at a regional scale to identify which climate risks are the most regionally significant and proposes adaptation actions and recommendations tailored to the Region. Among the 22 climate risk scenarios investigated through the CRVA, initial results indicate that river flooding and stormwater flooding pose high to very-high risks to the economy, the built environment, the natural environment, as well as citizen health and well-being.

Members of the Stormwater Collaborative participated in the CRVA workshops and informed the climate scenario risk rankings, as well as the adaptation actions, strategies, and recommendations that will be proposed in the final CRVA report. In addition, the ranking criteria established through the CRVA, and discussions facilitated through the climate risk ranking workshops, were used to inform flood risk thresholds assigned in the Regional Flood Risk Model. The final CRVA report, expected in December 2023, will outline the recommended adaptation measures for the Region. Depending on the proposed measures, the results from the EMR Flood Risk Assessment could further complement the CRVA work by helping to identify priority locations for the implementation of recommended flood adaptation measures.

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[9] Feltmate, B. and M. Moudrak. 2021. Climate Change and the Preparedness of 16 Major Canadian Cities to Limit Flood Risk. Intact Centre on Climate Adaptation, University of Waterloo.

Alberta Flood Hazard Identification Program (FHIP)

Recognizing the potential for significant damage to public and private property, the significant hardships to residents, and the possibility of loss of life due to creek or river flooding, flood hazard mapping began in the province in the 1970s. Mapping continues for vulnerable communities located along watercourses today under the province's Flood Hazard Identification Program. Through advanced data collection, hydraulic modeling, and high-resolution mapping, the program produces and publicly issues river flood hazard mapping[10] with the aims of increasing public safety and awareness of flooded hazards, promoting appropriate development of flood hazard areas, and reducing future flood damages and related costs. To date, 43 studies have been done across the province. Of those, three have been conducted within the Region. The flood depth grids produced as part the North Saskatchewan River and the St Albert Flood Hazard Studies serve as key inputs for determining flood likelihood in the Regional Flood Risk Assessment[11].

Insurance Industry Flood Hazard Mapping

Optional overland flooding coverage is increasingly offered by property insurance providers in Canada. While premiums can be prohibitive in areas deemed very high-risk, an increasing number of homeowners are including the optional coverage in their policies (53% in 2019[12]). Some providers offering this coverage may have internal catastrophic modeling teams that generate the flood hazard maps used to determine insurance pricing. Other brokers rely on mapping provided by external firms such as JBA Risk Management. EPCOR acquired the 2020 iteration of overland flood hazard maps from JBA Risk Management to support the Flood Risk Assessment underlying SIRP. They were shared with the EMRB for the purposes of the EMR Flood Risk Assessment.

Derived from topographic data and climate models, the JBA flood hazard maps depict the modeled flood depth from overland flooding for different storm scenarios across the Region. Where alternative flood hazard mapping was not available, JBA mapping for the following scenarios was used in the EMR Flood Risk Assessment:

- 1:20 year event – Stormwater Flooding
- 1:50 year event – Stormwater Flooding
- 1:75 year event – Stormwater Flooding
- 1:100 year event – Stormwater Flooding
- 1:20 year event – River Flooding
- 1:50 year event – River Flooding
- 1:75 year event – River Flooding
- 1:100 year event – River Flooding

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[10] https://floods.alberta.ca/

[11] Flood depth grids from the Nisku and Leduc County – Blackmud Creek – Flood Hazard Study are not available; the results are used to validate mapping from JBA Risk Management and not directly included in the model.

[12] https://www.epcor.com/products-services/drainage/flood-mitigation/Documents/CR_8090%20Attachment%202%20-%20EPCOR%20SIRP%20August%202021%20Secure%20Utility%20Committee%20Report%20and%20Appendices.pdf

- 1:200 year event – Stormwater Flooding
- 1:200 year event – River Flooding

Because the JBA flood mapping is based solely on topography, locally important factors like existing stormwater infrastructure (i.e. storm ponds, stormwater pipe network) or the infiltration capacity of the ground cover are not reflected in the flood hazard mapping. As a consequence, the resulting flood mapping may overestimate flood risk in areas where flood mitigation measures have been implemented.

