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Alberta Municipal Infrastructure Review

Risk Framework and Guide

Ministry of Transportation and Economic Corridors

September 23, 2025

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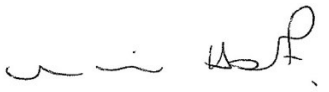
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Glossary of Terms

Abbreviation	Description
AADT	Average Annual Daily Traffic
AC	Asbestos Cement
ACC	Asbestos Cement Pipe (Panel Member Term)
AM	Asset Management
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
CCP	Concrete Circular Pipe
CI	Cast Iron
CIBI	Canadian Infrastructure Benchmarking Initiative
CMA	Calcium Magnesium Acetate
COF	Consequence of Failure
CP	Cathodic Protection
CPP	Concrete Pressure Pipe
CRMF	Common Risk Management Framework
DI	Ductile Iron
DR	Dimension Ratio
ESA	Environmental Site Assessment
ESL	Expected Service Life
FRP	Fiberglass Reinforced Plastic
GIS	Geographic Information System
HDPE	High-Density Polyethylene
IAM	Institute of Asset Management
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LOF	Likelihood of Failure
MAS	Maximum Allowable Stress
NPS	Nominal Pipe Size
PCCP	Prestressed Concrete Cylinder Pipe
PSI	Pounds per Square Inch
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
RS	Redundancy Score
SME	Subject Matter Expert
SP	Steel Pipe
SRS	System Redundancy Score
STL	Steel
STR	Short-term pressure rating
TM	Technical Memo
ULC	Underwriters Laboratories of Canada
WRF	Water Research Foundation

1. Risk Framework Model

Effective risk assessment is vital for Albertan municipalities to manage infrastructure assets sustainably. With aging infrastructure and growing service demands, municipalities must prioritize maintenance, renewal, and replacement, especially for underground systems like water and wastewater that often go unnoticed until they fail. A clear, data-driven risk assessment framework helps municipalities evaluate risks by measuring the likelihood and impact of failures. Using best practices and expert input, this framework supports proactive asset management, ensuring efficient use of resources and long-term infrastructure reliability across Alberta's diverse communities.

This report summarizes the risk assessment approach as well as provide a guide of how to use the created tool. This section outlines the risk assessment approach, showing how Alberta municipalities can identify and measure infrastructure risks. It explains key concepts like Likelihood of Failure (LoF) and Consequence of Failure (CoF), assessed using a Multi-Criteria Rating Technique suited to Alberta's specific conditions. The framework's flexible, semi-quantitative design works for communities of varying sizes including all towns and cities. It also describes how weightings are set through surveys of municipal leaders and data analysis, ensuring fair and scalable risk evaluations. Finally, it discusses framework calibration (of raw data to terms used in the framework) to balance the needs of small and large communities for equitable, effective risk management in Alberta.

1.1 Risk Assessment Overview

This section outlines the preliminary work undertaken as part of the project. It provides an overview of the initial risk assessment approach, key findings, and early insights developed to date. While the results from an initial pilot project and the associated recommendations are not included in this report, the information presented here will inform the refinement of the overall methodology and guide future implementation.

Risk assessment is a critical component of strategic decision-making within organizations, particularly for determining which projects or activities should be prioritized based on their economic and operational justification. Municipalities increasingly face the challenge of prioritizing infrastructure asset maintenance, renewal, and replacement—especially for linear underground networks that often remain "out of sight and out of mind." This requires effective methodologies for identifying, assessing, and mitigating risks, alongside optimized resource allocation.

The complexity of managing linear infrastructure lies in understanding inherent risks, identifying appropriate intervention strategies, and timing their implementation. By adopting proactive risk management strategies—such as inspections, operational adjustments, and resilience-building interventions—municipalities can mitigate failure risks, extend asset lifespans, and enhance service reliability within budgetary constraints.

Within infrastructure management, risk exposure refers to the identification of critical vulnerabilities within the system. Understanding risk exposure helps municipalities allocate resources effectively, improving overall resiliency. Risk-based planning provides the foundation for modern tactical asset management by enabling the prioritization of actions based on the LoF and CoF. Infrastructure-related risk exposure is quantified as:

$$\boldsymbol{Risk} = \boldsymbol{Likelihood\ of\ Failure}\ (\boldsymbol{LoF}) \times \boldsymbol{Consequence\ of\ Failure}\ (\boldsymbol{CoF}) \quad [1]$$

While LoF and CoF may seem abstract or challenging to quantify, structured, data-driven frameworks ensure that risk assessments are consistent, repeatable, and objective. These frameworks apply indices and factors derived from asset-specific parameters, such as age, condition, material type, and environmental exposure. The multiplication of LoF and CoF produces a risk score, which guides prioritization of interventions and resource allocation.

By focusing on both likelihood and failure consequences, the users can design targeted strategies to address risks. For example, reducing LoF through preventive maintenance minimizes the likelihood of failure, while mitigating CoF involves planning for redundancy and ensuring adequate response measures. Effective risk categorization enables data-driven investment decisions, thereby ensuring long-term sustainability and resilience.

In this framework a Multi Criteria Rating Technique is used to calculate the final CoF and LoF scores for each segment as below:

$$LoF\ or\ CoF_j = \sum_{i=1}^{N} I_i \times W_i \quad [2]$$

Where:

- LoF_j or CoF_j = CoF or LoF index for each category j (**Table 1-2** and **Table 1-6**)
- I_i = Factor score from 1 to 5
- W_i = Factor weight as percentage
- Therefore:

$$LoF\ or\ CoF_{segment} = \sum_{j=1}^{N} LoF\ or\ CoF_j \times W_j \quad [3]$$

1.2 Risk Framework Approach

The Risk-Based Assessment of Watermains in Alberta aims to have developed a standardized, structured approach for evaluating infrastructure risks, ensuring municipalities can make informed, data-driven decisions. The framework enhances asset management by prioritizing interventions based on LoF and CoF. It incorporates best practices, while also integrating insights from expert panel discussions. A key component of this initiative is pilot testing to validate the framework's application and refine methodologies before full-scale implementation. Ultimately, the framework will provide actionable recommendations to improve long-term risk management strategies.

The framework follows a semi-quantitative approach, leveraging structured, repeatable assessments while remaining flexible enough to account for the diverse range of factors influencing infrastructure conditions. Some multipliers used in the framework incorporate population (an indicator of increasing consequence of failure), and redundancy (which reduces consequence and the potential for of loss of service), ensuring that risk scores reflect real-world infrastructure pressures. These factors will be explained in greater detail in the following sections.

Risk assessment plays a critical role in achieving these objectives by systematically identifying and prioritizing infrastructure vulnerabilities. By quantifying LoF × CoF, communities can determine which assets require immediate intervention, optimize capital investments, and enhance overall system reliability. The framework ensures risk evaluations are both consistent and adaptable, supporting regulatory compliance, stakeholder engagement, and long-term infrastructure sustainability.

1.2.1 Risk Factors

For the purpose of this framework "risk factors" are defined as data sets that inform by correlation or causation, the LoF or CoF to be used in risk analysis.

These factors were identified following a review of best practice[1] and previous projects carried out across Canada. These factors were also presented to the Municipal Water Panel (convened for the purpose of this project including representatives from water utilities within Grand Prairie, Edmonton, Lethbridge, and Red Deer,) and discussed for relative importance, ease of collection and relevance to Albertan communities. Lists of the factors are provided in **Table 1-4** and **Table 1-8.**

1.2.2 Factor Weightings

Factors that relate consequence and likelihood of failure vary in importance across organizations; to accommodate these differences the following steps were taken to determine the weightings for each primary category and factor.

1.2.2.1 Step 1: Conduct a Risk Framework Survey

AECOM utilized Microsoft Forms to design a risk framework survey aimed at gathering insights from panel members on the significance of various risk factors pertinent to all types of municipalities. The ranking question type used

[1] AECOM (2025) TM#1 – Best Practice Summary

allows participants to order options based on their perceived importance, providing clear insights into priority areas. Once the survey data was collected, analysis of the responses was performed to pinpoint areas of consensus and discrepancies among panel members. This analysis informed necessary refinements to the risk framework, confirming that it accurately reflected the collective insights and addressed the most critical risk factors identified by the participants. By systematically gathering and analyzing stakeholder input through a structured survey, the risk management framework has been tailored to the unique needs and challenges of Alberta municipalities, making sure that it is robust and responsive.

1.2.2.2 Step 2: Refinement of Weightings Based on Survey Results

To determine the relative weighting of each category based on survey data, the exponential weighting method was applied. This approach assigns exponentially increasing scores to categories based on their perceived importance and aggregates the results to derive their proportional significance. The following steps were taken for this process:

1. **Assign Exponential Weights to Ranks**: Exponential Weighting: Assigns exponentially increasing weights to ranks as below, where N is the total number of ranks, and R is the rank position.

$$W = 2^{N-R} \quad [4]$$

2. **Compute Total Weighted Score for Each Option Scores**: Each category's values were multiplied by their respective exponential importance weights. The weighted total for each category was calculated using the formula:

- $Total\ Weighted\ Score = \sum (Number\ of\ votes\ at\ rank \times Rank\ weight)$ [5]

3. **Calculate Percentage Weighting**: Once the total weighted scores for all options were obtained, compute the percentage contribution of each option:

- $\text{Percentage Weight} = \frac{Option's\ Weighted\ Score}{Sum\ of\ all\ Weighted\ Scores} \times 100$ [6]

The calculated percentages reflect the adjusted weightings for each category, accounting for both the importance of the criteria and the survey responses. This ensures that decision-making prioritizes categories deemed most critical by stakeholders.

1.2.3 Worked Example

Table 1-1 illustrates an example of weighting scores for three options. This hypothetical case considers three options ranked across three ranks to demonstrate how the method assigns higher importance to top-ranked categories while maintaining proportional representation for lower ranks.

Exponential weights are calculated as follows:

- Rank 1: 2 ^ (3-1) = 4
- Rank 2: 2 ^ (3-2) = 2
- Rank 3: 2 ^ (3-3) = 1

Table 1-1: Example of Exponential Weighting Calculations Based on # Votes Received

Option	1st Rank	2nd Rank	3rd Rank	Sum Product	Final Weighting
A	5	3	2	28	37%
B	3	5	4	26	34%
C	2	4	6	22	29%

The calculated percentages reflect the adjusted weightings for each category, prioritizing categories deemed most critical by stakeholders. For example, Option A received the highest weighting (37%) due to strong performance in Rank 1. Option B followed with 34%, and Option C ranked last with 29%, indicating slightly less preference among respondents. This method ensures decision-making prioritizes top-ranked categories while still accounting for the relative importance of lower ranks.

1.3 Calibration Across Users

The original intent of the project was to develop two separate risk frameworks tailored to communities with differing levels of data availability and organizational capacity. However, it became evident during the process that even the largest municipalities often lack key data inputs necessary for a consistent data-based framework. As a result, the decision was made to proceed with a single, streamlined framework that can be applied consistently across all users.

This unified approach minimizes reliance on data that may be unavailable or incomplete, while still incorporating the core criteria needed to conduct meaningful and defensible risk assessments. It allows municipalities to engage in the process regardless of their size or internal resources, promoting broad applicability and ease of use.

By calibrating the framework to suit a range of community contexts, the project ensures that the model remains practical, inclusive, and capable of supporting informed decision-making across jurisdictions with varying data maturity and administrative structures.

1.4 Likelihood of Failure (LoF)

In asset management, the LoF quantifies the chance that an asset will fail within a specific period or under certain conditions. Assessing LoF involves analyzing factors such as the asset's age, condition, operational environment, and historical performance data. For instance, understanding the LoF is essential for determining an asset's risk, which combines both the likelihood and consequence of failure to prioritize maintenance and replacement strategies effectively. By accurately estimating the LoF, organizations can implement proactive maintenance schedules, allocate resources efficiently, and minimize unexpected downtimes, thereby optimizing asset performance and extending their operational lifespan. The specific factors considered in determining the LoF will be discussed in the following sections.

1.4.1 Defining LoF

Defining the LoF involves categorizing potential failure modes into three primary areas: condition, demand, and environmental factors. This structured approach supports a comprehensive assessment of risks specific to the project.

