Stantec

Memo

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Project/File:	160963932 Yellowknife CAP	Date:	May 5, 2025

Reference: Yellowknife CAP – Climate Vulnerability Assessment

1 Overview

The City of Yellowknife ("the City") has engaged Stantec to develop a Climate Action Plan (CAP). The overarching goals of the CAP are to determine the extent to which climate change considerations are considered in the City's goals and to develop a strategy to mainstream climate change mitigation and adaptation actions throughout the City's short and long-term planning.

As part of this project, a climate vulnerability assessment (CVA) was conducted on the City's infrastructure portfolio to establish which climate-related hazards are applicable to the City, identify the impacts they have had to infrastructure, services, and the community in the past, and provide guidance for climate action and adaptation measures to build the City's resilience to climate change.

This memo presents an overview of the CVA process and results of the assessment. These results were compiled from a desktop review of City documents and through engagement with Yellowknife staff and stakeholders in a series of engagement sessions in January-March 2025.

2 The CVA Process

A high-level, portfolio CVA was conducted for the City of Yellowknife. The portfolio CVA process followed the ISO 14091 and ISO 14092 Adaptation to Climate Change standards[1] and involved the following steps, also shown in Figure 1:

- **Step 1** – Identify the critical infrastructure and assets.
- **Step 2** – Identify relevant climate hazards.
- **Step 3** – Evaluate past impacts of climate hazards on infrastructure and assets.

[1] ISO 14091:2021 *Adaptation to climate change: Guidelines on vulnerability, impacts and risk assessment* and ISO/TS 14092:2020 *Adaptation to climate change: Requirements and guidance on adaptation planning for local governments and communities*.

- **Step 4** – Determine vulnerability of assets to climate hazards.

These steps were completed through a desktop assessment of City provided documents and with input from the engagement sessions.

Vulnerability is the measure of the extent to which assets, infrastructure systems and services are susceptible to, or unable to cope with, the impacts of climate-related hazards. The vulnerability of an asset is determined using the formula **V = E x S x C**, where:

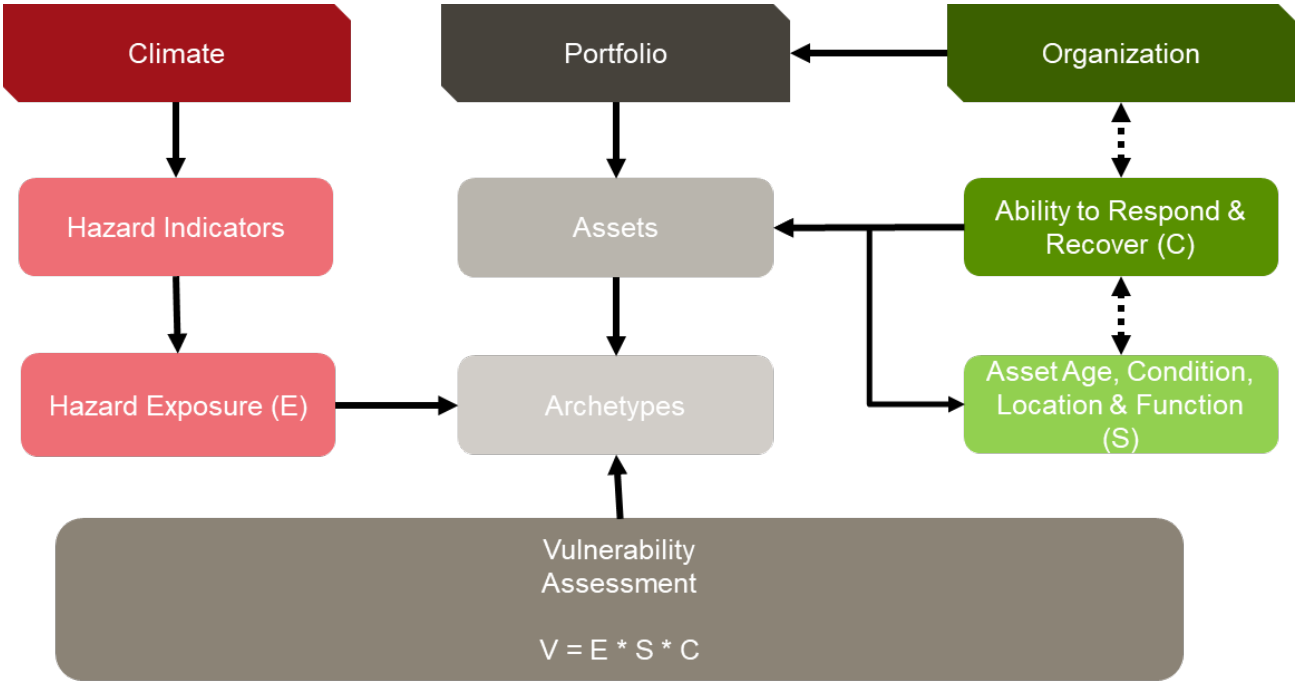
V = Vulnerability
E = Exposure (yes or no)
S = Sensitivity (low, medium, or high)
C = Adaptive Capacity (low, medium, or high)

Vulnerability is a function of an asset, infrastructure system, or service area's exposure, sensitivity, and adaptive capacity but also broader socioeconomic and environmental cross effects as well. These are defined as follows.

- **Exposure (E)** – The nature or degree to which assets, infrastructure systems, or service areas would interact with climate hazards. Exposure to climate-related hazards varies based on location and setting, design features, users, and other factors, which can change as climate impacts vary, interact, and compound.
- **Sensitivity (S)** – The degree to which assets, infrastructure systems, or service areas are either positively or negatively influenced/impacted by climate hazards. The degree of sensitivity to climatic hazards depends not only on asset/infrastructure and geographic conditions (e.g., age and condition) but also on socio-economic factors such as population and social equity. Indicators of sensitivity can encompass geographical conditions, land use, demographic characteristics, etc. In this assessment, sensitivity was considered in relation to general age and condition of assets and archetypes, complexity of assets and archetypes, the majority of users (e.g., seniors), and previous exposure to climate impacts.
- **Adaptive Capacity (C)** – The ability to prepare for and respond to impacts and consequences. Adaptive capacity depends on physical resources, access to technology and information, varieties of infrastructure, institutional capability, and the distribution of resources. Key determinants of adaptive capacity include economic and social resources, level of technology, available information and skills, social capital, and the effectiveness of existing institutions, etc. At an asset or asset component level, factors like age, design setting, load, service levels, etc. can also come into consideration. The adaptive capacity assessment considered the City's resources, emergency plans, redundancies (e.g., power supply, access routes), supply chain security, and potential duration of recovery efforts following climate-related disaster. Due to the City's response challenges (e.g., financial and staffing resources, limited major access routes, past impacts from wildfires and other severe hazards) the adaptive capacity was set to medium.

