RED DEER
CLIMATE ADAPTATION STRATEGY

A Collaborative Cross-Departmental Plan
for Corporate Climate Resilience

FEBRUARY 2024

THE CITY OF Red Deer

REPORT PREPARED BY

All One Sky FOUNDATION

IN PARTNERSHIP WITH

Associated STRATEGIC ADVISORY SERVICES

EXECUTIVE SUMMARY

The Red Deer Climate Adaptation Strategy (the "Strategy") is a collaborative cross-departmental plan for corporate climate resilience at The City of Red Deer. The Strategy provides a roadmap for how The City can improve the climate resiliency of the organization and reduce risks to corporate assets, services, and operations. It also identifies cross-linkages between climate change impacts and key actions to adapt the organization to those impacts, and the goals, metrics and targets outlined in the 2019 Environmental Master Plan. The Strategy was collaboratively prepared by The City of Red Deer project team and steering committee, and a consulting team from All One Sky Foundation and Associated Engineering.

Red Deer's climate is changing. The following changes in our climate are already apparent in the region and are anticipated to continue with further global warming:

- Hotter summers with more extreme heat and heat waves.
- Warmer winters with fewer cold days and fewer freeze-thaw cycles over the year.
- More precipitation overall and more extreme precipitation events.
- A longer frost-free season with earlier onset of spring and a later onset of the fall season.
- More extreme weather, including large hailstorms, freezing rain, wildfires, and wildfire smoke days.
- Changing environmental conditions, including changes to streamflow patterns, water temperatures, forests and ecosystems, the prevalence of invasive species and diseases.

Climate change presents significant risks to The City with economic analysis putting the expected economic losses from the physical impacts of climate change on Red Deer at about $200 million per year by mid-century. A comprehensive climate change risk assessment was performed to prioritize climate impacts affecting six core corporate service areas: the health and safety of staff; natural assets; buildings; utilities; municipal assets; and emergency management. A total 71 consequences of climate change for these service areas were identified, of which seven risks were assessed as 'Very High', and 28 as 'High'. These risks pose an unacceptable threat to the corporation's assets, services, and operations, and were the focus of the Climate Adaptation Strategy. Very High climate risks facing The City of Red Deer include:

Wildland-Urban Interface Fire

- Potential for evacuations and displacement requiring emergency response
- Damage to power lines and potential power outage
- Damage to trees and diminished urban tree canopy
- Health and safety risks to municipal staff, including emergency response personnel

Hailstorm

- Damage to buildings and facilities (roofing, cladding, etc.) including roof-mounted equipment (electrical, air conditioning, etc.)

Invasive Species & Pests

- Damaged trees or diminished urban tree canopy from insect pests (e.g., Emerald Ash Borer)

River & Creek Flooding

- Flooding and damage to major roadways and bridges, and disruption of supply chains

The City's Corporate Climate Adaptation Strategy includes a vision and 20 key actions to improve the resilience of City assets, services, and operations to climate change.

Vision: Red Deer is taking collaborative action and building on existing initiatives to enhance the climate resilience of The City's assets, services, and operations to best serve our community.

THEME	ACTION
Bylaws & Governance	▪ Natural Areas Policy ▪ Tree Protection Bylaw ▪ Update Land Use Bylaw ▪ Source Water Protection Plan
City Administration	▪ Procurement Policy ▪ Outdoor Worker Rotations
City Operations & Projects	▪ Urban Heat Island Assessment ▪ Electrical Grid Assessment ▪ Tree Planting
Climate Resilient Natural Landscapes	▪ Green Infrastructure Guidelines ▪ Ecological Goods and Services
Disaster Resilience & Emergency Preparedness	▪ Water Shortage Response Plan ▪ Neighbourhood Resilience Program ▪ Wildfire Management Program
Enhanced Stormwater Management	▪ Adopt a Storm Drain Program ▪ Stormwater Master Plan Update ▪ Stormwater Utility
Sustainable Buildings & Assets	▪ Sustainable Building Policy ▪ Climate Lens Tool ▪ Asset Management Plan

To support ongoing implementation of the Strategy it is recommended that:

- The City climate adaptation project team and steering committee should be maintained and continue to meet regularly;
- funding should be committed annually to support implementation of select actions;
- the Strategy should be updated at least every 5-10 years to ensure it remains effective and relevant; and
- now that a Strategy for the corporation has been completed, The City should develop a community-wide climate adaptation plan considering the effects of climate change across all aspects of Red Deer, including impacts affecting: the health and wellbeing or residents, including vulnerable populations; the vibrancy or attractiveness of the city; private property, local businesses; and the natural environment including impacts to local ecosystems and wildlife.