- **Condition**: This category evaluates the current state of infrastructure or system components, considering factors such as age, condition score, etc. Assessing these elements helps to determine the likelihood of failure due to physical deterioration.
- **Demand**: This involves analyzing the usage patterns and capacity requirements placed on the system. Understanding demand dynamics is crucial for identifying potential overloading scenarios that could lead to system failures.
- **Environmental**: This encompasses external conditions, including frost susceptibility, soil type, etc. Evaluating environmental factors allows for the identification of risks arising from external stressors.

By systematically assessing these categories, potential failure modes can be effectively identified and prioritized, enabling the development of targeted mitigation strategies aligned with the specific needs of both small and large communities.

Table 1-2 illustrates the main categories utilized to define the LoF, including weightings that has been calculated based on the approach described in **Section 1.2.2.1**. These categories were identified following a review of best practice[2] and previous projects carried out. These categories were presented to the Municipal Water Panel and discussed for relative importance (in parallel with the discrete factors), ease of collection and relevance to Albertan communities. Lists of the factors are provided in **Table 1-4** and **Table 1-8**. Subsequent ranking of the categories and factors was completed by the Panel, the process and analysis of which is described in **Section 1.2.2.1**.

[2] AECOM (2025) TM#1 – Best Practice Summary

Table 1-2: LoF Primary Category Weightings

Category	Weightings
Condition	52 %
Demand	32 %
Environmental	16 %

1.4.2 LoF Criteria and Factor Hierarchies

The assessment of LoF relies on a structured set of criteria and factors that define the likelihood of an asset deteriorating or failing over time. Each factor represents a key aspect influencing asset reliability, ranging from material degradation and environmental exposure to operational performance and maintenance history. **Table 1-3** provides a comprehensive overview of all defined LoF criteria, including detailed descriptions of each factor and their respective influence on failure likelihood. Each factor has also been determined to be applicable to all communities through discussion with the Municipal Panel and discussion with AECOM SMEs on the availability of data. This structured approach ensures consistency in evaluating asset risk, thereby supporting informed decision-making for maintenance, rehabilitation, and capital investment planning.

Following the summary of LoF factors, **Table 1-4** outlines the final weightings of each factor per primary category (condition, demand, and environmental) and the overall weighting that each factor has in its contribution to the LoF calculation.

Table 1-3: Likelihood of Failure Factors

Criteria	Factor	Description
Condition	Actual Condition Score	Actual graded condition score based on visual or other applicable inspection methods – Rated from Very Good to Very Poor
Condition	Installation Era	The era of pipeline installation has a significant influence on failure rates due to variations in materials, design standards, and construction practices. Pipelines installed during the 1970s and 1980s—particularly prestressed concrete cylinder pipes (PCCP)—tend to exhibit higher failure rates, largely due to the use of Class IV high-strength wires, which are more susceptible to hydrogen embrittlement and stress corrosion. Many pre-1990s pipelines also lack adequate corrosion protection and were subject to inconsistent manufacturing practices, making them more vulnerable to environmental stress and material degradation. In contrast, pipelines installed after 1990 benefit from improved materials and modernized design standards, resulting in greater reliability. Understanding these historical differences enables utilities to better prioritize maintenance and replacement efforts for high-risk pipelines, ultimately minimizing service disruptions and economic impacts.
Condition	Age vs ESL - Elapsed Life (%)	Elapsed time—or the percentage of a pipeline's design life that has passed—can serve as an indicator of failure likelihood, especially when detailed condition assessments are unavailable. While its influence may be modest compared to factors like corrosion or failure history, it provides a useful benchmark for identifying potential risks over time.
Condition	Break Counts	Frequent pipeline breaks signal advanced deterioration and significantly increase the likelihood of failure. In older metallic pipes, corrosion-related leaks can progress into major breaks if left unaddressed. For PCCP, wire breaks or leakage through cracks undermine structural integrity, raising the risk of sudden and catastrophic failure.
Condition	Cathodic Protection	Cathodic protection (CP) helps prevent corrosion in metal pipelines, especially in harsh environments. These systems use electrical current—either from sacrificial anodes or an external power source—to protect the pipe. If the system fails due to worn-out parts, electrical issues, or poor design, the pipe becomes more likely to corrode. Without proper maintenance and monitoring, corrosion can go unnoticed and increase the risk of failure. A working CP system is key to reducing this risk.
Condition	Liner (Lining)	A liner protects pipes from corrosion, erosion, and chemical damage. If the liner is missing, damaged, or worn out, the pipe is more likely to develop leaks, breaks, or suffer from stresses like ground movement or pressure surges. Without this protection, the pipe's structural strength can weaken, raising the risk of failure. Regular inspection and maintenance of liners are important to help prevent these issues.
Condition	Pipe Size	Pipe size can affect how likely a pipe is to fail. Larger pipes usually last longer because they have thicker walls and are more reinforced, but when they do fail, the damage is often more serious and expensive. Smaller pipes tend to fail more often due to higher pressure, faster wear, and weaker materials. Some older large pipes, like those from 1972–1984, are also known to have issues. Both large and small pipes need regular checks, but for different reasons.
Condition	Depth	Burial depth plays an important role in pipeline performance. In general, deeper pipes are less likely to fail because they are better protected from surface loads, traffic, and accidental damage. However, soil conditions at greater depths—such as moisture levels, oxygen, and corrosive elements—can still affect corrosion rates. In some cases, soil movement caused by changing moisture can also damage the pipe's coating. Understanding how burial depth interacts with soil characteristics helps in assessing failure risk more accurately.
Condition	Soil Corrosivity	Soil corrosivity significantly affects the degradation rate of metal pipelines. Factors such as low soil resistivity, acidic pH levels, and high concentrations of chlorides and sulfates can accelerate corrosion, leading to thinning, pitting, and potential failure if not properly managed. For instance, soils with high conductivity, such as those containing salts or acidic compounds, can significantly increase the rate of corrosion. Regular monitoring and appropriate mitigation strategies are essential to manage these risks.
Demand	Fire Flow (Current)	Fire flow can put extra pressure on pipes, causing leaks, cracks, or bursts. It can also speed up corrosion, especially in older pipes with damaged coatings. Some pipe materials handle high pressure better than others, making them less likely to fail.
Demand	Fire Flow (Future)	Fire flow in the future could cause problems like pipe leaks or breaks due to high pressure and stress. It can also speed up corrosion, especially in older pipes. Some materials handle pressure better, so choosing the right one matters. Surge analysis helps predict and reduce these risks.
Demand	Pressure (Current)	When pressure goes beyond what a pipe is designed for, it can cause fatigue, leaks, or bursts—especially during sudden surges like water hammer. High pressure also speeds up corrosion, which is a bigger problem in older pipes. These surges put a lot of stress on pipes and joints, so surge analysis is important to predict and reduce damage.
Demand	Pressure (Future)	Future pressure challenges can lead to pipe fatigue, faster corrosion, and pressure surges. Going beyond design limits weakens pipes, while high pressure speeds up damage and raises the risk of failure. Sudden changes, like water hammer, put extra stress on pipes and joints. Surge analysis will be important for predicting and managing these risks as infrastructure needs grow.
Environmental	Frost Susceptibility / Effect of Frost on Soil	In cold climates, frost can put pressure on buried pipes, causing bending and possible cracking. This is worse in soils that transfer heat quickly. Rigid pipes like cast iron can crack easily, while ductile iron bends a little but can still fail if it's already weak. Flexible pipes like PVC and HDPE handle frost better by bending and spreading out the pressure.
Environmental	Groundwater Levels	High groundwater levels can raise the risk of pipe failure by speeding up corrosion and adding stress. Chemicals like chlorides and sulfates break down materials, while wet or frozen soil puts extra pressure on the pipes. Regular monitoring and protection are important to reduce these risks.
Environmental	Road Clearing Types	Road clearing methods impact municipal water assets, primarily through corrosion and blockages. Road salt increases chloride levels, accelerating pipe corrosion and weakening infrastructure. Sand and grit, though less corrosive, can cause abrasion and clogging in drainage systems. Regular street sweeping helps reduce contaminants in stormwater, mitigating blockages. Alternatives like calcium magnesium acetate (CMA) and brine solutions lower corrosion risks but still require careful management.
Environmental	Proximity to Trees	Tree roots can enter pipes through cracks or joints, leading to blockages, leaks, and bursts. Older pipes, especially those made of clay or concrete, are more prone to root intrusion, which raises the risk of failure.
Environmental	Soil Type	Soil type affects how long pipes last. Corrosive soils can wear down metal pipes faster, causing thinning and pitting. Soils with low resistivity, acidic pH, and high chloride levels raise the risk of failure if not properly managed.
Environmental	Traffic - Loading (AADT)	High traffic volumes, measured by Average Annual Daily Traffic (AADT), increase the mechanical stress on buried pipelines. Constant heavy loading, especially from trucks and buses, can cause soil movement, settlement, and additional pressure on pipes, leading to cracks, joint failures, or collapses over time. Areas with higher AADT values generally have a greater risk of pipeline failure, making traffic loading an important factor in assessing likelihood of failure.

Table 1-4: Likelihood of Failure Weightings

Factor	Condition (52%)	Demand (32%)	Environmental (16%)	Combined (100%)
Actual Condition Score	36%	-	-	**19%**
Installation Era	22%	-	-	**11%**
Age vs ESL - Elapsed Life (%)	10%	-	-	**5%**
Break Counts	23%	-	-	**12%**
Cathodic Protection	2%	-	-	**1%**
Depth	1%	-	-	**1%**
Fire Flow (Current)	-	30%	-	**10%**
Fire Flow (Future)	-	13%	-	**4%**
Frost Susceptibility / Effect of Frost on Soil	-	-	43%	**7%**
Groundwater Levels	-	-	12%	**2%**
Liner	1%	-	-	**1%**
Pipe Size	3%	-	-	**2%**
Pressure (Current)	-	43%	-	**14%**
Pressure (Future)	-	14%	-	**4%**
Proximity to Trees	-	-	6%	**1%**
Road Clearing Types	-	-	7%	**1%**
Soil Corrosivity	2%	-	-	**1%**
Soil Type	-	-	24%	**4%**
Traffic / Loading (AADT)	-	-	8%	**1%**
Total	**100%**	**100%**	**100%**	**100%**

1.4.3 Model Hierarchy (fishbone diagram)

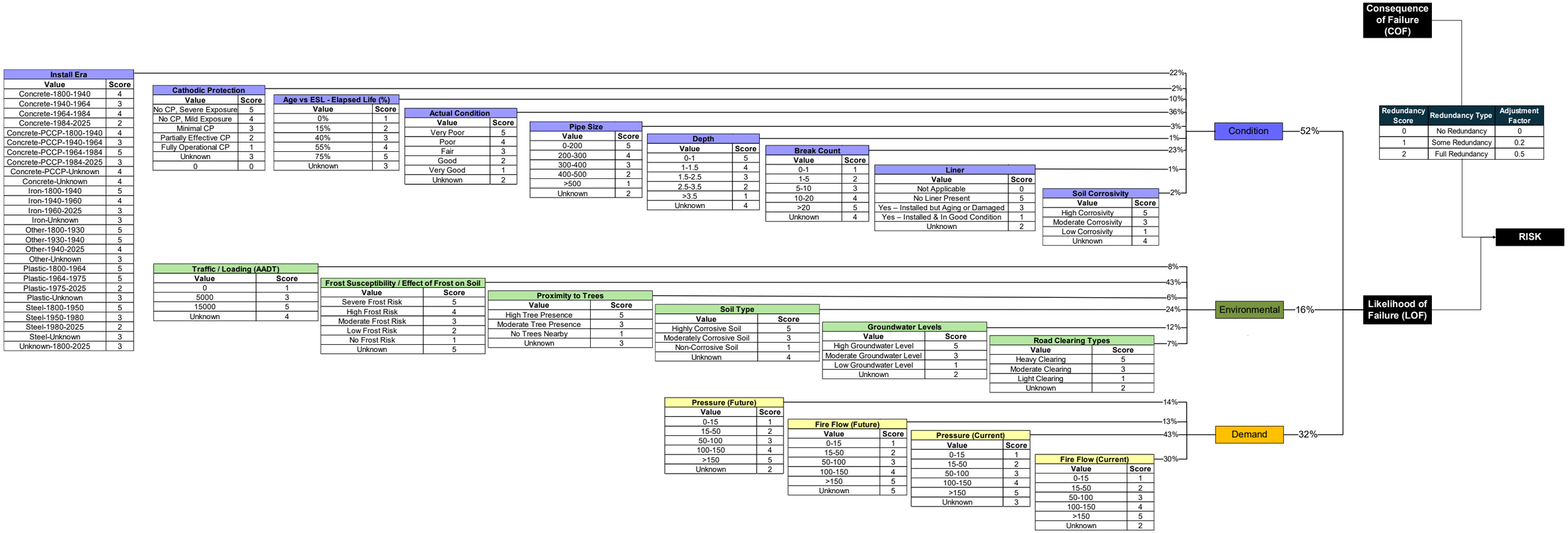


Figure 1-1: Fishbone Diagram – Likelihood of Failure Framework

1.4.4 Final LoF Ratings

A simplified 1-to-5 scoring method is commonly employed to evaluate the LoF. This scale allows for a standardized assessment across various factors, with each score representing a specific probability level:

- **Rare (1):** Failure is highly unlikely, with no recorded incidents and minimal theoretical possibility.
- **Unlikely (2):** Failure is possible but not anticipated; infrequent occurrences have been documented.
- **Possible (3):** Failure might occur occasionally; there is a distinct possibility under certain conditions.
- **Likely (4):** Failure is expected to occur in many circumstances; it has occurred several times in the past.
- **Almost Certain (5):** Failure is imminent or expected to occur in most circumstances; it has a history of frequent occurrences.