Reference: **Yellowknife CAP - CVA Preliminary Results**

Figure 1 **Schematic Diagram of the PIEVC Vulnerability Assessment Process**



By examining the climate-related hazards and possible interactions (exposure and sensitivity) with assets, infrastructure systems, and services as well as the ability to respond (adaptive capacity), the overall vulnerability to climate-related hazards can be determined using the heat map shown in Table 1. For example, an asset archetype with high exposure to climate risks, high sensitivity to climate hazard interactions, and low adaptive capacity to respond and recover to events is classified with high vulnerability.

Table 1 **Vulnerability Assessment Matrix**

		Sensitivity		
		Low	**Medium**	**High**
Adaptive Capacity	**Low**	Medium Vulnerability	High Vulnerability	High Vulnerability
	Medium	Low Vulnerability	Medium Vulnerability	High Vulnerability
	High	Low Vulnerability	Low Vulnerability	Medium Vulnerability

3 CVA Results

Assets, climate hazards, and exposures were identified for the CVA using information gathered from City provided documents. These exposures were updated through engagement sessions, during which information was gathered on impacts, sensitivity, and adaptive capacity of the City's assets. Results of the CVA are presented in the following subsections.

3.1 Step 1: Infrastructure and Assets

A list of assets, infrastructure, and systems considered in the CVA was developed from City provided documents and validated during staff engagement sessions. The list consists of archetypes (e.g., transportation networks, city-owned buildings) as well as individual, unique assets (e.g., Firehall, water treatment plant) as follows:

City-owned:

- Transportation networks (roadways, bridges, bike lanes, sidewalks)
- Land use
- Stormwater (including culverts and storm drains)
- Yellowknife Bay water treatment plant and collection/distribution network
- Wastewater treatment network (e.g., Fiddlers Lake sewage lagoon, wetland filtration area, sewage systems)
- Solid Waste Facility (SWF)
- Parks (green spaces, parks, playgrounds, trails, fields, docks)
- Recreational facilities and associated equipment (e.g., the Multiplex, heritage monuments and other structures)
- City-owned Administrative/operational buildings
- Yellowknife Firehall
- Cemetery

Not City-Owned:

- Commercial/industrial buildings (e.g., Engle Business District)
- Residential buildings
- Yellowknife Airport
- Power supply
- Telecommunications and IT networks
- North Slave Correctional Facility
- Stanton Territorial Hospital

3.2 Step 2: Climate Hazards Overview

A list of climate hazards was developed from City provided documents and Stantec's climate science expertise. The climate hazards, thresholds, and trends used in the CVA are presented in *Table 2*.

Table 2 Climate Hazards Used in the CVA.

Climate Hazard	Climate Threshold	Trend (Baseline to 2080s)
Higher Average Temperatures	Annual mean temperature (°C)	↗
Heating Degree Day (HDD)	Annual heating degree day	↘
Cooling Degree Day (CDD)	Annual cooling degree day	↗
Extreme Heat	Annual number of days where maximum temperature ≥ 25°C	↗
Extreme Cold	Annual Number of Days where Minimum Temperature is ≤ -35°C	↘
Cold Snap	Annual number of days where minimum temperature is ≤ -40°C	↘
Freeze Thaw - Winter	Annual number of days where maximum temperature > 0°C and minimum temperature ≤ -1°C in winter	↗
Freezing Rain	Annual median hours of freezing rain	↗
Snowstorms	Annual number of days with ≥ 5cm of snow with wind gusts ≥ 50 km/hr	↗
Seasonal Snow Cover	Relative Change from baseline	↘
Permafrost Thaw	Changes to permafrost active layer thickness	↗
Short Duration High Intensity Rainfall	Occurrence of 1:50 yr, 1 hour duration events (23.9 mm)	↗
Long Duration Rainfall	Occurrence of 1:50 yr, 24 hour duration event (70.3 mm)	↗
Drought*	Annual standardized Precipitation Evapotranspiration Index (12 month SPEI)	↘
Changes in Lake Level**	Changes in lake level - Yellowknife at Great slave lake - average annual lake level (m)	↔
Relative Humidity	Annual relative humidity	↔
High Winds	Annual number of days with wind gusts ≥ 90 km/hr	↗
Wildfire Interface	Annual number of large fires per year per 100, 000 km2	↗
	Annual area burned by large fire	↗

Climate Hazard	Climate Threshold	Trend (Baseline to 2080s)
Wildfire Smoke	Annual fire season length	↗

***A decreasing SPEI trend signals drier conditions**

****Annual average lake level changes are steady to slightly decreasing, however high variability in the year-to-year high and low extremes lake levels**

Yellowknife is located in a region of extensive discontinuous permafrost with medium to low ground ice content, meaning that 50-90% of the land in the area is underlain by permafrost and that up to 20% of the permafrost soil is made of ice, but there are patches of ground that remain unfrozen throughout the year. The ice content affects how the ground behaves when it thaws; areas with higher ice content are more prone to ground subsidence and instability when the ice melts. The active layer thickness is the top layer of soil that thaws and refreezes seasonally. The thickness of the active layer affects the stability of the underlying permafrost. Thicker active layers can lead to more significant seasonal ground movement, which can destabilize the permafrost beneath as well as allow more heat to reach the permafrost, potentially leading to deeper thawing and permafrost degradation. It is noted that permafrost thaw has impacted assets in some sections of the City (e.g., the airport) and can impact major entry and exit routes, such as the Mackenzie Highway. As such, permafrost thaw was retained in this assessment despite being discontinuous.