1 Recommendations were suggested by All One Sky Foundation.

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ACKNOWLEDGMENTS

This Climate Adaptation Strategy (the "Strategy") was collaboratively prepared by The City of Red Deer and the consulting team of All One Sky Foundation and Associated Engineering. A City project team and steering committee were instrumental in the development of the Strategy; meeting regularly, contributing time and resources, and participating throughout the planning process by providing essential local knowledge, advice, and direction to ensure project success. Many other staff members also participated by reviewing and providing input on draft documents.

CITY OF RED DEER DEPARTMENTS

Safe & Healthy Communities
Parks & Public Works
Engineering Services
Land & Economic Development
Utilities
City Planning & Growth
Emergency Services
Legal & Legislative Services
CSV Business Excellence
Transit & Fleet

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Funding for this project was provided by the Municipal Climate Change Action Centre's Climate Resilience Capacity Building Program. The Municipal Climate Change Action Centre is a partnership of Alberta Municipalities, Rural Municipalities of Alberta, and the Government of Alberta.

Municipal Climate Change Action Centre

Alberta

LAND ACKNOWLEDGMENT

The City of Red Deer acknowledges the Indigenous traditional territories represented by Treaty 6 and Treaty 7 as the land The City is situated on. This land is also acknowledged by The City as a historic Métis gathering site. The goal of The City of Red Deer is to work together with Indigenous peoples in building a welcoming and inclusive community.

1 PROJECT BACKGROUND AND SCOPE

1.1 BACKGROUND

A strong foundation for addressing climate change has been laid out by The City of Red Deer ("The City") in the past; however, there is still a need to strengthen past efforts to better prepare the organization and community for current and future risks. To these ends, The City contracted the services of All One Sky Foundation to assist with the development of Part Two of the Climate Change Adaptation Plan Part One (completed in 2014). Building from Part One, this project will help The City to better understand where the organization is most vulnerable to the physical risks of climate change, and to identify corporate actions that can be taken to adapt to these risks.

This project is intended to address the 2019 Environmental Master Plan (EMP), Action 19 to *"Advance Red Deer's leadership in addressing climate change through comprehensive adaptation and mitigation planning"*.

"Climate change planning is a bit like an insurance policy, in that we are seeking to be prepared. We really hope that we are not impacted but it makes sense to have a policy in place, just in case."

- Climate Change Adaptation Plan - City of Red Deer Part One, 2014

1.2 PROJECT GOAL

The goal of this project was to prioritize the physical risks of climate change facing The City of Red Deer and to develop a robust Climate Adaptation Plan (the "Strategy"). The Strategy provides a roadmap for how The City can improve the climate resiliency of the organization and reduce risks to corporate assets, services, and operations. An over-arching project goal was to develop a collaborative cross-departmental plan to enhance resilience.

An additional project goal was to identify the cross-linkages between climate change impacts and the themes, goals, metrics, and targets outlined in the EMP (see Section 6).

1.3 PROJECT SCOPE

The climate risk assessment is based on projected climate conditions for Red Deer under a "high emissions scenario" whereby global greenhouse gas emissions and global warming continue to increase at historic rates to the end of the century[2]. The climate risk assessment considers potential impacts anticipated for Red Deer in the 2030s – i.e., anticipated climate conditions corresponding to the 30-year average centered on 2035 (2021-2050)[3].

The project was focused on direct climate-related impacts affecting The City's assets, services, and operations. The climate risk assessment and adaptation planning process involved a collaborative cross-departmental effort. While each department contributed to the process, it was not intended to generate risks assessments and adaptation plans for individual City departments.