Federal Flood Damage Estimation Guidelines & Provincial Flood Damage Assessment Studies

The ability to quantify flood damages and evaluate the cost-efficiency of potential mitigation options is essential to effectively assess flood risk and plan appropriate mitigation strategies. In line with these objectives, the Federal Government issued the Federal Flood Damage Estimation Guidelines for Buildings and Infrastructure in 2021 to provide guidance on how to evaluate potential economic losses due to flooding. Focusing on damage estimation methodologies for buildings and infrastructure, the document provides guidance on best practices for the development and application of depth-damage curves. Depth-damage curves are mathematical functions specific to each building, land use or infrastructure type that describe the relationship between depth of flooding and estimated economic loss. When paired with flood hazard modeling, the financial damage incurred to any specific building can be estimated for any mapped storm event.

Following the significant damages experienced in Calgary from the 2013 flood event, the province launched a pilot study to develop a rapid flood damage assessment model. Key deliverables from the study were depth-damage curves for various residential and non-residential building types throughout the city. Methodologies to adjust for inflation and adapt curves across the province are also summarized along with a list of 60 additional high priority municipalities that they recommend the damage assessment be expanded to. Since the Calgary pilot, damage assessments have been conducted in a few of these high priority municipalities. None have been conducted within the EMR yet.

For the EMR Flood Risk Assessment, simplified derivations of the Calgary depth-damage curves are applied to estimate residential financial damages. Should the province conduct a damage assessment in the Region in the future, framework is in place to easily incorporate revised depth-damage curves.

Municipal and intermunicipal studies and asset management programs

Drainage planning and management is highly variable across the Region. The current iteration of the EMR Risk Assessment was conducted using sub-basins delineated as part of other municipal studies. Data were available for Devon, Leduc, St Albert, Strathcona County, Sturgeon County, Parkland County, Spruce Grove, and Stony Plain.

During the data collection phase of this work, the following data and studies were identified for use in the Flood Risk Model, but due to time constraints were not incorporated in the preliminary results.

- Leduc County: Blackmud Creek Flood Hazard Study & drainage districts
- Morinville: Municipal Utility Servicing Plan – Sanitary surcharge modeling
- Spruce Grove: City-wide Stormwater Management Facility Condition Assessment – Storm pond risk
- Sturgeon County: Culvert capacity information

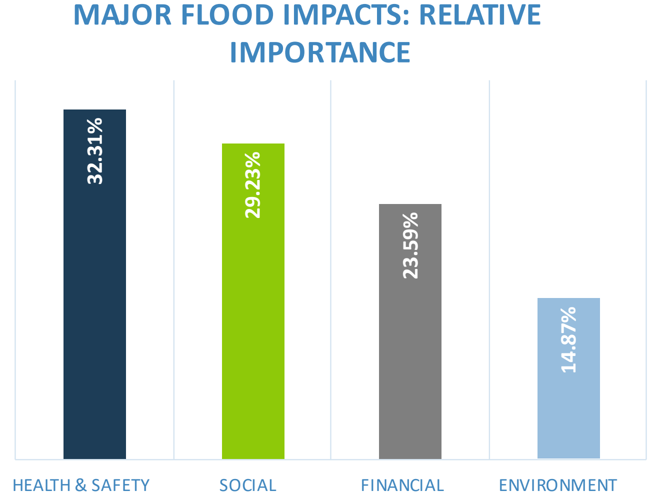
As additional information becomes available in any of the municipalities, the data model can be tweaked to accommodate it. Examples of additional data that could feed into future iterations of the risk assessment include:

- hydraulic modeling conducted for a Drainage Master Plan or Area Structure Plan,
- locations with historic flooding (311 reports),
- geolocated asset capacity or condition information,
- inflow/infiltration modeling results.