Each factor contributing to the LoF is assessed and assigned a score based on this scale. These scores are then adjusted according to different categories relevant to the asset or system under evaluation. This approach supports a comprehensive and tailored assessment, accounting for the unique characteristics and conditions of each infrastructure component.

Table 1-5 presents a comprehensive assessment of LoF factors. Each factor is assigned an LoF score from 1 to 5, where 1 represents a low likelihood of failure and 5 signifies a high likelihood of failure. These scores help prioritize risk management by identifying assets with the greatest failure risks. By integrating these factors, the framework supports data-driven decision-making for asset management, proactive maintenance planning, and risk mitigation strategies.

Table 1-5: LoF Factors and Their Corresponding Scores

Factor	Score						
Actual Condition	Unknown	Very Good	Good	Fair	Poor	Very Poor	
Score	2	1	2	3	4	5	
Installation Era	Unknown	Concrete	Concrete - PCCP	Iron	Other	Plastic	Steel
Era	• Concrete-PCCP-Unknown • Concrete-Unknown • Iron-Unknown • Other-Unknown • Plastic-Unknown • Steel-Unknown	• Concrete-1800-1940 • Concrete-1940-1964 • Concrete-1964-1984 • Concrete-1984-2025	• Concrete-PCCP-1800-1940 • Concrete-PCCP-1940-1964 • Concrete-PCCP-1964-1984 • Concrete-PCCP-1984-2025	• Iron-1800-1940 • Iron-1940-1960 • Iron-1960-2025	• Other-1800-1930 • Other-1930-1940 • Other-1940-2025	• Plastic-1800-1964 • Plastic-1964-1975 • Plastic-1975-2025	• Steel-1800-1950 • Steel-1950-1980 • Steel-1980-2025
Score	4 4 3 3 3 3	4 3 4 2	4 3 5 3	5 4 3	5 5 4	5 5 2	5 3 2
Age vs ESL / Elapsed Life (%)	Unknown	≤ 15%	40%	55%	75%	75%+	
Score	3	1	2	3	4	5	
Break Counts (#)	Unknown	≤ 1	5	10	20	20+	
Score	4	1	2	3	4	5	
Cathodic Protection	Unknown	Fully Operational CP	Partially Effective CP	Minimal CP	No CP, Mild Exposure	No CP, Severe Exposure	Not Applicable
Score	3	1	2	3	4	5	0
Depth (m)	Unknown	3.5 ≤	2.5	1.5	1	≤ 1	
Score	3	1	2	3	4	5	
Fire Flow (Current) – (L/S)	Unknown	≤ 15	50	100	150	150+	
Score	3	1	2	3	4	5	
Fire Flow (Future) – (L/S)	Unknown	≤ 15	50	100	150	150+	
Score	3	1	2	3	4	5	
Frost Susceptibility / Effect of Frost on Soil	Unknown	No Frost Risk (Deep Burial, Stable Soil)	Low Frost Risk (Moderate Depth, Some Seasonal Frost)	Moderate Frost Risk (Shallow Pipes, Clayey Soil)	High Frost Risk (Frequent Freeze-Thaw, Poor Drainage)	Severe Frost Risk (Very Shallow Pipes, Extreme Cold, High Ice Growth)	
Score	3	1	2	3	4	5	
Groundwater Levels	Unknown	Low Groundwater Leve	Moderate Groundwater Level	High Groundwater Level			
Score	3	1	3	5			
Liner	Unknown	Yes – Installed & In Good Condition	Yes – Installed but Aging or Damaged	No Liner Present	Not Applicable		
Score	3	1	3	5	0		
Pipe Size (mm)	Unknown	≤ 200	300	400	500	500+	
Score	3	5	4	3	2	1	
Pressure (Current) – psi	Unknown	≤ 50	70	100	150	150+	
Score	3	1	2	3	4	5	
Pressure (Future) – psi	Unknown	≤ 50	70	100	150	150+	

Factor	Score					
Score	3	1	2	3	4	5
Proximity to Trees	Unknown	No Trees Nearby	Moderate Tree Presence (Some Trees Nearby, Small Root Systems)	High Tree Presence (Large Trees, Aggressive Root Systems Close to Pipes)		
Score	3	1	3	5		
Road Clearing Types	Unknown	Light Clearing (Plowing, Minimal Disturbance)	Moderate Clearing (Snow Removal, Salt Application)	Heavy Clearing (Deep Grading, Heavy Machinery, Heavy salt application)		
Score	3	1	3	5		
Soil Corrosivity	Unknown	Low Corrosivity (Stable, Non-Aggressive Soil)	Moderate Corrosivity (Slightly Aggressive Soil)	High Corrosivity (Highly Aggressive Soil)		
Score	4	1	3	5		
Soil Type	Unknown	Non-Corrosive Soil (Rock, Well-Drained Sand & Gravel, Neutral pH)	Moderately Corrosive Soil (Loam, Mixed Sand & Clay, Slightly Acidic/Alkaline pH)	Highly Corrosive Soil (Clay, Peat, High Chloride, Acidic, or Low Resistivity Soils)		
Score	4	1	3	5		
Traffic / Loading (AADT)	Unknown	≤ 5,000	5,000 - 15,000	15,000+	Not Applicable	
Score	3	1	3	5	0	

1.5 Consequence of Failure (CoF)

The CoF refers to the potential adverse impacts resulting from an asset's failure, encompassing economic, environmental, operational, and social dimensions. These impacts can vary in severity, from minor disruptions to catastrophic events, and are often evaluated using both qualitative and quantitative methods. Qualitative assessments involve subjective evaluations based on experience and judgment, while quantitative assessments utilize numerical data and statistical analysis to estimate the impact of failure. Combining these approaches provides a comprehensive understanding of potential failure consequences, guiding effective asset management decisions.

1.5.1 Defining CoF

The CoF is determined by evaluating the potential impacts across four key dimensions: economic, environmental, social, and operational. This holistic assessment thoroughly examines and addresses the severity of risks linked to asset failure.:

- **Economic**: This dimension evaluates the financial implications of failure, including direct repair costs, property damage, and the impact on infrastructure accessibility. Factors such as pipe size, material, and the cost of repair are crucial in determining the economic risks.
- **Environmental**: Environmental impacts focus on the potential harm to ecosystems and nearby sensitive areas. This includes evaluating factors like proximity to environmentally sensitive areas, flow rates, and the presence of critical natural features such as water bodies.
- **Social**: Social impacts consider the effect of asset failure on communities, including disruptions to critical services, nearby population density, and land use. Key factors include the presence of critical customers, adjacent land uses, and road types.
- **Operational**: This dimension assesses the effect of failure on the functionality and continuity of the system. Factors such as system redundancy, accessibility, ease of repair, and the complexity of mitigation measures are essential for understanding operational risks.

By evaluating these dimensions systematically, the framework confirms that the consequences of failure are prioritized effectively, enabling targeted and proactive risk management strategies.

Table 1-6 illustrates the main categories utilized to define the likelihood of failure, including weightings that has been calculated based on Panel input and broad the approach described in **Section 1.2.2.1**.

Table 1-6: Consequence of Failure Primary Category Weightings

Category	Weightings
Economic	31 %
Environmental	18 %
Social	22 %
Operational	29 %

1.5.2 CoF Criteria and Factor Hierarchies

The evaluation of the CoF is based on a structured framework of criteria and factors that determine the potential impact of an asset’s failure. These factors encompass a range of considerations, including service disruptions, public safety, environmental consequences, and financial costs. **Table 1-7** outlines the defined CoF criteria, providing detailed descriptions of each factor and its role in assessing the severity of failure outcomes. Each factor has also been determined to be applicable to all communities through discussion with the Municipal Panel and discussion with AECOM SMEs on the availability of data. This systematic approach enhances consistency in risk evaluation, enabling data-driven decision-making for emergency preparedness, risk mitigation, and long-term infrastructure planning.

Following the summary of CoF factors, **Table 1-8** outlines the final weightings of each factor per primary category (condition, demand, and environmental) and the overall weighting that each factor has in its contribution to the LoF calculation.

Table 1-7: Consequence of Failure Factors

Criteria	Factor	Description
Economic	Depth	Deeper pipelines have higher repair costs due to excavation complexity, while shallower pipes are cheaper to access but more vulnerable to damage.
Economic	Capital Reinvestment Ratio	The Capital Reinvestment Ratio is defined as the ratio of Capital Expenditures (CapEx) to the Total Replacement Value of the asset. It provides an indication of the investment level relative to the asset's full replacement cost, helping to assess the potential financial consequences associated with asset failure. **Capital Reinvestment Ratio = Capital Expenditures (CapEx) / Total Replacement Value.**
Economic	Damage to Property	Pipe failures can lead to flooding, erosion, and water infiltration, resulting in damage to nearby structures and infrastructure. Secondary impacts may include road and utility damage, service disruptions, and economic losses, particularly in urban areas with high property values.
Economic	Material	The type of pipe material plays a critical role in determining the potential consequence of failure. Durable materials are generally more resistant to deterioration and easier to maintain, resulting in fewer impacts when failures occur. In contrast, materials that are more susceptible to corrosion or degradation may lead to higher repair complexity, extended service disruptions, and increased risk to surrounding infrastructure.
Economic	Pipe Size – Impact on Cost	Larger pipe sizes generally result in higher costs for manufacturing, transportation, and installation due to greater material and labor requirements. Ensuring appropriate sizing helps avoid over-design and unnecessary expenditures, supporting more cost-effective infrastructure planning.
Economic	Road Type	The type of road influences the economic consequences of a pipe failure. Failures beneath major roads can lead to substantial traffic disruptions, higher repair complexity, and increased restoration costs. In contrast, failures under local or minor roads typically result in less disruption and lower economic impact.
Environmental	Proximity to Environmentally Sensitive Area (ESA)	Pipes located near environmentally sensitive areas pose greater risks, as failures can cause significant ecological harm. Higher scores reflect this increased potential impact.
Environmental	Flow Rate	Higher flow rates increase the severity of failures by amplifying water loss, soil erosion, and the spread of contaminants.
Environmental	Pipe Size	Larger pipes carry greater volumes of water, making failures more impactful through significant water loss, widespread service disruptions, economic losses, health risks, and increased strain on emergency resources.
Environmental	Pressure	Failures in high-pressure pipes can cause severe soil erosion, sedimentation in water bodies, and deterioration of water quality. They may also introduce contaminants into the supply, posing health risks and impacting nearby ecosystems.
Environmental	Proximity to Other Critical Infrastructure	Failures near critical facilities, such as hospitals, fire stations, schools, municipal centers, and power plants, can trigger cascading disruptions. Proximity to these key sites increases the severity of service interruptions across multiple sectors.
Environmental	Slope	Excessive pipe slope can accelerate water flow, leading to soil erosion, infrastructure damage, and impacts on nearby land, watercourses, and habitats, potentially causing biodiversity loss.
Environmental	Proximity to Waterbodies	Pipeline failures near water bodies can cause significant environmental damage. Discharges of chlorinated water into fish-bearing streams or lakes can harm aquatic ecosystems and necessitate costly mitigation efforts.
Operational	Accessibility	Limited accessibility, such as pipes located in forested areas, beneath water bodies, or under structures, can delay repairs, prolong service disruptions, and increase operational downtime. Easy access enables faster emergency response, minimizing outages and reducing impacts on customers and operations.
Operational	Material	Pipe material impacts durability, repair costs, and service disruptions, influencing overall resilience and maintenance needs.
Operational	Mitigation Plan	Having a mitigation plan in place reduces the severity and extent of impacts when a failure occurs.
Operational	Pipe Size	Smaller pipes tend to fail more frequently due to thinner walls and higher corrosion vulnerability, causing localized leaks, service disruptions, and increased maintenance costs. Larger pipes fail less often but have more severe consequences when they do, leading to widespread water loss and costly repairs. Overall, smaller pipes have higher failure rates with localized impacts, while larger pipes, though more durable, cause greater economic and service disruptions when failures occur.
Operational	Peak Day Operating Pressure	Pressure is a key factor affecting the reliability and safety of infrastructure systems. Low pressure can cause service disruptions and compliance issues, while excessive pressure accelerates deterioration, leading to bursts, leaks, and costly repairs. Considering pressure in the CoF assessment improves risk evaluation and supports proactive asset management.
Operational	Slope	Steep slopes increase flow velocity, raising the risk of flooding, erosion, and infrastructure damage. Failures can cause hydraulic surges and sediment transport, leading to blockages and degraded water quality. Repairs in steep areas are more complex and costly, prolonging service disruptions.
Social	Adjacent Land Use	Drinking water pipe failures can pose health risks, cause property damage, disrupt services, and lower property values, particularly affecting vulnerable populations. Businesses may face financial losses, and environmental contamination can lead to broader social and economic impacts.
Social	Critical Customers	Pipes serving hospitals, emergency services, and municipal facilities require high reliability. Failures can disrupt essential operations, impacting public safety and welfare, making proactive maintenance and upgrades crucial.
Social	Flow Rate	Pipes with higher flow rates serve larger populations, making failures more disruptive. Disruptions can affect water supply, sanitation, and public health, leading to widespread social and economic impacts.
Social	Population Density	Higher population density amplifies the impacts of pipe failures, causing widespread service disruptions, public health risks, and greater logistical challenges. These areas require prioritization to mitigate disruptions and support emergency response.
Social	Road Type	Failures on major roads cause severe traffic disruptions, affecting commuters, logistics, and access to essential services. High-traffic areas face greater social and economic impacts, making road type critical in assessing failure consequences.