The assessment was structured according to specific categories or themes of impacts. The following six impact-consequence categories (Table 1) were considered:

Table 1: Climate Impact Consequence Categories

	The health, safety, productivity, and wellbeing of municipal staff (HS)
	Natural assets (NA), including the urban forest, parks, and natural areas such as wetlands, creeks, grasslands, and the soil.
	City-owned buildings, facilities, and properties (PR), including impacts to buildings systems and components: such as heating, ventilation, and air conditioning (HVAC), plumbing, electrical, communications, and the building envelop.
	Critical municipal utilities and services (UC), including power, water supply, wastewater, waste, stormwater infrastructure, major roadways, and City-owned information technology systems.
	Non-critical municipal assets and services (AS), including secondary roads, trails, sidewalks, the municipal fleet, sports fields, parks and recreation assets and services, equipment, City-owned community garden plots, skating rinks, etc.
	Emergency management (EM), including potential for public health emergency response, community evacuations, displacement, or need to shelter-in-place

The climate risk assessment considered both chronic (slow onset) and acute (rapid onset) climate-related impacts and their potential consequences. The former include, for example, gradual increases in average seasonal temperatures and changing streamflow patterns; the latter include, for example, storms and heat waves.

The climate risk assessment and adaptation strategy consider existing and planned measures in place to manage climate change impacts (e.g., actions included in the EMP). The goal was to identify the incremental impacts of climate change by overlaying the projected climate of the 2030s onto the Red Deer of today.

2 This scenario is consistent with the representative concentration pathway (RCP) 8.5, whereby global mean temperatures are projected to reach 4.3◦C [likely range of 3.2- 5.4◦C] above pre-industrial levels by 2081-2100.

3 The 2030s timeframe was chosen as it aligns with the timeframe of other City strategic plans.

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CLIMATE PROJECTIONS FOR RED DEER AREA

Earth's climate is changing rapidly with global mean surface temperatures already more than 1°C above pre-industrial levels[4]. Moreover, various observations, experiments, and studies have confirmed that it is extremely likely that greenhouse gas (GHGs) emissions resulting from human activities have been the dominant cause of the observed global warming since the mid-20th century[5]. Despite current efforts to reduce GHG levels in the atmosphere, climate change is still occurring, compounding existing pressures and giving rise to new risks for municipalities like Red Deer across the country. Consequently, there is a growing need to implement strategies to adapt to changing climate conditions and the physical risks these changes pose to communities.

Understanding how the local climate is projected to change relative to the recent past is a precursor to identifying and prioritizing risks for adaptation actions. In summary, the following changes in climate are projected for the Red Deer area:

HOTTER SUMMERS: more extreme heat, heat waves, and increased demand for space cooling

WARMER WINTERS: fewer cold days, frost days, and less demand for space heating

MORE TOTAL PRECIPITATION: higher total precipitation in most seasons (except for summer), and more extreme precipitation events

CHANGING SEASONS: earlier onset of spring and a later onset of the fall season, resulting in a longer growing season and frost-free season

MORE EXTREME WEATHER: large hail and freezing rain events, wildfires, and wildfire smoke days

CHANGING ENVIRONMENTAL CONDITIONS: streamflow patterns, water temperatures, forests and other ecosystems, more invasive species and pests, and the potential for new vector-borne diseases

The Climate Projections for Red Deer report presents historic climate trends and future projections for The City of Red Deer. Information is provided for both changes in average climate conditions and weather and climate extremes, as well as associated environmental changes.

Table 2: Climate Projections for Red Deer

Climate Variable	Historic	2030's	2060's
Mean Temperature (Summer) (0°C)	15.5	17.7	19.6
Days Above 30°C	5	15	29
Hottest Day (°C)	31.4	34.2	36.2
Mean Temperature (Winter) (°C)	-10.3	-8.3	-6.3
Days Below -15°C	57	43	31
Coldest Day (°C)	-36	-32.8	-29.8
Frost Free Season (Days)	124	143	162
Frost Days (Temperature Below 0°C)	200	183	163
Mean Annual Precipitation (Mm)	447	454	469
Summer Precipitation (Mm)	231	221	217
Spring precipitation (mm)	98	109	119

4 Bush, E. and Lemmen, D.S., (eds.), 2019: Canada's Changing Climate Report; Government of Canada, Ottawa, ON., 444 p.

5 Ibid.

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CLIMATE RISK ASSESSMENT

The climate risk assessment followed guidelines and best practices for such assessments, notably the Climate Resilience Express – Community Climate Adaptation Planning Guide developed by All One Sky Foundation, which is based on the International Organization for Standardization (ISO) guideline 14092 – Climate adaptation planning for local governments and communities and the Inter-government Panel on Climate Change (IPCC) concept of climate risk. The climate risk assessment is intended to help senior leadership better understand the case for allocating resources to the climate adaptation and risk management actions outlined in the Climate Adaptation Strategy (Section 5).