3.3 Step 3: Exposure and Impacts of Climate Hazards

The exposure and impacts assessment evaluates how current and future climate-related hazards might materialize as impacts to assets, operations, and residents of the City. Possible exposure and impacts can be used to determine vulnerability of each asset to the relevant climate hazards and develop recommendations for appropriate adaptive responses.

Exposures and impacts were identified from a desktop review of climate events that have impacted the City and were updated based on discussions with City of Yellowknife Council, staff, and stakeholders during the engagement sessions. Potential impacts.

Specific impacts noted in the desktop assessment and engagement are shown below.

- In January 2023, continued problems with settling in an area of the Yellowknife airport runway prompted the GNWT to commission a geotechnical study to investigate and determine long term solutions. The issue is thought to be shifting ground conditions brought on by thawing permafrost.
- The 2023 wildfires resulted in 12 community evacuations in NWT, including in Yellowknife, with insured losses from the city of Yellowknife and Behchokǫ̀ totaled around $30 million. No buildings were lost within the city of Yellowknife's municipal boundaries, however there were significant costs related to the evacuation of residents.

- In September 2022 there was series of power outages over two days due to a downed tree on transmission lines at Snare Hydro from high winds, problems maintaining electrical stability and Jackfish Lake generator issues.
- A city-wide power outage occurred in July 2016 due to a wildfire near Yellowknife damaging power lines from the Snare Lake hydro system.
- In 2014 385 fires burned 3.4 M hectares of forest land in the NWTs, costing $56.1 M in firefighting costs alone.
- Permafrost thaw has led to ground shifting, settlement, and damage to infrastructure in some areas of the City.
- Low water levels have reduced the output of the Snare and Talston Hydro systems, leading to increased dependence on diesel powered generators. Disruptions to power supply have also been experienced during periods of extreme heat and cold.
- Low water levels have raised concerns for availability of water for City uses (e.g., potable water from Yellowknife River).
- Stormwater drainage systems have been overwhelmed during heavy rainfall events, leading to localized flooding, erosion, and infrastructure damage.
- Transportation within the city (e.g., public transit) has been impacted by climate hazards that influence road conditions, such as snowfall and freezing rain.
- Winter weather impacts on transportation and distribution networks have resulted in disruption of supply routes.
- Extreme cold and winter hazards have made commuting more difficult for public transit users and result in delays in transportation of goods to and from the City.
- High winds have removed siding and roof shingles.
- Higher humidity has increased mould growth, particularly in homes with minimal HVAC and ventilation.
- Increased demand for air conditioning due to extreme heat has led to higher energy consumption.
- Periods of low rainfall and drought have led to increased need for grounds maintenance in natural areas and parks.
- Heavy snow accumulation can restrict access to parks, reducing public use.
- Ice accumulation and freeze-thaw cycles can lead to cracks, potholes, and uneven surfaces, making trails hazardous for pedestrians and cyclists. Increased freeze thaw cycles have accelerated road deterioration of roadways.
- The length of the winter season and period of ice formation on waterways has decreased, which has impacted winter recreation and hunting.

Additional impacts typical to infrastructure were also included based on the CVA team's experience with climate hazards occurring in the region and are presented in Table 3. These include impacts to buildings, transportation networks, water and wastewater infrastructure, natural areas, and power supply. Exposures of City assets to climate hazards identified through the desktop assessment are shown in Table 4.

Table 3 Summary of Possible Climate Impacts to Asset Categories by Climate Hazard.

Climate Hazard	Buildings	Transportation Networks	Power Supply	Water and Wastewater Systems	Natural Areas and Land Use
Heat and Humidity (Extreme Heat, Higher Average Temperatures, Relative Humidity)	• Increased cooling demands, leading to higher energy costs and GHG emissions. • Decreased asset life of HVAC systems due to increased use and greater need for repair / renewals. • Increased health and safety risks to staff and users (in buildings without A/C) and prolonged periods of inadequate indoor environmental conditions. • More frequent repairs and renewals to building roof, envelope, and seals due to deterioration (e.g., buckling, bowing, etc.). • Failure of electrical components including transformers due to maximum operating temperatures being exceeded (cascading impacts to IT and security systems). • Delay of regularly scheduled maintenance programs, procedures, and construction windows due to potential for heat-related illnesses. • Delay or cancelation of regularly scheduled programming of community buildings due to concerns of heat stroke in attendees and users. • Higher humidity and increased condensation inside buildings, leading to mould growth and mould-related illnesses.	• Deterioration of asphalt pavement, leading to cracking, rutting, surface depressions, and buckling. • Increased need for maintenance.	• Reduction in efficiency of sensitive equipment due to maximum operating temperatures being exceeded (e.g., SCADA). • Reduced efficiency of cooling systems. • Overheating of communications equipment, resulting in equipment failure and increased need for replacement.	• Reduction in efficiency of sensitive equipment due to maximum operating temperatures being exceeded (e.g., SCADA). • Reduced efficiency of cooling systems. • Overheating of communications equipment, resulting in equipment failure and increased need for replacement. • Overheating and malfunction of pumps and other machinery if ventilation and cooling are insufficient to maintain optimal temperatures.	• Wilting and damage to vegetation. • Ecological shifts and increased pest infestations due to warming.

Wildfire Interface and Smoke	• Poor air quality leading to respiratory and other illnesses in staff and users.
	• Smoke-related impacts to HVAC systems, leading to filters becoming blocked and needing increased maintenance.
	• Cascading impacts from surrounding wildfires, such as:
	  ○ Loss of City services on which facilities depend.
	  ○ Extended power outages affecting building and facility operations.
		• Loss of visibility for users, leading to accidents and injuries.
		• Fire damage to roads, requiring replacement of road sections.
			• Damage and loss of power infrastructure, leading to prolonged power outages.	• Damage and loss of surface infrastructure, leading to prolonged service delays.	• Increased need for urban / rural fire interface and vegetation management.