Table 1-8: Consequence of Failure Weightings

Factor	Economic (31%)	Environmental (18%)	Operational (29%)	Social (22%)	Combined (100%)
Accessibility	-	-	26%	-	8%
Depth	23%	-	-	-	7%
Adjacent Land Use	-	-	-	19%	4%
Capital Reinvestment Ratio	5%	-	-	-	2%
Critical Customers	-	-	-	45%	10%
Damage to Property	28%	-	-	-	9%
Flow Rate	-	16%	-	17%	7%
Material	11%	-	8%	-	6%
Mitigation Plan	-	-	21%	-	6%
Pipe Size	-	7%	23%	-	8%
Pipe Size (size impact on cost)	26%	-	-	-	8%
Population Density (Ppl/km²)	-	-	-	10%	2%
Pressure (current)	-	3%	-	-	1%
Peak Day Operating Pressure	-	-	20%	-	6%
Proximity to Environmentally Sensitive Area (ESA)	-	38%	-	-	7%
Proximity to Other Critical Infrastructure	-	23%	-	-	4%
Proximity to Waterbodies	-	11%	-	-	2%
Road Type	7%	-	-	9%	4%
Slope	-	2%	2%	-	1%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

1.5.3 Model Hierarchy (fishbone diagram)

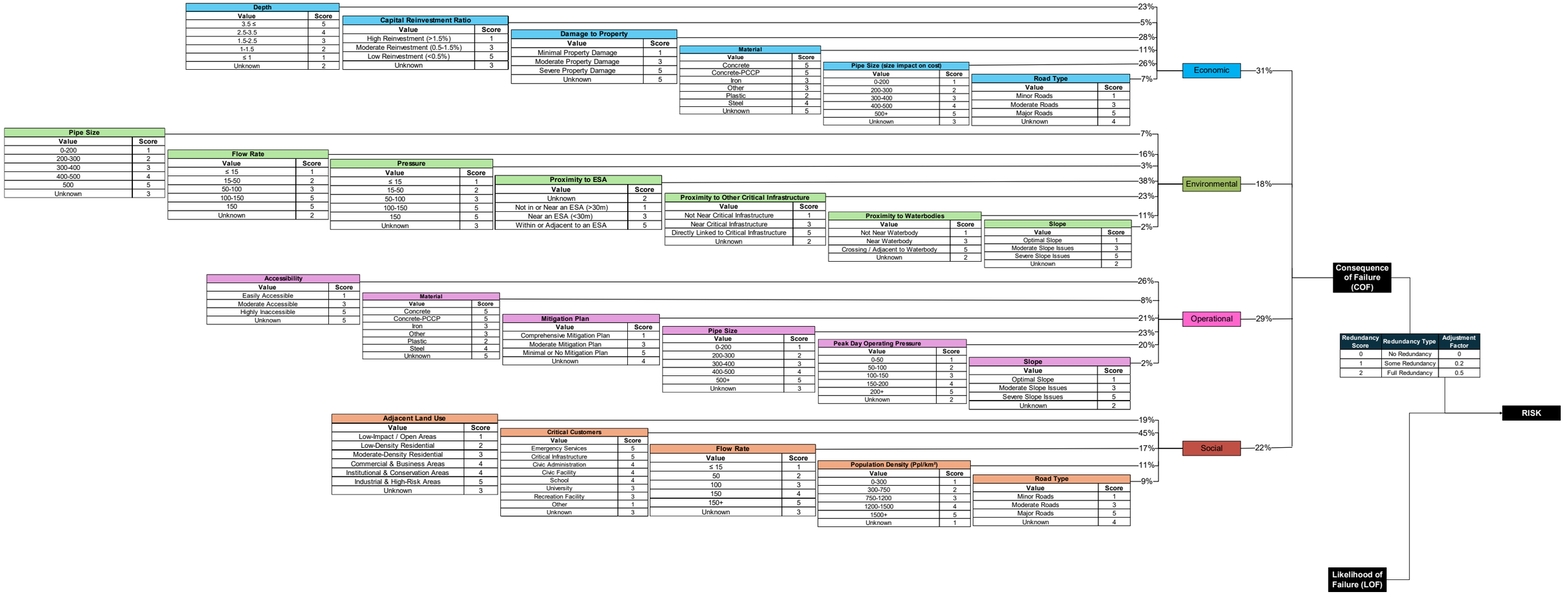


Figure 1-2: Fishbone Diagram – Consequence of Failure Framework

1.5.4 Final CoF Ratings

Evaluation of the CoF is crucial to understand the potential impact of an asset's failure. A standardized 1-to-5 scoring method is commonly used, with each score representing a specific level of impact:

- **Insignificant (1):** Negligible impact; no significant consequences or impact on the level of service.
- **Minor (2):** Minor impact; some loss of system capacity, but minimal costs or impacts.
- **Moderate (3):** Moderate impact; loss of some system capacity, yet important level of service still achieved.
- **Major (4):** Major impact; loss of system capacity, major consequences or costs, level of service compromised.
- **Catastrophic (5):** Severe impact; massive system failure, severe economic, environmental, health, and/or social consequences, persistent and extensive damage, unable to meet level of service goals.

Each factor contributing to the CoF is assessed and assigned a score based on this scale. These scores are then adjusted according to different categories relevant to the asset or system under evaluation. This approach ensures a comprehensive and tailored assessment, accounting for the unique characteristics and conditions of each infrastructure component.

Table 1-9 present a comprehensive assessment of CoF factors. Each factor is assigned a CoF score from 1 to 5, where 1 represents minimal impact and 5 signifies severe consequences. These scores help prioritize risk management by identifying assets with the highest failure consequences. By integrating these factors, the framework supports data-driven decision-making for asset management, maintenance planning, and risk mitigation strategies.

Table 1-9: CoF Factors and Their Corresponding Scores

Factor	Scores								
Accessibility	Unknown	Easily Accessible	Moderate Accessible	Highly Inaccessible					
Score	5	1	3	5					
Depth	Unknown	3.5 ≤	2.5	1.5	1	≤ 1			
Score	2	5	4	3	2	1			
Adjacent Land Use	Unknown	Low-Impact / Open Areas	Low-Density Residential	Moderate-Density Residential	Commercial & Business Areas	Institutional & Conservation Areas	Industrial & High-Risk Areas		
Score	3	1	2	3	4	4	5		
Capital Reinvestment Ratio	Unknown	High Reinvestment (>1.5%)	Moderate Reinvestment (0.5-1.5%)	Low Reinvestment (<0.5%)					
Score	3	1	3	5					
Critical Customers	Unknown	Emergency Services	Critical Infrastructure	Civic Administration	Civic Facility	School	University	Recreation Facility	Other
Score	3	5	5	4	4	4	3	3	1
Damage to Property	Unknown	Minimal Property Damage	Moderate Property Damage	Severe Property Damage					
Score	5	1	3	5					
Flow Rate (L/S)	Unknown	≤ 15	50	100	150	150+			
Score	2	1	2	3	4	5			
Material - Economic	Unknown	Plastic	Iron	Steel	Concrete	Other	Concrete - PCCP		
Score	5	2	3	4	5	3	5		
Material – Operational (lead time to replace)	Unknown	Plastic	Iron	Steel	Concrete	Other	Concrete - PCCP		
Score	3	2	3	4	5	3	5		
Mitigation Plan	Unknown	Comprehensive Mitigation Plan	Moderate Mitigation Plan	Minimal or No Mitigation Plan					
Score	4	1	3	5					
Pipe Size (mm)	Unknown	≤ 200	300	400	500	500+			
Score	3	1	2	3	4	5			
Pipe Size - By Cost of Repair (mm)	Unknown	≤ 200	300	400	500	500+			
Score	3	1	2	3	4	5			
Population Density (Ppl/km²)	Unknown	≤ 300	750	1200	1500	1500+			
Score	1	1	2	3	4	5			
Pressure (psi)	Unknown	≤ 15	50	100	150	150+			
Score	3	1	2	3	4	5			
Peak Day Operating Pressure (psi)	Unknown	≤ 50	100	150	200	200+			
Score	2	1	2	3	4	5			
Proximity to Environmentally Sensitive Area (ESA)	Unknown	Not in or Near an ESA (>30m)	Near an ESA (<30m)	Within or Adjacent to an ESA					
Score	2	1	3	5					
Proximity to Other Critical Infrastructure	Unknown	Not Near Critical Infrastructure	Near Critical Infrastructure	Directly Linked to Critical Infrastructure					
Score	2	1	3	5					

Factor	Scores			
Proximity to Waterbodies	Unknown	Not Near Waterbody	Near Waterbody	Crossing / Adjacent to Waterbody
Score	2	1	3	5
Road Type	Unknown	Minor Roads (Private, Residential, Local Collector)	Moderate Roads (Major Collector Secondary, Major Collector Primary)	Major Roads (Arterial Roads (Primary & Secondary), Freeways, Greenways)
Score	4	1	3	5
Slope	Unknown	Optimal Slope (results in flow at optimal speed)	Moderate Slope Issues (flow in excess or below optimal speed)	Severe Slope Issues (excessive slope that complicates intervention, >5%)
Score	2	1	3	5

2. Risk Analysis

The following section outlines the approach a community should pre-emptively take prior to using the framework and guide populating their own data.

2.1 Process Overview

Effective risk management is critical to ensuring the long-term sustainability and resilience of infrastructure in Alberta. This framework provides a structured process to identify, assess, and prioritize risks associated with various assets, enabling informed decision-making. Rooted in established provincial standards, such as Alberta's Common Risk Management Framework (CRMF)[3], this approach integrates data-driven methodologies and stakeholder insights to support strategic planning and resource allocation.

2.1.1 Data Collection

Gather comprehensive information on assets, including inventories, condition assessments, and historical performance data. Utilize Geographic Information System (GIS) tools to organize and preprocess data, ensuring consistency and accuracy for subsequent analysis. This aligns with practices outlined in Alberta's CRMF, which emphasizes a structured approach to risk assessment.