Perspective Weighting: City of Edmonton Results

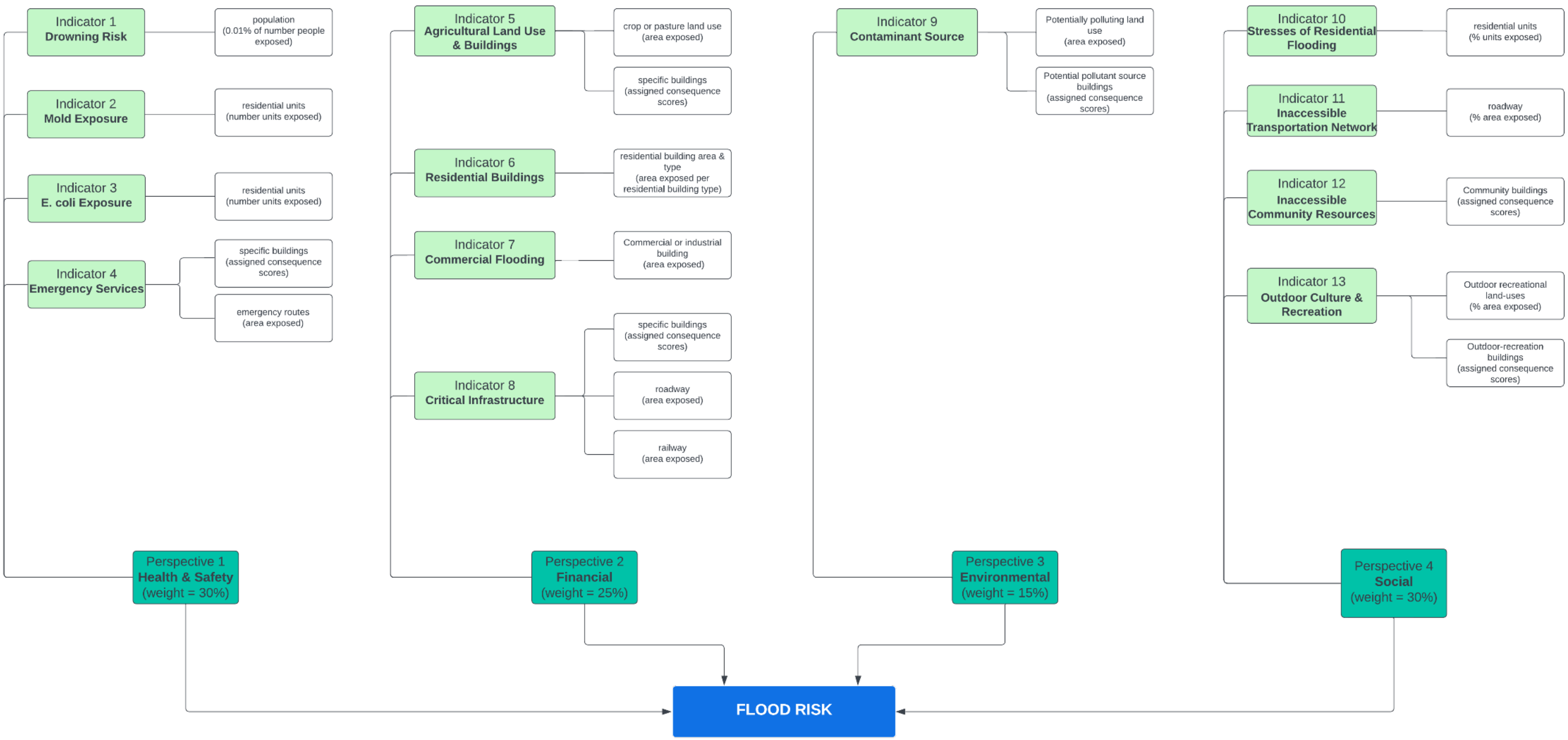
Principle findings:

- Financial damages were less important than expected
  - Driving perspective in traditional planning
- Concerns for environment were relatively small
- Primary concerns:
  - Hospitals
  - Essential services (e.g., power & water)
  - Risks to human life
  - Social service agencies