Reference: **Yellowknife CAP - CVA Preliminary Results**

Climate Hazard	Buildings	Transportation Networks	Power Supply	Water and Wastewater Systems	Natural Areas and Land Use
	○ Increased pressure on emergency response. ○ Increased insurance premiums.				
Low Water Levels (Drought, Changes in Lake Level)	• Increased water requirements for drinking and domestic use. • Poor air quality due to increased dust.		• Loss of hydropower generation capacity, leading to increased dependence on diesel generators.	• Reduced water availability from sources of potable and domestic water. • Low water levels making it difficult for water and wastewater pumps to operate, leading to stagnation, corrosion, and sediment buildup. • Decreased infiltration and inflow (I&I) into wastewater systems, resulting in increased sewage concentration passing through piping, long-term corrosion, and unpleasant odours from deposited solids. • Increased concentrations of pollutants in wastewater systems, creating higher demands on treatment equipment.	• Wilting vegetation due to lack of water availability. • Increased water requirements for irrigation.
Heavy Rainfall	• Water ingress and damage to structural building components due to localized flooding (e.g., foundations). • Compromised facility/building functionality and reduced level of service to the community. • More frequent repairs and renewals to buildings due to water-related damage, growth of organic material, and gradual deterioration of external components (e.g., flat roofs, window, foundation). • Increased need for emergency response due to the potential for accidents and injuries in flood events. • Increased insurance premiums.	• Road washouts and localized flooding, leading to loss of access to sections of the City. • Health and safety risks to users (e.g., physical injuries), leading to increased need for emergency response. • Overwhelmed drainage systems due to high water volume, leading to decreased capacity and localized flooding. • Increased usage of salts for de-icing due to freezing rain and ice accumulation, resulting in a decrease in the service life of roadways and sidewalks. • Ice accumulation on streetlights and traffic lights, which may require removal by maintenance crews.	• Loss of access to flood-damaged power systems, leading to delayed restoration.	• Sewer backup and overflow into surrounding areas due to high water volume. • Erosion of berms due to high volume of runoff. • Increased water volume in water and wastewater treatment systems due to heavy rainfall, leading to reduced efficiency of treatment.	• Waterlogging of vegetation due to high water volume. • Increase in localized flooding of open sites, resulting in a need for alternative land use considerations.
Winter Hazards (Snow, Extreme Cold, Freezing Rain, Freeze Thaw)	• Damage to building structure due to ground shifting and settlement caused by freeze thaw cycles. • Lake ice damming leading to potential flooding. • Increased snow load compromising structural integrity of existing building roofing.	• Deterioration of road, trail, and bridge structure due to ground shifting and settlement caused by freeze thaw cycles. • Ice and snow buildup in surface drainage and culverts, requiring thawing by maintenance staff to restore full functionality.	• Power outages due to freezing rain and ice accumulation weighing down transmission and distribution lines. • Damage and failure of sensitive equipment and communication systems due to ice and snow accumulation, temporarily limiting operations.	• Pipes and water mains freezing during extreme cold events and cold snaps. • Damage to underground piping and infrastructure due to ground shifting and settlement caused by freeze thaw cycles. • Degradation of berms around wastewater treatment facilities due to ground shifting resulting from freeze-thaw cycles.	• Increased snow load on vegetation branches, leading to breakage.

Reference: **Yellowknife CAP - CVA Preliminary Results**

Climate Hazard	Buildings	Transportation Networks	Power Supply	Water and Wastewater Systems	Natural Areas and Land Use
	• Ice and snow blockage of exterior HVAC components, leading to compromised functionality. • Blockage of drainage systems, leading to localized flooding during spring melt. • Increased ice buildup in surface drainage, requiring thawing by maintenance staff to restore full functionality. • Extreme cold leading to frost decay/deterioration of porous masonry materials. • Potential for roof damage due to ice dams and moisture damage.	• Increased need for maintenance to address degradation due to winter hazards. • Ice and snow accumulation on roads and parking areas, resulting in a health and safety risk to staff and users (e.g., increased potential for road accidents, slip-and-fall risk).	• Cracked insulators and flashovers due to extreme cold and freezing rain.	• Reduced efficiency of effluent processing systems. • Damage and failure of sensitive equipment and communication systems due to ice and snow accumulation, temporarily limiting operations. • Increased water volume in wastewater treatment ponds due to heavy rainfall, leading to snowmelt. • Blockage of water and wastewater intakes and discharge pipes, leading to reduced water flow and damaged pumps. • Increased blockages and wear-and-tear due to debris accumulation and increased sediment load resulting from rainfall run off.	
Permafrost Thaw	• Cracking and degradation of building foundations due to ground shifting and settlement.	• Cracking and degradation of road structure due to ground shifting and settlement.	• Shifting of poles and other electrical distribution infrastructure due to ground shifting and settlement.	• Shifting and damage to linear water and wastewater infrastructure due to ground shifting and settlement.	• Changes in soil hydrology and nutrients, leading to ecological shifts and increased need for alternative land use considerations.
High Winds	• Wind damage to building envelope, roof, and rooftop mechanical systems. • Windblown debris or trees falling on infrastructure resulting in damage. • Windblown debris in parking areas, requiring increased maintenance to clear potential obstacles. • Damage to external mechanical components leading to compromised building functionality (e.g., increased or decreased cooling and heating loads due to air leakage and impacts to air handling systems). • Health and safety risks to staff and users from high winds. • More frequent repairs and renewals to buildings due to damage and displacement of components. • Damage and displacement of signage and outdoor furniture. • Disruption of building and facility operations due to wind-related power outages.	• Blockage of roadways and trails by windblown debris (e.g., fallen trees). • Health and safety risks to users (e.g., physical injuries), leading to increased need for emergency response.	• Power outages due to damage to electricity distribution infrastructure (e.g., treefall on power lines). • Wind damage to communications equipment, leading to temporary inoperability of SCADA systems. • Conductor slapping resulting from high wind events.	• Wind damage to communications equipment, leading to temporary inoperability of SCADA systems.	• Damage to vegetation and uprooted trees.