This section describes the process that was followed and the results of the climate risk assessment for The City of Red Deer. The process involved five key steps:

1) Defining climate impact scenarios.
2) Developing scales to assess the likelihood and consequences of the impact scenarios.
3) Assessing the likelihood of each climate impact scenario occurring, both historically and in the future, in the Red Deer area.
4) Assessing the consequences of each climate impact scenario, should it occur.
5) Evaluating the results to determine priorities for action planning.

3.1 DEFINE CLIMATE IMPACT SCENARIOS

The starting point for a climate risk assessment is a set of impact scenarios that characterize the cause-and-effect relationship, or impact chain, between climate changes, impacts, and the potential consequences of those impacts. In addition to considering local exposure to climate hazards, the impact scenarios also considered the existing vulnerability of City assets, services, and operations. Vulnerability to a given climate impact influences the magnitude or severity of impacts and consequences.

Table 3 provides an overview of the climate impact scenarios identified for consideration in the climate risk assessment. The scenarios were drafted through ongoing dialogue with The City project team and steering committee and are based on:

- Results of the Climate Change Adaptation Plan Part One (completed in 2014).
- Projections of future climate change in the Red Deer area.
- Data and information gathered through a review of local documents, plans, policies, and bylaws.
- A review of climate impact research and literature.
- The consulting team's experience assessing climate risks and vulnerabilities in other jurisdictions across Canada.

The impact scenarios were reviewed and updated by the project team and steering committee to account for historical occurrences of climate-related events in the region, and risk mitigation measures implemented through 2023. In total, 18 climate impact scenarios were defined.

The defined climate impact scenarios are summarized in Appendix A. Only consequences that have potentially significant impacts and pose a material threat to City assets, services or operations were considered.

Table 3: Summary of Climate Impact Scenarios and their thresholds considered in the Climate Risk Assessment

HEAT WAVE Heat waves per year (daily maximum temperature> 29°C and daily minimum temperature >14°C)	**OVERHEATING INFRASTRUCTURE** Very hot days (>30°C) per year	**REDUCED NATURAL WATER QUALITY** Average summer maximum temperature
REDUCED OUTDOOR RECREATION The average number of non-winter days above -5°C	**INCREASED SPACE COOLING** Cooling Degree Days Index	**FREEZING PRECIPITATION** Ice depth 1:20 year ice-thickness design standard
HAILSTORM A "very large hail day" with hailstones > 4cm in diameter	**HIGH WINDS** Wind gusts of 90km/h of more	**DROUGHT** The 3-month Summer (June-August) SPEI moisture index[6]
TORNADO EF2-EF3 Tornado event with windspeeds between 178km/h to 265km/h	**INVASIVE SPECIES & PESTS** Length of the frost-free season	**SEVERE MULTI-YEAR DROUGHT** The 12-month SPEI moisture index
INCREASED WASTE Annual total precipitation	**OVERLAND FLOODING** A 1:100-year 24-hour rainfall event	**WILDLAND-URBAN INTERFACE FIRE** The average summer maximum temperature (90th percentile)
RIVER & CREEK FLOODING The 1:100-year flood peak discharge on the Red Deer River below Waskasoo Creek	**WILDFIRE SMOKE** Number of days where visibility is below 2 km due to wildfire smoke	**SHIFTING NATURAL ECOREGIONS** A shift from Dry Mixedwood Forest to Mixed Grassland ecosystems

6 The Standardized Precipitation Evapotranspiration Index (SPEI) is a water balance index based on the monthly difference between precipitation and potential evapotranspiration. The SPEI defines the value of -1.5 as 'Severely dry'

3.2 DEVELOP ASSESSMENT SCALES

A semi-quantitative approach was used to assess climate risks which involved assigning categorical (very low to very high) and numerical (1 to 5) values to the likelihood and consequence of each climate impact scenario. To achieve this, tailored rating scales for likelihood and consequence were developed which account for The City's priorities and objectives. The assessment scales were reviewed and agreed to by The City's project team and steering committee. Figure 1 provides Likelihood Scale and Figure 2 shows the scale used to assess the severity of the identified consequences—aligned with the climate impact consequence categories in Table 1.