Each field should be reviewed to find the most appropriate and complete data available. Values to be used in the cases of unknown data are provided.

2.1.2 Risk Assessment

Assess each asset's LoF and CoF using defined criteria. This includes evaluating economic, operational, social, and environmental impacts for CoF, and condition, demand, and environmental for LoF. Quantitative methods, such as Excel models, are applied to ensure structured, consistent, and repeatable assessments.

Population of the relevant data will result in automatic calculation of LoF and CoF scores.

2.1.3 Risk Ranking

Combine the CoF and LoF scores using a systematic risk matrix based on ISO 31010 (Risk Management – Risk Assessment Techniques). This matrix aligns LoF and CoF to categorize risks into very low, low, medium, high, and very high levels. The use of ISO 31010 ensures consistent ranking methodologies across asset classes.

- **LoF**: Evaluate the likelihood of an event occurring, with rankings informed by historical data collected.
- **CoF**: Assess the scale of consequences across different criteria and factors.
- **Risk Matrix**: Apply a standardized 5 x 5 matrix to determine risk levels and prioritize

The risk matrix presented in **Figure 2-1** should be used as a guide to manage the watermains risk-based decision-making. As shown the risk score is the product of the consequence and likelihood of the risk occurring, where 1 is considered a very low-risk score and 25 is a very high-risk score.

[3] Common risk management framework. Version 2.0, Alberta, https://open.alberta.ca/publications/common-risk-management-framework-version-2-0?utm

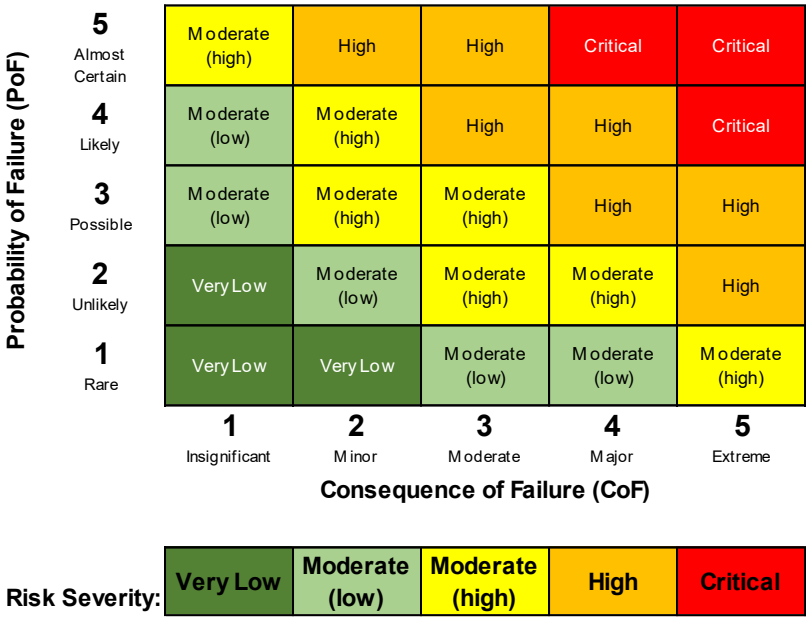


Figure 2-1: Risk Matrix

2.1.3.1 Calibration to Existing Risk Matrices

Each community may have its own risk matrix which may differ in scoring values and is required for consistent discussion and communication purposes. For example, is a 3x3 matrix rather than 5x5. Calibrating directly between different size matrices can result in an imbalance of assets appearing in particular risk categories so the following approach is suggested.

- Mapping of scores between matrices. Correspond each LoF and CoF score available to the relevant score in the community's matrix.
- Recalculate and map the risk scores using the updated scores. Note that risk scores may now be altered in comparison to the original process.
- Validate the results to ensure that the overall risk distribution is similar to the original framework.
- Throughout this process it is important to consider the following:
  - When converting, consider whether it is appropriate to err on the side of caution. The user may consider rounding risk values up to ensure the system does not underestimate risk when converting to a lower resolution matrix.
  - The mapping and thresholds should be tailored to the community's needs for internal use as the risk tolerance demonstrated in may be different to that currently in place.

2.2 Required Tools & Data

The implementation of this framework necessitates the utilization of robust data preparation and engineering tools to support the dataset's integrity and suitability for the risk model. Applications such as ArcGIS Pro and Microsoft Excel are instrumental in this process. ArcGIS Pro's Data Engineering tools facilitate the exploration, cleaning, and preparation of spatial data, offering functionalities to handle missing values, detect outliers, and perform data normalization. Similarly, Microsoft Excel provides a versatile platform for data manipulation and dashboarding, allowing for efficient organization, analysis, transformation and presentation of datasets and analysis results. Employing these tools confirms that the data is meticulously processed and primed for accurate and reliable risk assessment. Sample datasets are prepared for running the risk frameworks; however, each municipality across Alberta should own their risk model and prepare the data for the risk analysis as needed. It is important to note that in all data analytics processes, data preparation is often the most time-consuming phase, sometimes accounting for up to 70% of the total project time.

Table 2-1 identifies the data used to support the COF and LOF models. Each dataset is categorized based on its level of importance to the risk framework, ranging from A (very critical) to C (supportive but optional).

- **A – Very Critical**: This data is crucial to the integrity and performance of the risk framework. It directly influences key risk calculations, and its absence would significantly impair the ability to assess and prioritize risks. Must be collected, validated, and kept up to date.
- **B – Moderately Critical:** This data is important for supporting accurate and refined risk outputs. While the framework can function with limited or estimated values, its quality directly affects the robustness and credibility of the results.
- **C – Supportive but Optional:** This data is valuable for added context or detail, but it is not essential for the core functionality of the risk framework. These factors help enhance interpretation but may be excluded from the final Technical Memo if data quality, availability, or relevance is limited.

Table 2-1: LoF and CoF Data Requirements

Category	Data Fields	Importance
CoF	Accessibility	B
CoF	Depth	B
CoF	Adjacent Land Use	A
CoF	Capital Reinvestment Ratio	C
CoF	Critical Customers	A
CoF	Damage to Property	C
CoF	Flow Rate	B
CoF	Material	A
CoF	Mitigation Plan	C
CoF	Pipe Size	A
CoF	Population Density (Ppl/km²)	C
CoF	Pressure	B
CoF	Peak Day Operating Pressure	B
CoF	Proximity to Environmentally Sensitive Area (ESA)	A
CoF	Proximity to Other Critical Infrastructure	C
CoF	Proximity to Waterbodies	B
CoF	Road Type	A
CoF	Slope	C
LoF	Actual Condition	A
LoF	Installation Era	A
LoF	Age vs ESL - Elapsed Life (%)	A
LoF	Break Counts	B
LoF	Cathodic Protection	C
LoF	Depth	B
LoF	Fire Flow (Current)	B
LoF	Fire Flow (Future)	C
LoF	Frost Susceptibility / Effect of Frost on Soil	B
LoF	Groundwater Levels	C
LoF	Liner	C

Category	Data Fields	Importance
LoF	Pipe Size	A
LoF	Pressure (Current)	B
LoF	Pressure (Future)	C
LoF	Proximity to Trees	C
LoF	Road Clearing Types	C
LoF	Soil Corrosivity	C
LoF	Soil Type	A
LoF	Traffic - Loading (AADT)	B

2.3 Ranking Assets Based on Community

When multiple assets have the same risk score, a structured ranking approach is required to prioritize them effectively. This section outlines a methodology for ranking for community-level ranking:

- **Community-Level Ranking**: Based on the percentage of the community population affected by an asset's failure, analyzed separately for Community A and Community B as an example.

By maintaining separate rankings, decision-makers can prioritize interventions that address both localized and widespread impacts.

2.3.1 Community Level Ranking

The community-level ranking evaluates the relative impact of an asset's failure within its specific community. Given that Community A and Community B have vastly different population sizes, rankings are conducted separately for each.

2.3.1.1 Calculation Methodology

For each asset, the percentage of the community population affected is calculated using:

$$\%\,\mathbf{P}\,(\mathbf{community\ affected}) = \frac{\boldsymbol{P}\,(\boldsymbol{affected})}{\boldsymbol{P}\,(\boldsymbol{community})} \times \mathbf{100} \quad [7]$$

Where:

P (affected) = Population affected by asset failure

P (affected) = Total population of the asset's community (either Community 1 or Community 2)

Also, by using:

$$\boldsymbol{N}\,(\boldsymbol{community\ i}) = \frac{\%\,\mathbf{P}\,(\mathbf{community\ i\ affected}) \times \mathbf{Risk\ Score}}{\sum_{n=1}^{\infty}(\%\,\mathbf{P}\,(\mathbf{community\ affected}) \times \mathbf{Risk\ Score})} \quad [8]$$

Where:

N (community i) = Normalized score for community i

After all normalized scores are calculated, the assets are ranked based on their respective normalized scores.

Table 2-2 and **Table 2-3** summarize asset rankings for Community A and Community B, showcasing differences in prioritization based on population impact and risk score.

In Community A, Asset A ranks first due to its significantly higher population affected (875,000 or 44% of the community), despite having a lower risk score of 6. Other assets, such as Asset B and Asset C, both with higher risk scores (12), are ranked lower because they impact smaller populations. This highlights how population impact significantly influences the rankings.

In Community B, Asset A ranks first again due to its higher risk score (10) and the largest population affected (180,000 or 90% of the community). In contrast, Asset B, also with a risk score of 10 but a smaller population affected (25,000 or 13%), is ranked second. Lower-ranked assets like Asset C, Asset D, and Asset E show decreasing normalized scores due to smaller populations affected and lower risk scores.

These rankings illustrate how normalized scores effectively balance population impact and risk score to prioritize assets fairly within each community. The differences in rankings between Community A and Community B underscore the importance of tailoring the prioritization framework to local community characteristics and needs.

Table 2-2: Community-Level Ranking for Community A

Asset	Community	Risk Score	Population Affected	% of Population Affected	Normalized Score	Rank
A	Community A	6	875,000	44	50%	1
B	Community A	12	150,000	8	17%	2
C	Community A	12	130,000	7	15%	3
D	Community A	12	90,000	5	10%	4
E	Community A	12	70,000	4	8%	5

Table 2-3: Community-Level Ranking for Community B

Asset	Community	Risk Score	Population Affected	% of Population Affected	Normalized Score	Rank
Asset A	Community B	10	180,000	90	83%	1
Asset B	Community B	10	25,000	13	12%	2
Asset C	Community B	5	10,000	5	2%	3
Asset D	Community B	5	8,000	4	2%	4
Asset E	Community B	5	5,000	3	1%	5

2.4 Incorporating Redundancy

Network redundancy is an important factor to include as it significantly impacts CoF. This section describes the use of a multiplier (referred to as the “Bump-Up Factor”) in the Risk Assessment to adjust CoF for Operational and Social Criteria.

In this framework, only operational and social impacts of failure are moderated by redundancy as the economic impact of failure (typically the cost of repair) and the environmental impact (damage to local environment) are not reduced by redundancy.

2.4.1 Why Include Redundancy as a Bump-Up Factor?

Redundancy in municipal watermains significantly affects the CoF because:

- Dead-end pipes or single-feed areas lack alternative supply routes, leading to higher service disruption risks.
- Redundant (looped) systems mitigate failure impacts, reducing potential damage and ensuring continued service.
- Applying a bump-up factor to CoF ensures risk assessments reflect the actual service impact of a failure.

Without accounting for redundancy, risk scores may underestimate the true impact of failure in areas with no backup supply, leading to misaligned priorities in asset management.

2.4.2 Understanding the Adjustment Factor (F) and System Redundancy Score (RS)

The adjustment factor and system redundancy factors are two multipliers used to modify the CoF to consider additional network features that individual asset analysis does not consider. There are summarized below.

2.4.2.1 Adjustment Factor (F)

The adjustment factor (F) is a multiplier that quantifies how much the lack of redundancy should increase the CoF. This factor is introduced because a non-redundant pipe failure (i.e., a pipe that has no alternative supply route) is inherently more severe than a failure in a system with inbuilt redundancy. The adjustment ensures that this additional risk is captured quantitatively.

The value of F is typically chosen based on:

- Historical Failure Data – Analysis of past watermain breaks to see how redundancy affects service disruptions and consequences.
- Engineering Judgment – Qualitative opinions from infrastructure professionals who assess failure scenarios.
- Industry Standards – Reviewing guidelines and best practices from municipal water infrastructure assessments, if there is any.