Table 4 Overview of Climate Hazard-Asset Interactions Identified

Assets	Higher Average Temperatures	Heating Degree Day (HDD)	Cooling Degree Day (CDD)	Extreme Heat	Extreme Cold	Cold Snaps	Freeze Thaw - Winter	Freezing Rain	Relative Humidity	Short Duration High Intensity Rainfall	Long Duration Rainfall	Snowstorms	Seasonal Snow Cover	High Winds	Drought	Wildfire Interface / Smoke	Changes in Lake Level	Permafrost Thaw
Transportation network (roadways, bridges, bike lanes, sidewalks)	X			X	X	X	X	X		X	X	X	X	X		X		X
Land Use	X			X	X	X	X			X	X	X	X	X	X	X		X
Cemetery	X			X			X	X		X	X	X	X	X	X	X		X
Stormwater (including culverts and storm drains)					X	X	X	X		X	X	X	X	X		X		X
Yellowknife Bay water treatment plant and collection/distribution network	X	X	X		X	X	X			X	X				X	X	X	X
Wastewater treatment network (e.g., Fiddlers Lake sewage lagoon, wetland filtration area, sewage systems)	X	X	X		X	X	X			X	X					X		X
Solid Waste Facility (SWF)				X						X	X			X	X	X		X
Parks (green spaces, parks, playgrounds, trails)	X			X			X	X		X	X	X	X	X	X	X		X
Recreational facilities and associated equipment (e.g., the Multiplex, heritage monuments and other structures)	X	X	X	X	X	X	X	X		X	X	X	X	X		X		X
City-owned Administrative/operational buildings	X	X	X	X	X	X	X			X	X	X	X	X		X		X
Commercial/industrial buildings (e.g., Engle Business District)	X	X	X	X	X	X	X			X	X	X	X	X		X		X
Residential buildings	X	X	X	X	X	X	X		X	X	X	X	X	X		X		X
Yellowknife Airport	X	X	X	X	X	X	X	X		X	X	X	X	X		X		X
Power supply	X	X	X	X	X	X		X				X		X		X	X	X
Telecommunications and IT networks								X						X		X		X
North Slave Correctional Facility	X	X	X	X	X	X	X			X	X	X	X	X		X		X
Yellowknife Firehall	X	X	X	X	X	X	X			X	X	X	X	X		X		X
Stanton Territorial Hospital	X	X	X	X	X	X	X			X	X	X	X	X		X		X

3.4 Step 4: Vulnerability Assessment Results

Several vulnerabilities were identified through the desktop assessment and engagement with City staff and stakeholders, including the following:

- **Knowledge gaps** – The City's capacity to address its climate concerns is hindered by key knowledge gaps, which limit the development of plans specific to critical infrastructure and population groups. These gaps include:
  - A central critical infrastructure list clearly identifying assets and infrastructure the City is dependent on to maintain regular operations.
  - Identification and mapping of vulnerable populations and communities that may be disproportionately impacted by climate events.
  - City-specific climate change risk assessments and geotechnical studies identifying key concerns specific to the City's key infrastructure and operations.
  - Location data and mapping of permafrost, flood zones, geotechnical hazards, and natural resources for the City.
- **Capacity during emergencies** – Yellowknife serves as a hub for evacuations from surrounding communities during regional disasters. The primary locations for hosting evacuees are currently the Multiplex and Fieldhouse, with other sites being identified for larger community requirements. During these events, the City heavily depends on external partners for food, financial support, volunteer management, and other supports. Hosting puts a strain on the City's emergency response resources, food supplies, and shelter and staff capacity, which may not be sufficient for large regional events.
- **Key transportation and supply routes** – Yellowknife serves as a transportation and distribution hub to support supply chains to smaller, more remote NWT communities. Extreme events that limit use of the City's transportation routes impact not only supplies moving into and out of Yellowknife, but also hinder downstream supply chains to other communities. This makes the City's transportation routes sensitive to climate impacts due to the potential disruption of operations internal to the City and to other NWT communities dependent on Yellowknife for supplies.
- **Permafrost thaw** – Melting permafrost has been a challenge for development in much of the City due to associated changes in ground stability, soil structure, and hydrology. Increased ground shifting and settlement have led to ongoing deterioration and damage to City infrastructure (e.g., Yellowknife Airport, power supply infrastructure). Permafrost thaw is likely to continue into the future driven by rising temperatures, which may limit land development options, necessitate changes to construction practices, and increase maintenance costs.
- **Lack of climate adaptation policies and plans** – The City has been experiencing an increased pace of climate events accompanied by a lack of recovery time. While climate change has been recognised by the City as a major concern, climate risk assessment and adaptation have not yet been mainstreamed into the City's policies and capital planning. For example, there is currently no streamlined effort to complete building condition or climate risk assessments for City buildings, which limits the City's knowledge of where retrofits may be necessary and what assets may need immediate

resilience measures. The City currently has no risk management framework for the corporate risk evaluations that would inform the development of these policies but is in the process of developing one.

- **Resource limitations** – The City does not currently have adequate staff and resources for preparing for and responding to climate-related impacts. With respect to maintaining City assets, the City has an inadequate maintenance budget, no replacement budget, and high staff turnover. These factors pose a challenge to climate adaptation, especially if additional funding cannot be acquired by the City.
- **Population changes** –There has been an increase in NWT residents migrating to Yellowknife over time in search of employment and other opportunities, and nearly all the NWT's projected population growth is expected to occur in Yellowknife. This has led to a strain on the City's resources, an increase in economic hardships, and an increase in rates of homelessness. Population growth in the City has been particularly rapid among seniors. Along with the declining birth rate, this has resulted in an aging population that is increasingly dependent on City services and programming. These changes in demographics and economic development increase the proportion of the population most sensitive to changes in climate and increase the need for climate relief structures and resources, such as cooling centres, green spaces, and bus shelters.
- **Water levels determine power and water supply** – The City is sensitive to low water levels in surrounding water bodies due to its dependence on them for hydropower, particularly from the Snare and Bluefish hydroelectric plants. Loss of hydropower results in increased use of generators powered by diesel, which can be expensive. The City's sensitivity to low water levels also stems from its dependence on local water bodies for its water supply. The water treatment plant was constructed in 2015 to process water from Yellowknife's two major water sources, Yellowknife River and Yellowknife Bay. However, the main pipeline that carries potable water from Yellowknife River to the water treatment plant was built in 1969 and is nearing end of use, making it particularly vulnerable to corrosion and damage. While the City has decided to replace the pipeline, the replacement will be costly and time consuming. Water from Yellowknife Bay will be used in the interim. However, the 2019 Community Plan Update Background Report stated that there is a concern that arsenic contamination from the nearby Giant Mine site cannot be consistently controlled, which may compromise long-term safe water availability from Yellowknife Bay. The City currently conducts regular testing to monitor the arsenic content of the water.
- **Sewage and Wastewater treatment lagoon overflow** – The City's sewage and wastewater treatment system discharges into Fiddler's Lake (a natural lake lagoon and wetland system) and ultimately to Great Slave Lake. Sewage treatment is achieved naturally in the lagoon and downstream wetlands. The wastewater system is strongly impacted by overland flow associated with intense rainfall and snowmelt, given there are no surrounding berms to limit runoff into the lake. Increased inflow to the lagoon increases the need for decanting and decreases the treatment performance of the system. Additional resources may be required to upgrade wastewater management capacity and adapt the system to changes in precipitation intensity and frequency, particularly if the City's population continues to grow as expected.
- **Stormwater drainage capacity** – Drainage capacity has been impacted by development and associated paving around the City. The result has been a change in natural flow patterns of runoff and snowmelt and a decrease in natural ground infiltration. The capacity of existing drainage systems is