Figure 1: Likelihood Scale

SCORE	DESCRIPTOR	LIKELIHOOD / PROBABILITY
1	Rare	Impact scenario is expected to happen less than once every 100 years (Annual chance < 1% in the 2050's)
2	Unlikely	Impact scenario is expected to happen about once every 51-100 year (1% ⇠ annual chance < 2% in the 2050's)
3	Possible	Impact scenario is expected to happen about once every 11-50 years (2% ⇠ annual chance < 10% in the 2050's)
4	Likely	Impact scenario is expected to happen about once every 3-10 years (10% ⇠ annual chance < 50% in the 2050's)
5	Almost Certain	Impact scenario is expected to happen once every two years or more frequently (Annual chance ⇢ 50% in the 2050's)

Figure 2: Scale for Rating the Consequences of Climate Risks[7]

	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
Health, Safety, Productivity and Wellbeing of Staff (HS)	▪ Negligible impact		▪ Some injuries or illnesses ▪ Potential absenteeism / reductions in workforce productivity		▪ Many serious injuries or illnesses, some fatalities ▪ Significant absenteeism / reductions in workforce productivity
Natural Assets (NA)	▪ Minimal or no impact to natural assets or additional costs		▪ Could cause localized but reversible damage or impacts to trees, green areas, or other managed natural assets ▪ Additional costs may exceed budget		▪ Could cause severe and irreversible damage or impacts to trees, green areas, or other natural assets; ▪ Significant additional costs exceeding budget
Buildings, Facilities, and Properties (PR)	▪ Not likely to result in damage to property or additional costs		▪ Localized moderate accelerated deterioration or damage to buildings, facilities, or property ▪ Additional costs may exceed budget		▪ Widespread severe accelerated deterioration or damage to buildings, facilities, or property ▪ Significant additional costs exceeding budget
Municipal Utilities and Critical Services (UC)	▪ Not likely to result in impacts to municipal utilities or critical services, or operating revenues/expenses		▪ Localized moderate damage to City owned utilities ▪ Temporary interruption (12-24 hours) and moderate lost revenues and/or moderate additional costs which may exceed budget		▪ Widespread and severe damage to City owned utilities; ▪ Long-term interruption (> 72 hours) and significant lost revenues and/or significant additional costs that exceed operating budget and/or financial reserves
Municipal Assets and (non-critical) Services (AS)	▪ Not likely to result in impacts to municipal assets or critical services, or operating revenues/expenses		▪ Localized moderate damage to municipal assets and (non-critical) services ▪ Temporary (12-24 hours) localized interruption and/or moderate lost revenues and/or additional costs which may exceed budget		▪ Widespread and severe damage to municipal assets and (non-critical) services ▪ Long-term (> 72 hours) widespread interruption and/or significant lost revenues and /or additional costs that exceed operating budget and/or financial reserves
Emergency Management (EM)	▪ Not likely to result in implications for emergency management		▪ Moderate public health emergency, some temporary evacuations, or displacements, or need to shelter-in-place; ▪ Response costs may exceed budget		▪ Widespread and severe public health emergency, many evacuations, possible permanent displacements, and need to shelter-in-place; ▪ Response costs far exceed operating budget

7 Note: the descriptions for 2 (Low) and 4 (High) have been left blank intentionally.

3.3 LIKELIHOOD ASSESSMENT

The goal of the likelihood assessment was to determine the annual probability of each climate impact scenario occurring, both historically and in the future as a result of climate change. The likelihood assessment is specific to the thresholds defined for each climate impact scenario identified in Appendix A.

There are generally five methods that can be used to assess the likelihood of a scenario occurring. These include, from highest to lowest priority:

1. Climate data analysis.
2. Historic event occurrences.
3. Existing research.
4. Local sources.
5. Professional judgment.

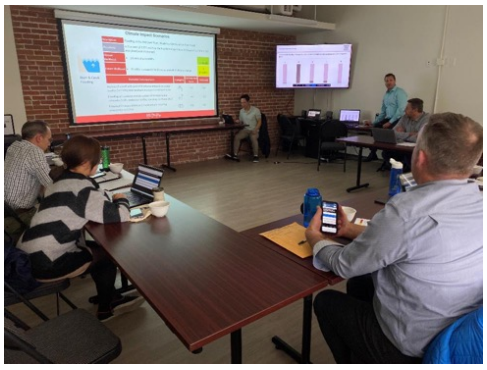
Each method can be employed on its own or in tandem with others. Where possible, actual weather and climate data from the Red Deer area was used to quantitatively determine the likelihood of each impact scenario, as an annual probability – method 1. The estimated probabilities are then transcribed onto a 1-5 score using the likelihood scale (Figure 1). Results of the likelihood assessment are provided in the climate risk assessment results in Appendix B (Table 6) and in the detailed climate impact scenario descriptions provided in Appendix A.