Adapted from Susan Ancel presentation to ICLR, 2021

Edmonton Metropolitan Region Board



Appendix F: Regional Flood Risk Data Model & Indicators

Indicator 1: Drowning

Perspective	Health & Safety	Indicator Confidence: Very Low
Description	A person can drown in as little as two inches of water; this indicator estimates the number of deaths and missing persons due to a flood.	
Assumptions	• Fatalities can be estimated based on past events that have occurred elsewhere in Canada (Mortality = 0.01 %, EbbWater, Public Safety Canada 2019). • People are most exposed to drowning risk when at home, but not necessarily within a building (risk is a function of land being flooded).	
Limitation	• Assumes population is evenly distributed across land parcels. • Based on statistics that assume a very quick onset of flooding • Increased drowning risk near storm ponds is not considered	
	Proxies	**Data Source**
Primary Datasets	Permanently inundated portions of land parcels (lakes, channels) are excluded, and the exposed population is calculated based on population density allocated to inundated landcover. Population at risk of drowning is 0.01% of the exposed population. 1. **Population** 2. **Parcels** 3. **Zoning**	1. **2021 Census** 2. **2021 Altalis or municipal source** 3. **Municipal source**
Consequence Modifiers	4. **Number of people older than 75 (+):** Elderly are more likely to be affected by health consequences of flooding. 5. **Number of people younger than 10 (+):** Drowning risk is higher for young children.	4. **2021 Census** 5. **2021 Census**
Likelihood Modifiers	1. **Presence of nearby drainage infrastructure (-):** Nearby culverts, ditches or other major drainage features will reduce the likelihood of flooding.	7. **Municipal source (stormwater infrastructure) & Alberta Transportation**
Flood Hazard	6. **River** 7. **Stormwater**	6. **AEP & JBA** 7. **JBA**

Indicator 2: Mold Exposure

Perspective	Health & Safety	Indicator Confidence: Moderate
Description	Flooding of homes and basements can increase health consequences through mold exposure. This indicator estimates the number of residences that could be exposed to mold from river or stormwater flooding.	
Assumptions	• People are primarily affected where they live and not in their work environment or during recreation. • Assumes living space remains damp so that mold can grow. If clean up and remediation are immediate and done properly, the chances for mold exposure are much lower. • Buildings considered in indicator are based on zoning. If located in mixed use, direct control, or agricultural zones, buildings are assumed to have at least one residence on them. • Based on an unlikely worst-case scenario: all modeled flood depth that intersects with the flood footprint is translated directly into flooding in a home.	
Limitation	• Does not account for any preventative measures in place (e.g., sump pump, weeping tile). • For residential parcels where accessory buildings could not be distinguished from primary residences, surcharge in the accessory buildings also increases risk.	
	Proxy	**Data Source**
Primary Datasets	Mold exposure is determined for each primary building on a parcel zoned for residential. If the building footprint is intersected by a modeled flood extent, it is at risk of mold exposure. 1. **Building Footprints** 2. **Parcels** 3. **Zoning**	1. **Municipal source** OR **OpenStreetMap and AI generated** 2. **2021 Altalis or municipal source** 3. **Municipal source**
Consequence Modifiers	4. **Number of people older than 75 (+):** Elderly are more likely to be affected by health consequences of flooding. 5. **Multi-family units (+):** Flooding of a multi-unit home could impact more people than flooding of a single-family unit.	4. **2021 Census** 5. **Municipal source (zoning)**
Likelihood Modifiers	6. **Lack of a basement (-):** Residences without basements, typically apartment buildings or manufactured homes, are less likely to experience severe flooding and higher levels of mold exposure. 7. **Presence of nearby drainage infrastructure (-):** Nearby culverts, ditches or other major drainage features will reduce the likelihood of flooding.	7. **Municipal source (zoning)** 8. **Municipal source (stormwater infrastructure) & Alberta Transportation**
Hazards Assessed	8. **River** 9. **Stormwater**	8. **AEP & JBA** 9. **JBA**