2.4.2.2 System Redundancy Score (RS)

The System Redundancy Score (SRS) is used to quantify the level of redundancy available for a given pipe segment. This score is categorized into three levels:

- 0 (No Redundancy): The segment operates as a single-feed system with no alternative supply route. A failure in this segment results in complete service loss until repairs are made, leading to high consequence severity.
- 1 (Partial Redundancy): The segment has some level of backup, such as a secondary supply with limited capacity. In case of failure, service can be maintained at a reduced level, leading to a moderate consequence severity. If the extent of redundancy is unknown this value shall be selected.
- 2 (Full Redundancy): The segment is part of a fully looped or redundant system, with sufficient capacity to ensure continuity of supply. A failure in this segment causes minimal or no service disruption, leading to a significantly lower consequence severity.

By integrating the System Redundancy Score (RS) into the risk assessment framework, we ensure that assets with higher redundancy receive appropriate risk reductions, while non-redundant assets are accurately prioritized for proactive maintenance and renewal.

Table 2-4 outlines the impact of system redundancy on the CoF. No Redundancy (RS = 0) keeps the CoF unchanged, while Partial Redundancy (RS = 1) applies a moderate adjustment (F = 0.2), and Full Redundancy (RS = 2) applies a higher adjustment (F = 0.5), reflecting the reduced failure consequences due to available alternative supply routes. It is important to note this adjustment is applied only to operational and social factors within the CoF framework.

Table 2-4: Redundancy Score and Adjustment Score

System Redundancy	Redundancy Score (RS)	Adjustment Score (F)
No Redundancy	0	0
Partial Redundancy	1	0.2
Full Redundancy	2	0.5

2.4.2.3 Methodology for Applying the Bump-Up Factor

The CoF value is adjusted using a multiplicative factor based on the Redundancy Score (RS) and Adjustment Score (F). The adjustment CoF is calculated by:

$$\boldsymbol{CoF\ Adjusted} = \boldsymbol{CoF} \times (\mathbf{1} - \boldsymbol{F}) \quad [9]$$

Table 2-5 demonstrates the impact of redundancy on risk reduction by adjusting the CoF for different assets. Asset 1, with no redundancy (RS = 0), maintains its initial Final Risk Score of 6, remaining in the Low-Risk Category. Assets 2

and 4, which have partial redundancy (RS = 1) with an Adjustment Factor of 0.2, see a moderate reduction in CoF to 3.2, lowering their Final Risk Score to 9.6 and shifting their risk category from High to Medium. In contrast, Assets 3 and 5, with full redundancy (RS = 2) and an Adjustment Factor of 0.5, experience a greater reduction in CoF, bringing their Final Risk Score down to 6 and reclassifying them from High to Low Risk. This analysis highlights how increasing redundancy significantly reduces failure consequences and overall risk, reinforcing the importance of redundancy considerations in risk-based asset management strategies.

In the scenario of constrained budgeting, the understanding of system redundancy can significantly assist in directing funding towards areas of the greatest impact. Assessment of redundancy can be easily performed using the networks hydraulic model (quality and completeness dependant) and bespoke analysis tools created by AECOM.

Table 2-5: Example of Adjusting COF Based on the Redundancy Score

Assets	LoF	Initial CoF	Initial Risk	Adjustment Factor	Redundancy Score	Adjusted COF	Adjusted Risk Score	Final Risk Score	Initial Risk Category	Adjusted Risk Category
Asset 1	2	3	6	0	0	3	6	6	Low	Low
Asset 2	3	4	12	0.2	1	3.2	9.6	10	High	Medium
Asset 3	3	4	12	0.5	2	2	6	6	High	Low
Asset 4	3	4	12	0.2	1	3.2	9.6	10	High	Medium
Asset 5	3	4	12	0.5	2	2	6	6	High	Low

3. How to Guide

This guide provides step-by-step instructions for using the accompanying Excel tools to support the application of the risk framework. It covers the three core Excel files**: Raw Data Input, Raw Scores, and Risk Tool**. The guide explains the structure and purpose of each file, provides an overview of the key sheets inside them, and outlines how to navigate, update, and practically apply the tools.

The spreadsheet tools are designed for everyone involved in the decision-making process, including asset managers, engineers, planners, financial analysts, senior decision-makers, and support staff. To use the tools effectively, users should have basic Excel skills (such as navigating sheets, entering data, and understanding basic formulas) and understand the risk framework principles developed in this project. Familiarity with the framework will ensure that users can interpret the outputs correctly, apply the results to real-world asset management decisions, and align their work with the overall risk-based approach defined in the report.

It is important to note that this tool has successfully passed the pilot stage and has been tested for practical use. However, as with any evolving framework, it may require further improvements and refinements over time to adapt to future needs. Incorporating feedback and aligning with changes in data availability, organizational priorities, or regulatory requirements will be crucial to maintain the reliability of the tools.

This guide is designed to help navigate spreadsheets with confidence, avoid common mistakes, and make the most of these tools by ensuring that decisions are based on a consistent and well-documented process.

⚠ ***Important:*** *To be able to fully work with the spreadsheets, users must ensure that* ***macro functionality is enabled*** *in Microsoft Excel. Certain calculations, automated data processes, or refresh actions rely on embedded macros, and these functions will not operate correctly if macros are disabled. Please make sure that your Excel security settings allow the file's macros to run when opening the spreadsheet.*

The tools are secured to protect AECOM intellectual property but allow users to populate as guided herein. AECOM contact details are included in each file should users require assistance.

3.1 Overview of the Excel Files

As outlined above the tool consists of 3 MS Excel files. The purpose of these files is summarized as follows:

- Raw Data Input – serves as the input file for all raw data that feeds into the risk framework tool.
- Raw Scores - contains the raw scores assigned to various LoF and CoF factors used in the risk framework.
- Risk Tool – is the core analysis of the risk framework and provides the risk outputs.

Each file is explained in further detail below along with instruction on how it should be used.

3.1.1 Raw_Data_Final_V1.xlsm

This Microsoft Excel spreadsheet serves as the main repository for all raw and input data that feeds into the risk framework tool. It is designed to collect, organize, and store the asset-related data required for generating risk scores and conducting meaningful risk analysis.

The spreadsheet is structured to receive pre-prepared datasets sourced from Geoprocessing systems, GIS exports, or other asset data repositories, and to ensure that the incoming information is aligned with the requirements and structure of the risk framework. This alignment is critical for maintaining consistency and ensuring that the subsequent scoring and risk calculations are accurate and reliable.

This file captures a range of data types, quantitative, semi-quantitative, and qualitative inputs, each having a contributing role in the risk evaluation process. For detailed information about the specific types of data required (such as, unique identifiers, condition ratings, performance indicators, environmental context, and other relevant attributes), please refer to **Section 1** of the Risk Framework Report, where the data requirements and their role in the risk model are described in detail.

More detailed explanations regarding the structure, individual sheets, and user instructions for working with **Raw_Data_Final_V1.xlsm** are provided in the following sections of this How-to Guide. This will ensure that users understand how to correctly input or update data, where to focus their attention, and how this file integrates with the overall workflow of the risk tool. **Figure 3-1** illustrates the sheets defined in this spreadsheet.

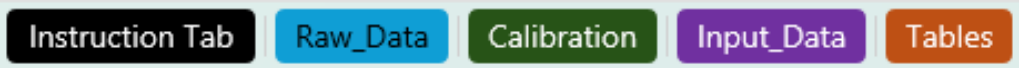


Figure 3-1: Raw_Data_Final_V1.xlsm Sheets

3.1.2 Raw_Score.xlsx

This Microsoft Excel spreadsheet contains the raw scores assigned to various Likelihood of Failure (LoF) and Consequence of Failure (CoF) factors used in the risk framework. It acts as the critical middle layer between the raw input data and final risk analysis, providing the standardized scores that quantify the risk profile of each asset or component.

The scores captured in this spreadsheet are imported directly into the Risk Tool (described in **Section 3.1.3**) to perform the essential calculations that generate the final risk scores. These scores serve as the foundation for ranking risks, identifying critical assets, and informing management decisions.

While the values and weightings in this spreadsheet can be adjusted as needed to reflect updated knowledge, priorities, or risk tolerances, it is strongly recommended that any modifications be made only after consulting with subject matter experts (SMEs). This ensures that the updates remain aligned with the principles, assumptions, and methodology defined in **Section 1** of the Risk Framework Report. Making uncoordinated changes to the scoring system could disrupt the consistency, realism, and comparability of the results across assets or projects.

More detailed explanations regarding the structure, key sheets, and instructions for working with **Raw_Scores.xlsx** are provided in the following sections of this How-to Guide. **Figure 3-2** presents a visual overview of the sheets included in this spreadsheet.



Figure 3-2: Raw_Score.xlsx Sheets

3.1.3 Risk Tool_2025_05_16_V2.xlsm

The **Risk_Tool_Final_V2.xlsm** spreadsheet is the core analysis engine of the risk framework. This tool integrates and processes the data sourced from both the **Raw_Data_Final_V1.xlsm** and **Raw_Scores.xlsm** files to perform the full risk analysis. It applies the framework's calculations to determine overall risk scores by combining the LoF and CoF factors, which consolidates the results into a user-friendly risk matrix for easy interpretation and decision-making.

The Risk Tool is designed to support users at all levels by providing a transparent and structured view of asset risks. It helps prioritize actions, allocate resources efficiently, and guide strategic planning. Each sheet in this spreadsheet serves a specific role in the analysis process — from integrating and scoring data to performing intermediate calculations, and ultimately generate final summaries and visual outputs. To get the most value from the tool, users are strongly recommended to review and familiarize themselves with each key sheet. This will provide a deeper understanding of how the results are generated, interpreted, and applied in practice.

Importantly, the Risk Tool has already been successfully tested in a pilot study, where it was run on real data to validate its performance, consistency, and applicability. The pilot demonstrated that the tool can support robust risk evaluations and can be confidently used to guide decision-making. However, like any advanced analysis tool that incorporates diverse input variables, weighting factors, and assessment criteria, this tool remains open to further refinement and enhancement. As more users engage with the tool and as organizational priorities evolve, ongoing feedback will be collected to identify opportunities for continuous improvement — ensuring the tool remains responsive, relevant, and aligned with user needs.

⚠ Important: To ensure the Risk Tool functions as designed, users must enable macro functionality in Microsoft Excel. The tool relies on embedded macros to automate certain calculations, refresh data links, and support its interactive features.

More detailed explanations about the structure of the Risk Tool, key sheets, and user instructions are provided in the following sections of this How-to Guide. These details will help users apply the tool with confidence, maximizing its potential to support informed, risk-based asset management decisions. **Figure 3-3** presents a visual overview of the sheets included in this spreadsheet.

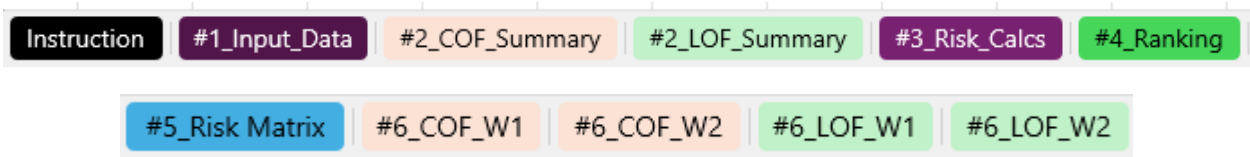


Figure 3-3: Risk_Tool_Final_V2.xlsm Sheets

Figure 3-4 illustrates the process by which geospatial data, database inputs, and risk framework scores flow through the Excel tools to generate the final risk analysis and summary outputs.