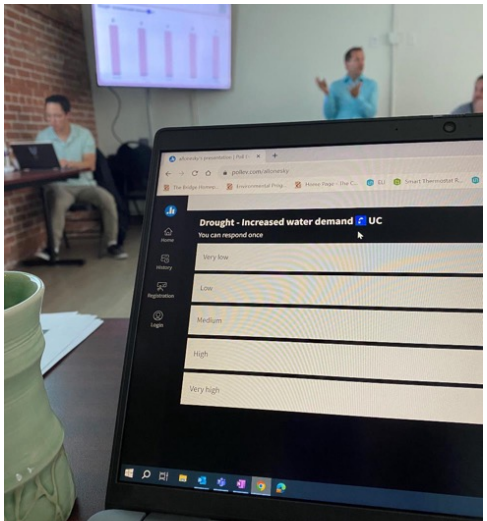
The likelihood assessment was completed by the consulting team and validated with The City of Red Deer project team and steering committee.

3.4 CONSEQUENCE ASSESSMENT

The goal of the consequence assessment was to determine the severity of potential consequences of each climate impact scenario for The City's assets, services, and operations. The consequence assessment was completed by staff and stakeholders at The City of Red Deer, those who are best positioned to understand how changes in the climate may affect The City, through a facilitated workshop that occurred on September 28, 2023. At this session, participants assigned categorical and numerical (1 to 5) values to the potential consequences of each climate impact scenario (workshop photos at Figure 3).
Results of the consequence assessment are provided in Appendix A: Detailed Climate Impact Scenarios and in Appendix B: Detailed Climate Risk Assessment Results.

Figure 3: Climate Risk Assessment Workshop





3.5 CLIMATE RISK EVALUATION

The results of the risk assessment were used to produce a climate risk matrix (or "heat map") for each of the six consequence categories (Figure 11 through Figure 16 in Appendix B), and a rank-ordered risk-rating spectrum (Table 6) in Appendix B, which delineates between risks that pose an unacceptable threat to The City and those that do not. Impact scenarios with higher consequence and higher likelihood of occurrence represent larger risks for The City.

The risk matrices and risk-rating spectrum were evaluated to verify the results and to identify priorities to take forward to the adaptation planning phase. The evaluation allowed City staff to review the relative ranking of the impact scenarios and make well-reasoned arguments to adjust their scoring and ranking if judged—when viewed collectively—to have been either over or under-estimated in comparison to one another during the risk assessment step. The evaluation process was a collaborative process involving input from City staff across all departments.

Once the evaluation process was complete, the next step was to determine which climate impact consequences would be considered for climate adaptation action planning. Table 4 provides the decision framework that was used to prioritize impacts for action planning, based on their relative risk level.

Table 4: Decision Criteria for Action Planning

COLOURED CELL IN RISK MATRIX	RECOMMENDATION
Very high priority	Adaptation actions should be developed in the near-term to reduce risks or take advantage of opportunities.
High priority	Adaptation actions should be developed in the near- medium-term, to reduce risks or take advantage of opportunities.
Medium Priority	Adaptation actions may be developed, particularly where low-cost options are available that provide other social, economic, or environmental benefits.
Low Priority	No action required at this time beyond monitoring and consideration as part of regular reviews.
Very low priority	No action required at this time beyond monitoring and consideration as part of regular reviews.

3.6 CLIMATE RISK ASSESSMENT RESULTS

Table 6 provides a detailed summary of the climate risk assessment results. It provides the following information:

- The climate impact, corresponding with one of the 18 climate impact scenarios in Appendix A. Each climate impact is defined using a unique threshold and likelihood score. The tables below summarize the impacts for each consequence category (Table 1).
- The specific consequence of the climate impact, which is linked to one of the six impact categories, is the basis of the consequence score.
- The likelihood (score) of the climate impact scenario occurring in the future, based on the scale at Figure 1.
- The consequence score, as determined at the climate risk assessment workshop held on September 28, 2023, and the subsequent evaluation process to verify the results.
- The risk level corresponding to the placement of the climate-related consequence within the climate risk matrices (Figure 11 through Figure 16) based on the combination of likelihood and consequence scores.
- The rank order of the consequence relative to all other consequences—from highest risk to lowest risk. The rank order was determined first by the placement of the scenario within the climate risk matrix (Very high, High, etc.). Second, risks within the same risk level (e.g., high) are ranked by the numerical risk score (the product of the likelihood and consequence scores); climate impact-consequences with higher risk scores are ranked higher.