Indicator 3: *E. coli* Exposure

Perspective	Health & Safety	Indicator Confidence: High
Description	Sanitary surcharge into homes can increase health risks through *E. coli* exposure. This indicator looks at the number of homes affected by sanitary surcharge.	
Assumptions	• People are primarily affected where they live and not in their work environment or during recreation. • Buildings considered in indicator are based on zoning. If located in mixed use, direct control, or agricultural zones, buildings are assumed to have at least one residence on them.	
Limitation	• Assumes no preventative measures in place (e.g. back-flow valves). • For residential parcels where accessory buildings could not be distinguished from primary residences, surcharge near accessory buildings also increases risk.	
	Proxy	**Data Source**
Primary Datasets	*E. coli* exposure is determined for each building on each parcel. If it is within a determined radius or the same sub-basin as a surcharged sanitary pipe or manhole, the residents of that building are at risk of *E. coli* exposure. 1. **Building Footprints** 2. **Parcels** 3. **Zoning**	1. **Municipal source** OR **OpenStreetMap and AI generated** 2. **2021 Altalis or municipal source** 3. **Municipal source**
Consequence Modifiers	4. **Number of people older than 75 (+):** Elderly are more likely to be affected by health consequences of flooding. 5. **Multi-family units (+):** Flooding of a multi-unit home could impact more people than flooding of a single-family unit.	4. **2021 Census** 5. **Municipal source (zoning)**
Likelihood Modifiers	6. **Lack of a basement (-):** Residences without basements, typically apartment buildings or manufactured homes, are less likely to experience surcharge. 7. **Presence of nearby drainage infrastructure (-):** Nearby culverts, ditches or other major drainage features will reduce the likelihood of flooding.	6. **Municipal source (zoning)** 7. **Municipal source (stormwater infrastructure) & Alberta Transportation**
Hazards Assessed	7. **Sanitary Surcharge**	7. **Municipally provided surcharge modeling**

Indicator 4: Emergency Services

Perspective	Health & Safety	Indicator Confidence: Moderate
Description	Emergency services can be directly affected by flooding if associated emergency service buildings or emergency routes are inundated.	
Assumptions	• If an emergency services building or route is impacted by flooding, there will be significant negative health consequences (e.g., lower capacity in ERs to deal with other issues, lower capacity of fire service to respond to emergencies). • Emergency services are assumed to be impeded if any portion of an emergency service building is exposed to flooding. Risk is scaled to the type of emergency service building (e.g., an exposed hospital would carry a higher flood risk than an exposed medi-centre). • Risk associated with emergency routes scales to the area of the emergency route exposed to flooding.	
Limitation	• Impacts of a flooded emergency service building or route could be regional, or at least community-wide. This indicator only associates those risks to the sub-basin within which they are located.	
	Proxy	**Data Source**
Primary Datasets	If any of the following are impacted by flooding, there is a calculated flood risk to emergency service operations. 1. **Hospitals, fire halls, RCMP detachments, ambulance bays , emergency shelters , medi-centres** 2. **Emergency routes**	1. **Municipal source** OR **OpenStreetMap & GoC Open Data** 2. **Municipal source** OR **major roads from National Road Network**
Consequence Modifiers	**N/A**	**N/A**
Likelihood Modifiers	1. **Presence of nearby drainage infrastructure (-):** Nearby culverts, ditches or other major drainage features will reduce the likelihood of flooding.	7. **Municipal source (stormwater infrastructure) & Alberta Transportation**
Hazards Assessed	3. **River** 4. **Stormwater**	3. **AEP & JBA** 4. **JBA**

Indicator 5: Agricultural Land Use & Infrastructure

Perspective	Financial	Indicator Confidence: Low
Description	Significant ponding can delay seeding or harvest or can lead to rot reducing agricultural productivity. Flooding of agricultural buildings used to store equipment, grain or animals could have significant financial consequences.	
Assumptions	• All crops and pasture lands are equally susceptible to flooding. If at least 4,046.86 m^2 any of the crop area is intersected by a modeled flood extent it is considered at-risk, with risk scaling to the area exposed to flooding. • Agricultural buildings are assumed to be at-risk any portion of the building footprint is exposed to flooding.	
Limitation	• Flood extents do not translate into timing or persistence of flooding, which are the main factors in determining whether flooding leads to reduced productivity. Occasional flooding that quickly drains would not necessarily be bad for a crop. • Flooding of across all types agricultural buildings is considered equally severe (e.g., flooding in a shed or a concentrated animal feeding operation both yield the same flood risk score)	
Proxy		Data Source
Primary Datasets	1. Crop or pasture landcover 2. Non-residential building located on agricultural land.	1. Agriculture & Agri-Food Canada (2018) 2. Municipal source OR OpenStreetMap
Consequence Modifiers	N/A	N/A
Likelihood Modifiers	N/A	N/A
Hazards Assessed	3. River 4. Stormwater	3. AEP & JBA 4. JBA