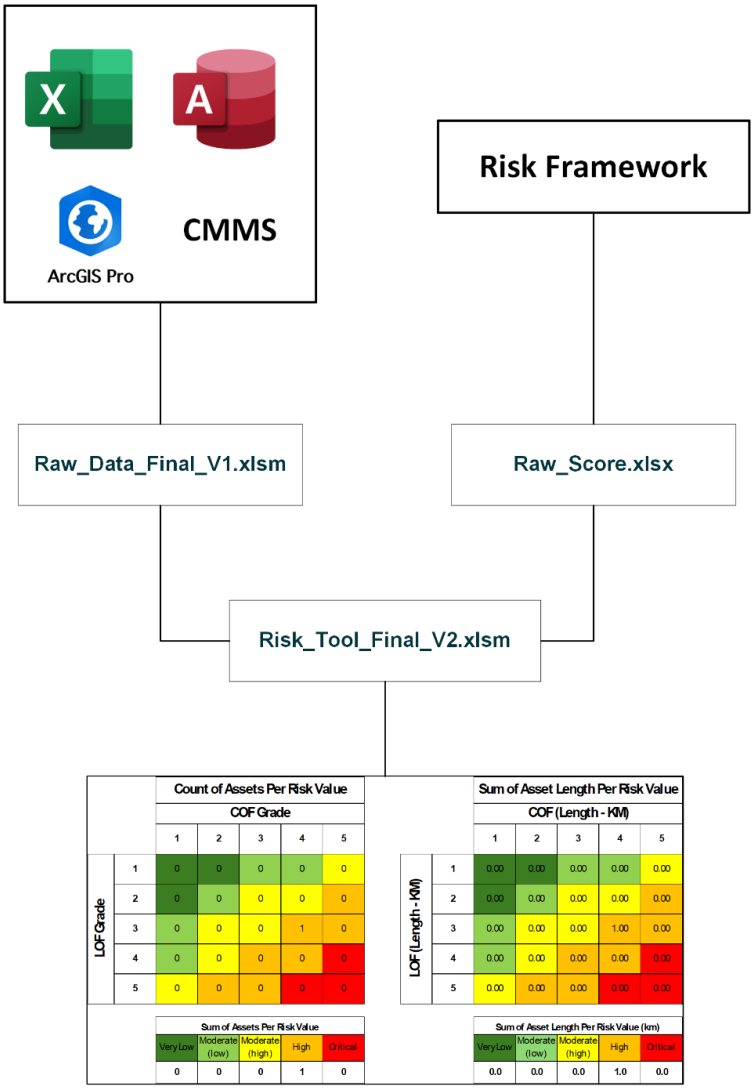


Figure 3-4: Risk Analysis Process

3.2 Sheet-by-Sheet Breakdown

This section describes each file in sheet-by sheet detail.

3.2.1 Raw_Data_Final_V1.xlsm

The Raw_Data_Final_V1.xlsm file includes the following primary sheets, each playing an essential role in preparing the input data for the risk analysis process:

- Instruction Tab

This sheet provides users with essential guidance, outlining how to navigate the workbook, where to input data, and any important notes or warnings for proper use.

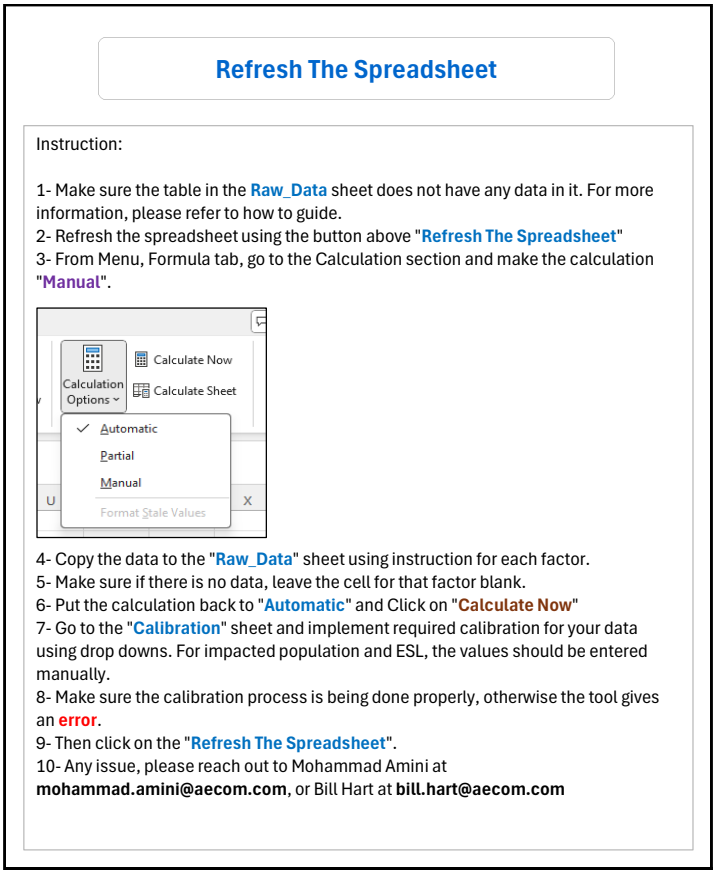


Figure 3-5: Instruction Sheet

- Raw_Data

This is the main data collection sheet, where preprocessed datasets (e.g., from GIS or database exports) are loaded and organized for further processing.

⚠ ***Note:*** *A detailed explanation for each column — including what type of data should be used, expected formats, and any dropdowns or validations — is included directly within the spreadsheet to help guide users and ensure correct data entry.*

Global ID/Asset ID	Length	Diameter	Material	Installation Year	Depth	Accessibility
AAAAAA	1		AC	2000	1	5

Figure 3-6: Sample Columns in the Raw_Data Sheet

These attributes represent the critical data fields required for the risk analysis, covering aspects such as asset characteristics, condition, performance, and environmental context. For detailed definitions, descriptions, and guidance on how each attribute fits into the overall risk evaluation process, please refer to **Section 1** of the Risk

Framework Report. This section provides important context on why each attribute is needed, and how it contributes to the final risk scores.

- Accessibility
- Actual Condition
- Adjacent Land Use
- Break Counts
- Capital Reinvestment Ratio
- Cathodic Protection
- Critical Customers
- Damage to Property
- Depth
- Diameter
- Distance_Proximity to Environmentally Sensitive Area (ESA)
- Fire Flow (Current)
- Fire Flow (Future)
- Flow Rate
- Frost Susceptibility / Effect of Frost on Soil
- Global ID/Asset ID
- Groundwater Levels
- Impacted Population
- Installation Year
- Length
- Liner
- Material
- Mitigation Plan
- Peak Day Operating Pressure
- Population Density (Ppl/km²)
- Pressure (Current)
- Pressure (Future)
- Proximity to Other Critical Infrastructure
- Proximity to Trees
- Proximity to Waterbodies
- Redundancy
- Road Clearing Types
- Road Type
- Slope
- Soil Corrosivity
- Soil Type
- Total Population
- Traffic / Loading (AADT)

⚠ ***Note:*** *Please note that it is recommended to delete the entire rows (if needed) before refreshing the data using the method below, rather than just clearing the cell contents*.

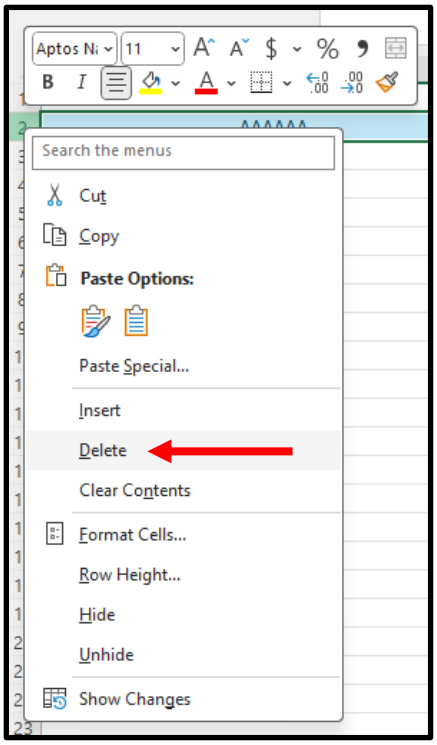


Figure 3-7: Deleting Rows Before Refreshing the Spreadsheet

- Calibration

This sheet is designed to fine-tune and adjust key factors, so the input data aligns accurately with the risk framework assumptions. Users are expected to review and calibrate several critical factors, including:

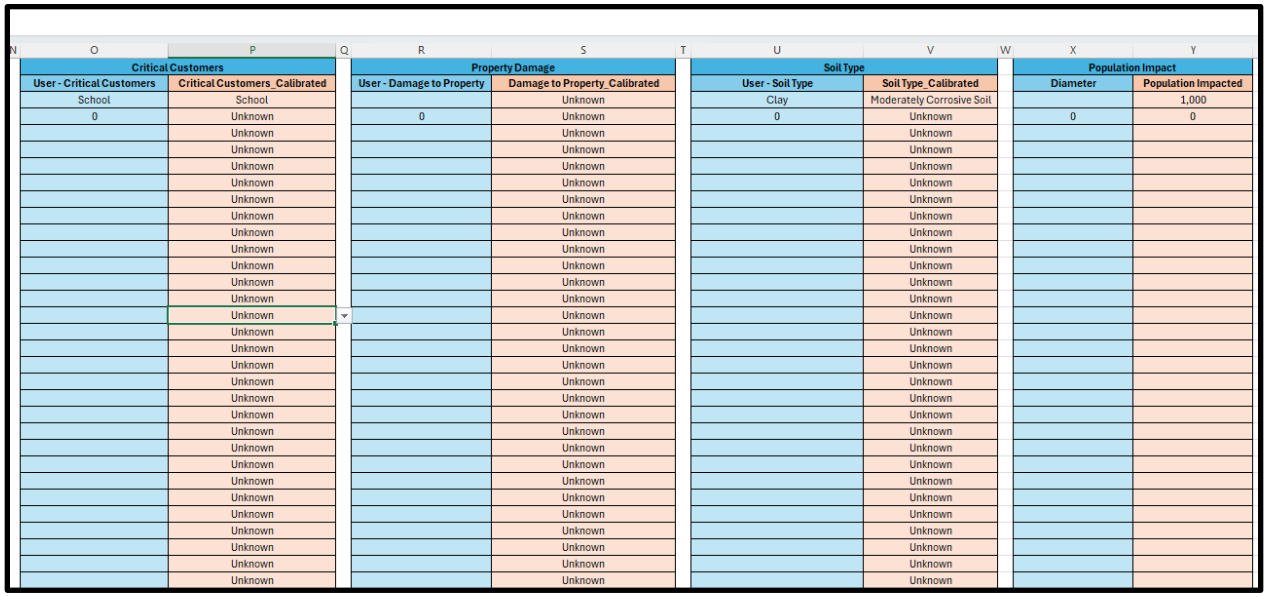
- Material
- Road Type
- Material Expected Service Life (ESL)
- Adjacent Land Use

- Critical Customers
- Property Damage
- Soil Type
- Population Impact*

Note: For the population impact factor, the pipe diameter is used as an identifier to help classify and scale the impact accordingly.

Proper calibration ensures that the scoring and risk analysis reflect local conditions, organizational priorities, and realistic performance expectations.

⚠ ***Important:*** *Please note that additional calibration factors may be identified and incorporated for the* ***final submission****, based on further review, user feedback, and evolving needs. Users should work closely with subject matter experts (SMEs) to ensure all calibration adjustments are well-justified and consistent with the risk framework principles.*



Critical Customers		Property Damage		Soil Type		Population Impact	
User - Critical Customers	Critical Customers_Calibrated	User - Damage to Property	Damage to Property_Calibrated	User - Soil Type	Soil Type_Calibrated	Diameter	Population Impacted
School	School		Unknown	Clay	Moderately Corrosive Soil		1,000
0	Unknown	0	Unknown	0	Unknown	0	0
	Unknown		Unknown		Unknown		
	Unknown		Unknown		Unknown		
	Unknown		Unknown		Unknown		
	Unknown		Unknown		Unknown		
	Unknown		Unknown		Unknown		
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	Unknown		Unknown		Unknown		

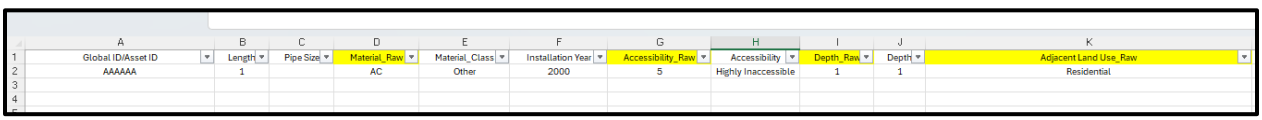
Figure 3-8: Calibration Sheet

Input_Data

This sheet compiles the cleaned and calibrated data, structuring it for seamless integration into the risk scoring system.

This sheet receives the processed and calibrated data directly from the **Raw_Data** sheet. It serves as the final staging area before the data is transferred to the scoring and risk analysis tools.