based on historical precipitation and levels of development. Considering the City's continued growth and development, the City is sensitive to localised flooding due to intense rainfall events and snowmelt.

- **Food security** – Food security has been recognised as a concern for both the City of Yellowknife and the NWT, particularly during disasters and extreme events when the City serves as an evacuation hub. There are high rates of food insecurity in Yellowknife (and generally in NWT) due to various factors, such as food costs, limited supply chains, and lack of suitable and available agricultural land. The City has taken steps to address these concerns through the 2015 Yellowknife Food Charter and the 2019 Yellowknife Food and Agriculture Strategy (GROW). However, the GROW initiative is currently on hold due to lack of funding. Climate change may also pose a challenge to future agricultural success if climate resilience is not integrated into agricultural land use planning, crop selection, protective structures (e.g., greenhouses), and other areas.
- **Wildfire management** – The City is in an area that is prone to wildfires and has been evacuated due to nearby wildfires in the past. Fuelbreaks were established around the City during the 2023 wildfire season, which the City would need to allocate its already limited resources to maintain. An additional concern for fire management in the City is the limited distribution of fire hydrants, which are only installed across approximately half of the City due to the terrain and permafrost. Areas without fire hydrants are serviced by portable water tanks and water shuttles in the event of a fire. The City does not currently have a specific debris management plan for post-disaster cleanup of debris generated by wildfires (e.g., burnt cabins, trees), which inhibits efficient removal of debris due to a lack of direct coordination. While there is no direct wildfire debris management plan, some amount of debris clearance is considered in the City's emergency planning.

Results of the CVA are shown in Table 4 for each of the assets and archetypes assessed. Of the 18 assets and archetypes assessed, 12 were found to have high vulnerability and 6 had medium vulnerability. No low vulnerability archetypes were identified in this assessment. In addition to the impacts noted in Section 3.3, specific vulnerabilities of each asset and archetype assessed are noted below.

High Vulnerabilities

- **Transportation Networks** are highly vulnerable to degradation and damage from ground settlement due to permafrost thaw and winter freeze thaw. Road conditions have also been hindered by ice and snow accumulation, which has hindered use of transportation and supply routes in winter months.

- The operations of **Yellowknife Water Treatment Plant and Collection/Distribution Network** are highly vulnerable due to the condition of the potable water pipeline and the water quality of Yellowknife Bay. There is potential for ground shifting and settlement to damage the submarine pipeline due to its poor condition. Low water levels may also lead to an increase in concentration of contaminants in Yellowknife Bay, decrease in water availability for residents of the City, challenges to maintaining water pressure, and functionality of fire hydrants.

- The **Wastewater Treatment Network** is highly vulnerable to weather events, particularly precipitation. While the City's sanitary sewer system has not historically been overloaded by

increased water volumes, runoff entering the Fiddler's Lake lagoon due to intense rainfall and snowmelt impact operations of the lagoon by extending the time needed for decanting, which can affect the system's performance and effluent quality. Higher temperatures may also impact operation by altering the effluent quality and increasing treatment requirements.

- **Parks** and natural areas are highly vulnerable due to their sensitivity to a wide range of hazards occurring in the area, particularly wildfires and drought.
- **Residential Buildings, Stanton Territorial Hospital,** and **North Slave Correctional Facility** are highly vulnerable to climate hazards because they are occupied by individuals who may be disproportionately affected by climate events (e.g., seniors, young children, individuals with illnesses, addiction, and mental health concerns). This increases their sensitivity to health and safety impacts, such as smoke-related respiratory issues, heat-related illnesses, and slip-and-fall accidents in winter conditions. These concerns are likely to be exacerbated as the population continues to increase. Buildings are also sensitive to physical damage and loss of component functionality.
- **Recreational Facilities** are highly vulnerable due to their users and age. Like residential buildings and hospitals, recreational facilities are used by a large cross-section of the City's population, which may consist of individuals who may be disproportionately affected by climate events. Heritage structures (e.g., buildings, monuments, statues) are likely to be highly sensitive to degradation and damage from climate hazards due to the age of these structures.
- **Yellowknife Airport** is highly vulnerable and has been impacted by ground shifting and settlement along its runway in the past, which has been attributed to permafrost thaw. The airport is also vulnerable due to the potential impacts of weather events to operations, such as loss of visibility due to wildfire smoke and storms, slippery surfaces due to ice and snow accumulation, failure of sensitive equipment due to extreme heat, and delays due to high winds. Given the large number of users and staff, health and safety concerns would be similar to those of recreational facilities and residential buildings.
- **Power Supply** to the City is highly vulnerable due to its dependence on hydropower. Extended periods of drought and low water levels have led to reduced output from local hydro stations (e.g., Snare Hydro system), resulting in loss of power to the City and increased dependence on generators. Power disruptions are also likely to occur from damage to electrical infrastructure caused by permafrost thaw, extreme events, and high temperatures.
- The **Yellowknife Firehall** is highly vulnerable because it is an older building and is a critical emergency response hub, as it is the only firehall in Yellowknife. A 2020 Firehall Building Study[2] identified some key issues that will be addressed in future renovations, including ineffective HVAC

[2] Dillon Consulting. 2020. City of Yellowknife Firehall Building Study.

systems, ponding on asphalt close to the building, no fire alarm or sprinkler system, and insufficient space for additional staff. Stress on the emergency response resources of the fire department may increase during local extreme events and during regional disasters, when the City becomes a hub for incoming evacuees from surrounding communities. Plans for future renovation of the firehall have been approved by the City and will soon be underway.