Across all 71 identified impact-consequences:

7 climate risk identified as **Very High**
28 climate risks identified as **High**
25 climate risks identified as **Moderate**
11 climate risks identified as **Low**

Table 4: Summary of impacts from climate risk assessment results

	Low	Moderate	High	Very High
Health, Safety, Productivity and Wellbeing of Staff (HS)	Health and safety risks from freezing rain (64)	Health and safety risks from tornado (59)	Negative health impacts from heat waves (19) Negative health impacts from wildfire smoke (11) Health and safety risks from high winds (12)	Health and safety risks from wildfire (6)
Natural Assets (NA)	Impacts to terrestrial and aquatic health from shifting ecoregions (66)	Damage to trees from tornado (58) Drying out of trees and green areas from drought (45) Changing suitability of tree species (52) Overland flooding impacts to parks and green areas (54)	Damage to trees from freezing rain (29) River flooding impacts to parks and green areas (37) Damage to trees from high winds (9) Heat stress on trees (10)	Health and safety risks from wildfire (6) Damage to trees from wildfire (3) Damage to trees from invasive pests (2)
Buildings, Facilities, and Properties (PR)	Overland flooding of buildings (63)	Damage to buildings from freezing rain (50) Damage to buildings from high winds (41)	Damage to buildings from tornado (35) Damage to buildings from river flooding (25) Increased space cooling (16) Damage to buildings from wildfire (20) Accelerated degradation of buildings from heat (14) Impacts to building filtration (HVAC) systems from smoke (18)	Damage to buildings from hail (5)
Municipal Utilities and Critical Services (UC)	Increased turbidity from overland flooding (water quality) (67) Increased weight of waste from precipitation (61)	Flooding damage to critical infrastructure (46) Freezing rain damage to power lines (47) Increased water demand from drought (48) Increased turbidity from river flooding (water quality) (49 Reduced efficiency of power lines from heat (39) Increased surface water temperatures, degradation of water quality (38)	Tornado damage to power lines (33) Tornado damage to water and wastewater infrastructure (34) Loss of water supply from severe drought (30) Overland flooding damage to underground critical infrastructure (21) Flooding of roads from hail (blocked catch basins) (28) Wildfire damage to water and wastewater infrastructure (22) Wildfire degradation of surface water quality (23) Invasive weeds impact stormwater management system (8) High wind damage to power lines (13)	River flooding damage to critical infrastructure (7) Wildfire damage to power lines (4)
Municipal Assets and (non-critical) Services (AS)	River flooding of transportation networks (65) Drying out of sports fields and landscaped areas from drought (68) Overland flooding damage to sports fields and landscaped areas (69) River flooding damage to sports fields and landscaped areas (71)	Asset damage from tornado (60) Hail damage to vehicles and outdoor equipment (53) Damaged to landscaped areas from wildfire (56) Reduced winter recreation (57) Increased maintenance of landscaped areas from weeds (36) Accelerated degradation of roads and sidewalks from hotter summers (40) Asset damage from high winds (44) Heat stress on sports and manicured spaces from hotter summers (55)	Overland flooding damage to roadways and transportation disruption (26) Increased road and sidewalk maintenance from freezing rain (27) Reduced participation in summer recreation from heat waves (24)	
Emergency Management (EM)	Evacuations from river flooding (62) Evacuations from high winds (70)		Evacuations from tornado (32) Drought and water shortage emergency (31) Heat wave health emergency (15) Wildfire smoke health emergency (17)	Evacuations from wildfire (1)

4

COST OF INACTION AND INVESTING IN CLIMATE ADAPTATION

Municipalities like Red Deer are facing an array of economic risks emanating from the changing climate. As discussed above, climate change is linked to rising temperatures, changing precipitation patterns, more volatile weather, and an increase in the frequency and intensity of extreme weather events, like wildfires, drought, heatwaves, and storms. These changes have and will continue to damage buildings and infrastructure, disturb ecosystems, threaten public health and safety, and disrupt services, supply chains and economic activity. Protecting the fiscal health and economic competitiveness of Red Deer, and positioning it for a thriving future, will increasingly depend on the ability of The City to assess climate-related economic risks in ways that can improve decision-making to support short-term budgeting and longer-term capital and strategic planning.