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Indicator 6: Residential Buildings

Perspective	Financial	Indicator Confidence: High
Description	Flooding to private residences can result in substantial clean-up, maintenance and repair costs as well as significant costs to replace damaged contents.	
Assumptions	• Worst case scenario: all flood depth that intersects with the flood footprint is translated directly into flooding in a home. • The residential building depth damage curves from AEP's 2015 Flood Damage Assessment reasonably characterize the flood related costs associated with different building types and their contents. • Majority of financial cost is experienced by damage to the building and not land.	
Limitation	• Assumes no preventative measures in place (e.g. sump pump, weeping tile). • Does not consider indirect costs (e.g. displacement costs).	
	Proxy	**Data Source**
Primary Datasets	Each building type is classified according to simplified AEP Flood Damage classes. The building type and area of flooded footprint are used to create a cost of flooding index. Risk scales with the cost of flooding risk. 1. **Building footprints** 2. **Building classification** (single family residence, multi-family residence, manufactured home, apartment) 3. **Depth-damage curves**	1. **Municipal source OR OpenStreetMap & AI generated** 2. **Municipal source OR Zoning** 3. **AEP Flood Damage Assessment 2015**
Consequence Modifiers	4. **Median neighborhood income (+):** Low-income residents may be less resilient to costs associated with flood damage	4. **Municipal source**
Likelihood Modifiers	5. **Lack of a basement (-):** Residences without basements, typically apartment buildings or manufactured homes, are less likely to experience severe flooding. 6. **Presence of nearby drainage infrastructure (-):** Nearby culverts, ditches or other major drainage features will reduce the likelihood of flooding.	5. **Municipal source (zoning)** 6. **Municipal source (stormwater infrastructure) & Alberta Transportation**
Hazards Assessed	7. **River** 8. **Stormwater**	7. **AEP & JBA** 8. **JBA**

Indicator 7: Commercial & Industrial

Perspective	Financial	Indicator Confidence: Moderate
Description	Flooding to commercial and industrial buildings can result in substantial clean-up, maintenance, and repair costs as well as significant costs to replace damaged contents.	
Assumptions	• Worst case scenario: all flood depth that intersects with the flood footprint is translated directly into flooding in a business. • Majority of financial cost is experienced by damage to the building and not land.	
Limitation	• Assumes no preventative measures in place (e.g., sump pump, weeping tile). • Assumes financial damages are only determined by area flooded. This indicator does not distinguish between service or content type when estimating financial damages. • Does not consider indirect costs (e.g., business interruption, loss of production).	
	Proxy	**Data Source**
Primary Datasets	Risk is determined as a function of building area exposed to flooding, with risk scaling with the exposed area. 1. **Building footprints** 2. **Building classification** (identifies all commercial and industrial buildings considered in indicator)	1. **Municipal source** OR **OpenStreetMap & AI generated** 2. **Municipal source** OR **Zoning** OR **OpenStreetMap**
Consequence Modifiers		
Likelihood Modifiers	3. **Presence of nearby drainage infrastructure (-):** Nearby culverts, ditches or other major drainage features will reduce the likelihood of flooding.	3. **Municipal source (stormwater infrastructure) & Alberta Transportation**
Hazards Assessed	4. **River** 5. **Stormwater**	4. **AEP & JBA** 5. **JBA**