- **Telecommunications and IT Networks** are highly vulnerable due to their importance to the City's operation and sensitivity to damage from ground shifting and extreme events (e.g., high winds). Damage to telecommunications and IT networks would result in loss of communications for residents, disruption of City operations, and a potential need for large scale maintenance.

Medium Vulnerabilities

- **Land Use** and **Cemeteries** are vulnerable due to the potential for loss of access due to localized flooding and ground instability due to permafrost thaw, as well as damage from other climate events to which open areas are exposed (e.g., wildfire interface). These shifts may impact how land can be repurposed and whether cemeteries can be accessed but may not result in damage or total loss. Following completion of the cemetery, a columbarium park has been proposed to improve land usage and provide an alternative to in-ground burials.

- **Stormwater Systems** are vulnerable, particularly due to impacts from heavy rainfall, snow accumulation, and shifts due to permafrost thaw and freeze thaw cycles. Increased development in the City has led to an increase in runoff entering drainage systems, which were designed according to historical climate rather than future projections. Spring snowmelt increases the potential for drainage systems to become overwhelmed by high water volume. Stormwater piping may also become worn and damaged from ground shifting and settlement due to permafrost thaw and freeze thaw events.

- The **Solid Waste Facility** and **City-owned Administrative/Operational Buildings** are vulnerable to physical damage, loss of functionality of components, and service disruptions due to climate events. These buildings are maintained by the City and are not occupied by highly vulnerable individuals for prolonged periods, hence medium sensitivity.

- **Commercial/Industrial Buildings** (e.g., business districts) are also vulnerable to physical damage, loss of functionality of components, and service disruptions due to climate events. These buildings are maintained by the owners and are not occupied by highly vulnerable individuals for prolonged periods, hence medium sensitivity.

Table 5 Results of the Climate Vulnerability Assessment

Asset/Archetype	Transportation Networks	Land Use	Cemetery	Stormwater Systems	Water Treatment Plant and Collection/ Distribution Network	Wastewater Treatment Network	Solid Waste Facility	Parks	Recreational Facilities and Associated Equipment	City-Owned Administrative/ Operational Buildings	Yellowknife Firehall
Sensitivity	High	Medium	Medium	Medium	High	High	Medium	High	High	Medium	High
Adaptive Capacity	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Vulnerability	High	Medium	Medium	Medium	High	High	Medium	High	High	Medium	High

Asset/Archetype	Commercial/ Industrial Buildings	Residential Buildings	Yellowknife Airport	Power Supply	Telecommunications and IT Networks	North Slave Correctional Facility	Stanton Territorial Hospital
Sensitivity	Medium	High	High	High	High	High	High
Adaptive Capacity	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Vulnerability	Medium	High	High	High	High	High	High

4 Existing/Planned Adaptation Actions

The following is a list of some of the existing climate adaptation related actions currently underway in the City identified through a literature review of City documents and engagement with City staff and stakeholders (Table 6). The list is not exhaustive but demonstrates how the City has been addressing issues surrounding climate change and overall vulnerabilities that may indirectly exacerbate climate impacts. High level considerations for further enhancing adaptation planning in the CAP in response to the vulnerabilities identified for the City are also provided in Table 6. Actions will be further developed in later stages of the climate action planning process.

Table 6 Existing City Actions Influencing Climate Adaptation and Considerations for the CAP

Existing Actions Being Implemented by the City	Considerations for the CAP
• The City has formally recognized the need for integration of climate adaptation into its departments and operations. For example, Yellowknife joined the Federation of Canadian Municipalities Climate and Asset Management Network in 2017 and noted climate change as an asset management driver in its Asset Management Roadmap. • Asset management plans are scheduled to be developed in 2026. A risk management framework is currently in development. • The City is currently updating the Community Plan. • Feasibility studies have been conducted to identify potential options and costs to replace and repair key City systems (e.g., potable water pipeline from Yellowknife River, piped sewage service network, addition of treatment cells and berms at the Fiddler's Lake lagoon). • FireSmart building practices are considered for new City developments. • A fuel break was established in 2023 to protect the City against wildfire damage. The	• Enhance enforcement of current City policies and procedures that incorporate climate-related response (e.g., use of FireSmart in new development). • Increase consideration of climate risks to individual assets and infrastructure through climate risk assessments and incorporation of past and future climate change into City projects, planning, and standards (e.g., asset management plans). • Evaluate possible engineering options for vulnerable facilities and systems (e.g., water supply systems, drainage, wastewater treatment system). • Enhance operations and maintenance of City facilities to include climate-related monitoring and response. • Evaluate climate impacts on Yellowknife's natural areas. • Conduct additional studies to identify areas prone to climate-related impacts. • Explore opportunities for restoration of degraded green spaces and fuel breaks, while maintaining defensible zones for future fire protection.

Existing Actions Being Implemented by the City	Considerations for the CAP
City is beginning to explore options for how best to manage fuelbreaks. • The City is in the process of completing condition assessments for larger municipal facilities. • The City is working with the Territory to gather data on permafrost and the impacts of permafrost thaw in the region. • Two sites are currently designated as host sites for evacuees of regional emergencies (Multiplex and Fieldhouse). • Data collection is underway to identify the City's data gaps and develop a central information repository. • The City is currently evaluating its service level standards. • The 2024 Community Emergency Plan centralizes and guides the City's emergency response planning. • An updated Hazard Identification and Risk Assessment (HIRA) is expected to be conducted for the City in 2025. A HIRA was completed for the overall Territory in 2024. • The City conducted a community risk assessment in 2022, which included risks from climate hazards (e.g., permafrost thaw, localized flooding, winter storms) to infrastructure.	• Improve food security by exploring options for increased agriculture. • Enhance capacity for emergency response and hosting evacuees when regional extreme events occur. • Explore options for post-disaster debris management. • Explore opportunities to identify population groups that are more sensitive to the impacts of climate change. • Enhance climate-related public outreach to educate the Yellowknife community on climate impacts and how individuals can work towards adaptation and mitigation.