⚠ ***Important:*** *No further adjustments or edits are required (or recommended) on this sheet. All necessary data preparation and calibration should be completed in the earlier sheets (****Raw_Data*** *and* ***Calibration****). The* ***Input_Data*** *sheet is designed to function automatically, ensuring that data flows correctly and consistently into the subsequent analysis steps.*



Global ID/Asset ID	Length	Pipe Size	Material_Raw	Material_Class	Installation Year	Accessibility_Raw	Accessibility	Depth_Raw	Depth	Adjacent Land Use_Raw
AAAAAA	1		AC	Other	2000	5	Highly Inaccessible	1	1	Residential

Figure 3-9: Input_Data Sheet

- Tables

This sheet holds reference tables, lookups, or mappings that support automated calculations and ensure consistency across the data processing steps.

⚠ ***Important:*** *No further adjustments or edits are required on this sheet. Users should avoid making any changes here, as the reference data has been preconfigured to align with the risk framework and is critical for maintaining the integrity of the calculations.*

Material	Road Class	Adjacent Land Use	Critical Customers	Damage to Property	Soil Type
Plastic	Moderate Roads (Major Collector Secondary, Major Collector Primary)	Low-Density Residential	Unknown	Unknown	Unknown
Iron	Major Roads (Arterial Roads (Primary & Secondary), Freeways, Greenways)	Institutional & Conservation Areas	Emergency Services	Minimal Property Damage	Non-Corrosive Soil
Other	Minor Roads (Private, Residential, Local Collector)	Industrial & High-Risk Areas	Critical Infrastructure	Moderate Property Damage	Moderately Corrosive Soil
Steel	Unknown	Moderate-Density Residential	Civic Administration	Severe Property Damage	Highly Corrosive Soil
Concrete		Commercial & Business Areas	Civic Facility		
Unknown		Unknown	School		
Concrete-PCCP			University		
			Recreation Facility		
			Other		

Figure 3-10: Tables Sheet

3.2.2 Raw_Score.xlsx

The Raw_Scores_Final_V1.xlsx file contains the following primary sheets, each playing a key role in calculating the LoF, CoF, and overall risk scores:

- COF - Contains the raw Consequence of Failure scores defined based on the framework in Section 1.
- LOF - Contains the raw Likelihood of Failure scores defined based on the framework in Section 1.
- COF_W1 - Stores the first layer of weighting factors applied to the CoF scores, adjusting their relative importance according to the framework in Section 1.
- COF_W2 - Stores the second layer of weighting factors applied to the CoF scores, refining the results and ensuring alignment with the framework in Section 1.
- LOF_W1 - Stores the first layer of weighting factors applied to the LoF scores, adjusting their relative importance according to the framework in Section 1.
- LOF_W2 - Stores the second layer of weighting factors applied to the LoF scores, refining the results and ensuring alignment with the framework in Section 1.
- Risk_Score - Defines the threshold values used to categorize overall risk levels (e.g., low, medium, high) based on the combined CoF and LoF scores. These thresholds are essential for interpreting the final risk outputs and assigning each asset to its appropriate risk category.
- Redundancy_Score - Captures the initial assumptions regarding system redundancy. It defines whether redundancy is not available, partially available, or fully available for each asset or system. This factor plays an important role in adjusting the final risk scores, ensuring the model realistically reflects the reduced operational risk where backup systems or alternative supply routes are in place. Please see **Section 2.4**.

⚠ *Important: While values in this spreadsheet can technically be adjusted, it is strongly recommended that users only make changes after consulting with subject matter experts (SMEs) to ensure alignment with the risk framework and maintain consistency across the analysis.*

3.2.3 Risk Tool_2025_05_16_V2.xlsm

The Risk Tool_2025_05_16_V2.xlsm file contains the following primary sheets, each playing a key role in calculating the LoF, CoF, and supporting the overall risk evaluation process:

- Instruction - This sheet provides an overview of the file and how to use it effectively. It offers guidance on how the different sheets work together, outlines key steps for running the analysis, and highlights important notes and cautions for users to follow. Users should review this sheet before interacting with other parts of the file to ensure they understand the workflow and avoid common mistakes.

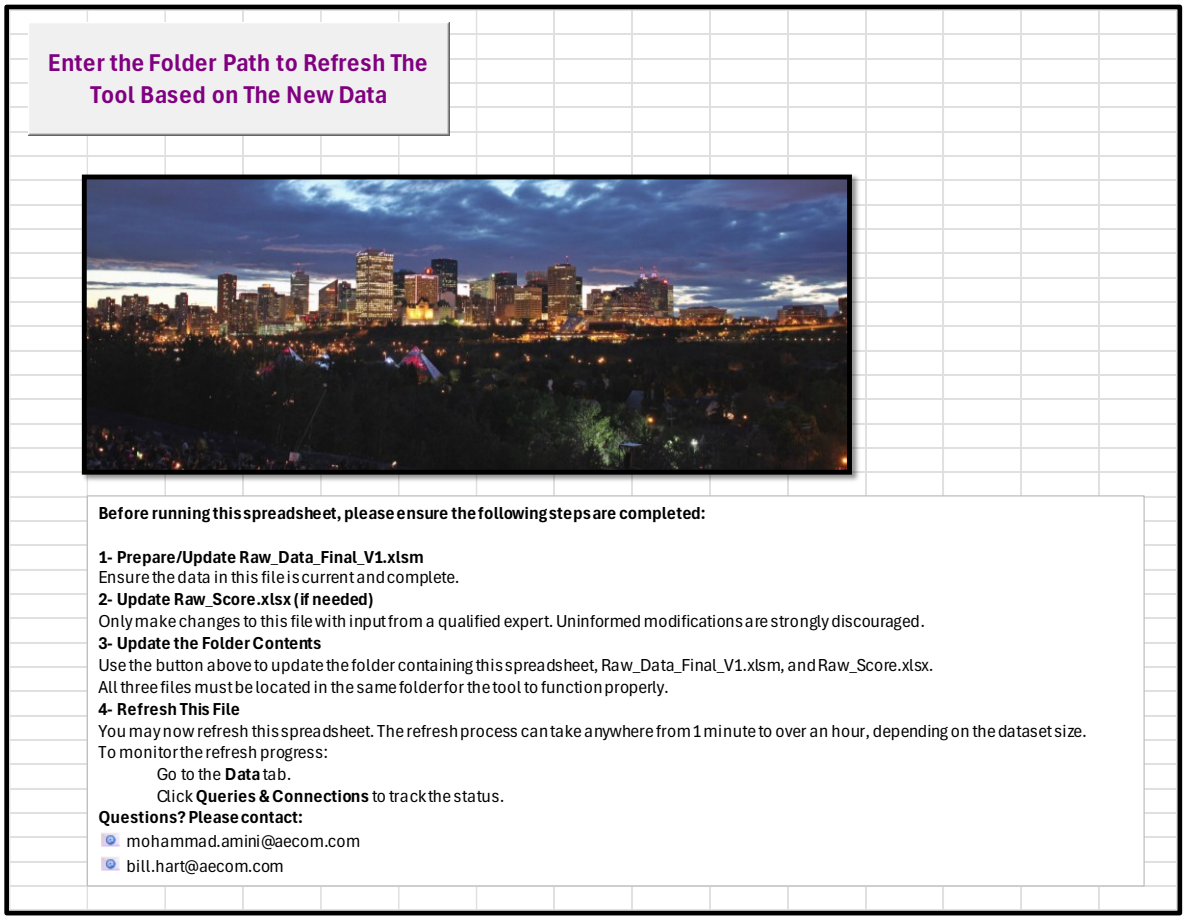


Figure 3-11: Instruction Sheet

- #1_Input_Data - This sheet receives all its data directly from the **Raw_Data_Final_V1.xlsm** file. It acts as the main input source for the Risk Tool's calculations.

  ⚠ ***Important:*** No updates or edits should be made by users on this sheet. All data preparation and adjustments should be completed in the upstream Raw_Data file before being imported here.

- #2_COF_Summary and #2_LOF_Summary - The #2_COF_Summary and #2_LOF_Summary sheets receive the summarized CoF and LoF scores, respectively, directly from the **Raw_Scores.xlsx** file.

  ⚠ ***Important:*** No updates or edits should be made by users on this sheet. All data preparation and adjustments should be completed in the upstream Raw_Score file before being imported here.

- #3_Risk_Calcs - This sheet is where all critical risk calculations are performed, using the combined inputs from the two source spreadsheets (**Raw_Data_Final_V1.xlsm** and **Raw_Scores.xlsx**) as well as data from other internal sheets within this workbook.

  ⚠ **Important:** Users should not make any changes or edits in this sheet, as it contains the core formulas and logic essential for the risk analysis process.

- #4_Ranking - This sheet ranks the assets based on their final risk scores, incorporating adjustments for redundancy and population impact. Once all previous steps and data updates have been completed, users should refresh this sheet to ensure the rankings reflect the most current analysis.

  ⚠ ***Important:*** *Users should not make any changes or edits in this sheet, as it contains the core formulas and logic essential for the risk analysis process.*

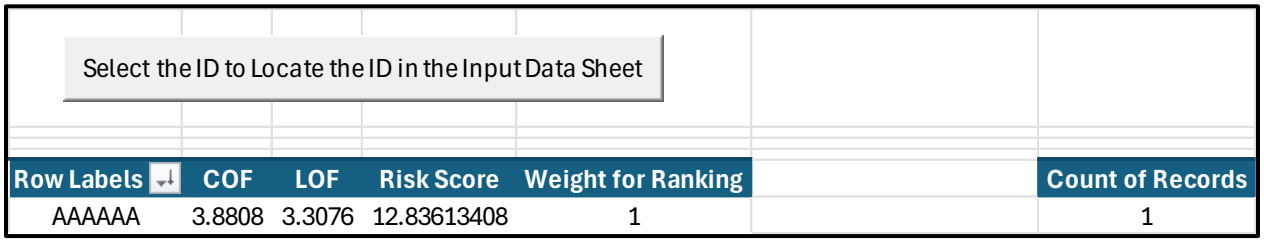
- 

Figure 3-12: Risk Ranking Sheet

- #5_Risk Matrix - This sheet summarizes the final risk analysis results, presenting them by both count (number of assets) and length (total inventory length) across the different risk categories. It provides a clear, high-level overview of how the assets are distributed across the defined risk levels, helping users understand the overall risk profile of the system.
- #6_COF_W1, #6_COF_W2, #6_LOF_W1, and #6_LOF_W2 - The #6_COF_W1, #6_COF_W2, #6_LOF_W1, and #6_LOF_W2 sheets store the weighting factors applied to the CoF and LoF scores, respectively. These weights are imported directly from the **Raw_Scores.xlsx** file and play a critical role in refining the final risk calculations. ⚠

  ⚠ ***Important:*** No updates or edits should be made by users on this sheet. All data preparation and adjustments should be completed in the upstream Raw_Score file before being imported here.

The three core spreadsheets — Raw_Data_Final_V1.xlsm, Raw_Score.xlsx, and Risk_Tool_2025_05_16_V2.xlsm — work together as an integrated system to support the full risk analysis process.

The Raw_Data_Final_V1.xlsm file serves as the primary data input hub, gathering and preparing all asset-level, condition, and contextual data needed for the framework.

Raw_Score.xlsx file processes this input to calculate detailed Likelihood of Failure (LoF) and Consequence of Failure (CoF) scores, applying weighting factors and thresholds aligned with the risk framework.

Finally, the Risk_Tool_2025_05_16_V2.xlsm file pulls together these inputs and scores to perform the final risk calculations, generate rankings, and summarize results in an actionable and user-friendly format.

⚠ ***Important****: Throughout the process, users should carefully follow the outlined workflows and avoid making unauthorized edits, particularly in sheets containing formulas, calculations, or imported data. Where changes are required (e.g., adjusting weights or scores), these should always be made in the appropriate source files to maintain the consistency and integrity of the entire system.*

Together, these tools provide a robust and transparent approach to asset risk assessment, support evidence-based decision-making and enable organizations to prioritize resources effectively.

🔔 *If users notice any issues, inconsistencies, or errors while using the spreadsheets, please reach out to the AECOM team for support and clarification. The AECOM team is available to assist with troubleshooting, address questions, and ensure the tools continue to meet project needs.*

Appendix A
Risk Framework Tool
Provided In Separate File

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Suite 330
Burnaby, BC V5A 4R4
Canada

T: 604.444.6400
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