Indicator 8: Public Buildings & Critical Infrastructure

Perspective	Financial	Indicator Confidence: Moderate
Description	Damage to critical infrastructure from flooding can have significant direct and indirect costs. From the CRVA: approximately $ 1 million annually from damage and indirect costs to water and wastewater treatment plants, $ 230 million damage to linear water infrastructure, $ 12 million direct and indirect costs due to road flooding.	
Assumptions	• Anywhere the flood extent intersects with a piece of critical infrastructure, there is a risk for damage or service interruption leading to increased financial losses.	
Limitation	• Other indirect and intangible costs are not accounted for (e.g. safety risks if substation goes out)	
	Proxy	**Data Source**
Primary Datasets	1. If any building critical to municipal function is exposed to flooding, there is a calculated flood risk with risk depending on the building type. Examples considered in the assessment are:. **Water Treatment Plant, Wastewater Treatment Plant, Electrical substation, Electrical transformer, Pump station, Booster Station, RCMP detachment, hospital, Town hall, emergency operations centre, public works lot and buildings.** 2. **Roadway Network** – risk scales to the area exposed to modeled flood extent. 3. **Railway Network**– risk scales to the area exposed to modeled flood extent.	1. **Municipal Source** 2. **NRCan National Road Network** 3. **NRCan National Railway Network**
Consequence Modifiers	**N/A**	**N/A**
Likelihood Modifiers	4. **Presence of nearby drainage infrastructure (-):** Nearby culverts, ditches or other major drainage features will reduce the likelihood of flooding.	4. **Municipal source (stormwater infrastructure) & Alberta Transportation**
Hazards Assessed	5. **River** 6. **Stormwater**	5. **AEP & JBA** 6. **JBA**

Indicator 9: Contaminant Sources

Perspective	Environmental	Indicator Confidence: Low
Description	Flooding into buildings or landcovers containing sources of contamination could lead to spills with deleterious environmental effects.	
Assumptions	• Anywhere where the flood extent intersects with a potential source of environmental contamination, the environment is at-risk.	
Limitation	• Assumes that if a site is exposed to flooding, contaminants are released. Does not account for protective mechanisms in place. • Only able to consider contaminant sources in a single unit, can not consider compounding effects of upstream release.	
	Proxy	**Data Source**
Primary Datasets	If any of the following sources are impacted by flooding, there is a calculated flood risk. The associated consequence varies according to building type or, for agricultural and industrial land uses, according to area exposed to flood hazards. **1. Sewage lagoon, septic tank, garbage dump, transfer station, auto-shop, chemical or plastic plant, industrial building, gas station.** **2. Agricultural land-use** **3. Industrial park**	**1. Municipal source** **2. Agriculture & Agri-Food Canada (2018)** **3. NRCan National Road Network**
Consequence Modifiers	**4. Environmentally Significant Areas (+):** Spills in ESAs would be more detrimental to the environment.	**4. AEP ESA Report (2014)**
Likelihood Modifiers	**5. Presence of nearby drainage infrastructure (-):** Nearby culverts, ditches or other major drainage features will reduce the likelihood of flooding.	**5. Municipal source (stormwater infrastructure) & Alberta Transportation**
Hazards Assessed	**6. River** **7. Stormwater**	**6. AEP & JBA** **7. JBA**

- Indicator not used

Indicator 10: Stresses of Residential Flooding

Perspective	Social	Indicator Confidence: High
Description	Flooding of many residences in a neighbourhood leads to increased community stress.	
Assumptions	• Worst case scenario: all flood depth that intersects with the flood footprint is translated directly into flooding in a home. • Community-level stress is a function of the proportion of neighbourhoods in a sub-basin that are at risk of flooding.	
Limitation	• Assumes no preventative measures in place (e.g., sump pump, weeping tile). • Due to the relative risk scaling, sub-basins that contain few residences will be overrepresented by this index (e.g., if one out of only two homes located in a particular sub-basin are at risk of flooding, the risk score will be unrepresentatively high).	
	Proxy	**Data Source**
Primary Datasets	If a residential building footprint is intersected by a flood extent, the home is considered at-risk. 1. **Building footprints** 2. **Zoning**	1. **Municipal source** OR **OpenStreetMap & AI generated** 3. **Municipal source**
Consequence Modifiers	3. **Median neighborhood income (+):** Low-income residents may be less resilient to stresses associated with flood damages 4. **Residence type (+):** Flooding of multi-family units, senior's residences, prisons, group homes, etc. will have a more widespread impact on residents than the flooding of a single-family home.	4. **2021 Census** 5. **Municipal source** OR **OpenStreetMap & GoC Open Data**
Likelihood Modifiers	5. **Lack of a basement (-):** Residences without basements, typically apartment buildings or manufactured homes, are less likely to experience severe flooding. 6. **Presence of nearby drainage infrastructure (-):** Nearby culverts, ditches or other major drainage features will reduce the likelihood of flooding.	5. **Municipal source (zoning)** 6. **Municipal source (stormwater infrastructure) & Alberta Transportation**
Hazards Assessed	7. **River** 8. **Stormwater**	7. **AEP & JBA** 8. **JBA**