As part of the ongoing CAP development process, Stantec also completed a literature review of documents containing information on the City's, as well as the Northwest Territories', planned and proposed climate adaptation actions. A summary of these actions is provided in Table 7. This list represents a sample of the planned climate action in the City and Territory.

Reference: Yellowknife CAP - CVA Preliminary Results

Table 7 City of Yellowknife and Government of Northwest Territories Planned/Proposed Climate Adaptation Actions

Theme	City Strategies	Northwest Territories Strategies
Buildings and Infrastructure	• Consider future infrastructure development area suitability based on ground conditions and susceptibility to permafrost degradation • Create a built environment that lowers the risk of wildfire spread to structures and key infrastructure (e.g., FireSmarting throughout all development activities) • Conduct asset condition assessments and upgrade and/or replace City facilities and deteriorating assets • Install back-up power for critical infrastructure/facilities • Restore/construct wetlands and floodplains • Ensure new infrastructure exceeds the National Building Code and the National Energy Code for New Buildings • Improve housing equity and climate resiliency of housing • Ensure climate change considerations are incorporated in municipal decision making including in asset management planning and strategy, in engineering design of buildings and infrastructure and in terms of procurement contracts • Improve maintenance programs and activity along primary road corridors • Dedicate annual funding for trail maintenance and expansion • Consider impacts of road alignments and surface covers on permafrost	• Complete flood zone and fire risk mapping for vulnerable communities • Obtain accurate climate data sets for all regions in the NWT that account for regional variability to inform new infrastructure design and risk assessments for existing infrastructure • Develop a climate projection model to use for infrastructure design and risk assessments • Understand the climate vulnerability of existing and future infrastructure • Adapt existing infrastructure to climate change impacts through regular maintenance and upgrades • Complete community infrastructure risk assessments and high-level adaptation options • Develop a plan to undertake regional terrain sensitivity and geohazard mapping and monitoring for permafrost • Continue to implement the Climate Change Adaptation Plan to protect infrastructure and maintain transportation service levels with expected increased permafrost degradation and severe weather events • Enhance existing information technology systems and add new data collection platforms across the NWT transportation system to monitor traffic, weather and the condition of our infrastructure to improve asset management and service delivery • Continue to implement the Green Light environmental strategy to uphold high standards of environmental stewardship, including implementing an environmental management plan and supporting NWT greenhouse gas reduction targets through enhancing vehicle and equipment procurement, operations, maintenance and asset management procedures

Reference: Yellowknife CAP - CVA Preliminary Results

Theme	City Strategies	Northwest Territories Strategies
Land Use and Natural Areas	• Consider the impacts of extreme weather events, wildfires, changing permafrost, gradual warming and flood/drought conditions on wildlife and marine animals in lakes, parks and natural spaces • Create shoreline protection and natural vegetation policies for land use planning • Inventory degraded green spaces and brownfield sites and develop rehabilitation and monitoring plans • Implement FireSmart aligned vegetation management and vegetation-based wildfire risk mitigation activities •	• Complete vulnerability assessments that integrate research, monitoring and traditional knowledge to develop effective adaptation measures of aquatic and terrestrial ecosystems and all species at risk • Conduct research to understand where heritage resources, such as archeological sites, are at greatest risk of impact due to coastal erosion, thawing permafrost, melting alpine ice and wildland fires • Incorporate climate change considerations into conservation network planning and the establishment of existing candidate areas as protected areas • Increase the resilience of wildlife populations to climate change by mitigating other impacts and stressors • Conduct vulnerability assessments for forest landscape areas of interest • Conduct wildlife climate change vulnerability assessments • Continue monitoring invasive and nonindigenous species and assess impacts from range shifts on wildlife • Assess cumulative impacts to fish, including climate change, as reflected in the NWT Cumulative Impact Monitoring Program Fish Blueprint • Undertake NWT Wetland Inventory Mapping
Emergency Management	• Development, implementation and annual review of a local emergency plan and other measures with respect to emergency response management by a designated emergency management organization • Regularly review and update the City of Yellowknife Community Wildfire Protection Plan (and comparable wildfire risk management documentation) • Consider opportunities to coordinate with the GNWT and neighbouring communities on wildfire mitigation and risk reduction measures in advance of wildfire seasons	• Address climate-related hazards and adaptation measures in updated community emergency plans and operations and maintenance procedures.

Reference: Yellowknife CAP - CVA Preliminary Results

Theme	City Strategies	Northwest Territories Strategies
	• Conduct a physical risk assessment to identify risks to critical City services and potential impacts of disruptions on critical services and resources, to inform continuity planning efforts • Consider the needs of vulnerable populations in all evacuation planning, response and recovery activities and implement a system to register these individuals to ensure their safety during evacuation and re-entry • Develop continuity plans for the City across all departments, which include the identification of critical City services, and the staff required to ensure the continuity of these services • Develop a detailed wildfire evacuation plan that includes roles and responsibilities, procedures, logistics processes and recovery and re-entry processes and considerations • Utilize municipal assets for extreme weather events and coordinate with other levels of government as necessary	
Community Education and Engagement	• Create a central repository of climate adaptation related information and guide the public on how to access the information • Develop educational materials for the public related to preparation and response to emergencies • Develop a strategy for managing public information before, during and after evacuations to ensure that communications to the public are clear, accessible, informative, and timely • Support the sustainable growth of urban agriculture and related activities	• Develop a central repository to share and access climate change knowledge and information • Enhance the availability of climate and environmental information by providing data, along with products such as summaries of data trends and variability, and projections of future climate • Support community and Indigenous governments in the development and implementation of adaptation plans • Support the collection, analysis or synthesis of traditional knowledge through the NWT Cumulative Impact Monitoring Program to better understand environmental trends and cumulative impacts for use in decision-making

5 Next Steps

The CVA identified climate vulnerability of the assets and archetypes of the City of Yellowknife, providing an understanding of the potential climate impacts on the City's infrastructure. The vulnerabilities and knowledge gaps identified in the assessment will be used to inform the development of adaptation measures for the City of Yellowknife CAP, with consideration of the priorities noted by staff and stakeholders during engagement sessions.

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Attachment: N/A