Indicator 11: Inaccessible Transportation Network

Perspective	Social	Indicator Confidence: High
Description	When many roads are inaccessible due to flooding, residents will have to use alternative routes increasing their commute times, or certain areas may become inaccessible.	
Assumptions	• Associated stresses are proportional to the percent of roads that are flooded (e.g., in a rural area with few roads, one road closing would be more consequential than one inaccessible road in an urban neighbourhood where more may be detours available).	
Limitation	• Index considers all road types to be equal (e.g., flood-related road closures on a highway could have the same representation as a closure on a resource road). • This indicator only considers flooding to the road network, no multi-use paths or flooding at transit terminals are considered.	
	Proxy	**Data Source**
Primary Datasets	If a portion of the road network is intersected by a flood extent, that road is considered at-risk. 1. **Road network**	1. **NRCan National Road Network**
Consequence Modifiers	**N/A**	**N/A**
Potential Likelihood Modifiers	2. **Presence of nearby major drainage infrastructure (-):** Nearby culverts, ditches or other major drainage features will reduce the likelihood of flooding.	2. **Municipal source (stormwater infrastructure) & Alberta Transportation**
Hazards Assessed	3. **River** 4. **Stormwater**	3. **AEP & JBA** 4. **JBA**

Indicator 12: Inaccessible Community-Level Resources

Perspective	Social	Indicator Confidence: Moderate
Description	Flooding that results in the temporary or permanent closure of certain buildings or services will have a significant impact on the wider community.	
Assumptions	• Worst case scenario: all flood depth that intersects with the flood footprint is translated directly into flooding in a building. • If a community service building is impacted by flooding, resident stress will be very high and mental health could be at-risk. • Community services are assumed to be impeded if any portion of the building is exposed to flooding. Risk is scaled to the type of building	
Limitation	• Assumes no preventative measures in place. • Impact of flooded resource is only factored into the risk score for the area it is located in, even if it likely affects populations located outside the area.	
	Proxy	**Data Source**
Primary Datasets	1. If any building considered an important community-level resource is exposed to flooding, there is a calculated flood risk with risk depending on the building type. Examples considered in the assessment are: **School, church, community hall, library, social services building, mental health centre, recreation centre, grocery store, museum, food storage sites, pharmacies, doctor office, RCMP detachment, covered transit station, substation, transformer, WTP, WWTP, booster station.**	1. **Municipal source** OR **OpenStreetMap**
Consequence Modifiers	2. **Median neighborhood income (+):** Low-income residents may be less resilient to stresses associated with flooding and may be more reliant on community supports.	2. **2021 Census**
Likelihood Modifiers	3. **Presence of nearby drainage infrastructure (-):** Nearby culverts, ditches or other major drainage features will reduce the likelihood of flooding.	3. **Municipal source (stormwater infrastructure) & Alberta Transportation**
Hazards Assessed	4. **River** 5. **Stormwater**	4. **AEP & JBA** 5. **JBA**

Indicator 13: Outdoor Recreation & Cultural Sites

Perspective	Social	Indicator Confidence: Moderate
Description	Flooding of certain outdoor sites could result in their temporary or permanent closure having a significant social impact on residents.	
Assumptions	• Anywhere where the flood extent intersects with an outdoor recreation building or site, that asset is at risk.	
Limitation	• Assumes the site is temporarily inaccessible or damaged anytime and depth of flooding runs over a site, which may not be the case for many outdoor resources (e.g., certain sports fields).	
	Proxy	**Data Source**
Primary Datasets	1. If any of the following sources are impacted by flooding, there is a calculated flood risk. Risk scales with asset type. Examples considered in this assessment are: **sports field, playground, playing court, park, outdoor pool, campground, golf course, archaeological site, outdoor gun range, outdoor building (e.g., gazebo, campground administrative building, golf clubhouse).**	1. **Municipal source** OR **OpenStreetMap**
Consequence Modifiers	**N/A**	**N/A**
Likelihood Modifiers	**N/A**	**N/A**
Hazards Assessed	2. **River** 3. **Stormwater**	2. **AEP & JBA** 3. **JBA**