4.1 WHAT ARE THE "COSTS-OF-INACTION"?

The economic costs of climate change assuming that the existing policy regime (i.e., the status quo) is kept in place and no new policies and measures are introduced are commonly known as the "costs-of-inaction"[8].

In support of the case for climate action in Red Deer, estimates of the costs-of-inaction were developed to:

- Monetize the overall scale of the challenge presented by the physical risks of climate change and convey the urgency for ramping up adaptation efforts.
- Highlight the distribution of economic impacts across climate-sensitive systems in Red Deer to identify systems incurring the largest losses.
- Guide levels of investment in adaptation to achieve desired risk reductions and associated benefits.

Information on the costs-of-inaction can also be used to support: the prioritization of climate-related threats and opportunities as part of a climate risk assessment; and the selection, timing, and sequencing of specific adaptation options, during development of implementation plans.

The estimated costs-of-inactions for Red Deer are presented below. They capture aggregate climate-related economic risks to both The City and the wider community.

8 OECD, 2008: Costs of Inaction on Key Environmental Challenges, Organization for Economic Cooperation and Development, Paris, France, 213 pp; or Ackerman, F. and Stanton, E., 2006: Climate Change – the costs of inaction. Report to Friends of the Earth England, Wales and Northern Ireland, Global Development and Environment Institute, Tufts University, Medford, Massachusetts, 38 pp.

4.2 COSTS-OF-INACTION FOR RED DEER

Under a *high* future climate scenario[9], expected economic losses from the physical impacts of climate change on climate-sensitive systems in Red Deer—such as roads, buildings, public health, natural assets—are estimated to amount to $201M (million) per year (in 2021 dollars) by mid-century (2055). By 2085, expected losses are estimated to total $484M per year; this represents a seven-fold increase in annual losses compared to estimated costs for 2025[10].

The scale and direction of projected economic losses for Red Deer vary across climate-sensitive systems, as shown in Table 5. The largest source of future losses for Red Deer are related to:

- Impacts on residential and non-residential buildings structures and function due to exposure to more frequent and intense storms and floods, though damage costs are partially offset by reduced energy costs.
- Damage and disruption to natural assets and living systems, such as urban trees, greenspace, and ecosystem services.
- Adverse public health impacts, including illnesses, anxiety and stress, hospitalizations, and premature deaths resulting from climate-driven deteriorations in air quality, extreme heat, and other extreme weather.

While the results suggest agriculture will benefit from climate change, the estimated benefits should be viewed as overly optimistic due other challenges presented by climate change, including water availability and increased risk of pests and invasive species.

9 A high future climate scenario is one in which heat-trapping emissions continue to increase at current rates through the end of the century, causing more severe warming. In terms of physical impacts, it describes a worst-case scenario. This is the same climate scenario used for the risk assessment.

10 Economic losses by 2025 are estimated to amount to $74M (million) per year.

Table 5: Scale and direction of projected economic losses (2021 dollars) across climate-sensitive systems in Red Deer under a high climate scenario[11]

SYSTEM	PROJECTED LOSSES
	Losses of **$101M** (2050s) to **$242M** (2080s) annually from public health impacts caused by higher temperatures and periods of poor air quality (e.g., from wildfire smoke).
	Losses of **$6M** (2050s) to **$18M** (2080s) annually from reduced labour supply and worker productivity due to higher temperatures.
	Losses of **$9M** (2050s) to **$26M** (2080s) annually from damages to transportation infrastructure and associated delays in the movement of people and freight due to high temperatures and heavy precipitation events.
	Losses of **$12M** (2050s) to **$24M** (2080s) annually from damages to electricity transmission and distribution (T&D) infrastructure due to a range of climate-related hazards.
	Losses of **$15M** (2050s) to **$44M** (2080s) annually from damages to water, wastewater, and drainage infrastructure due to river and stormwater flooding, drought conditions, extreme cold, and freeze-thaw cycles.
	Losses of **$9M** (2050s) to **$19M** (2080s) annually from damages to building structures and contents resulting from riverine and stormwater flooding.
	Losses of **$36M** (2050s) to **$85M** (2080s) annually from damages to building structures resulting from increased storms (e.g., high winds, hail) and freezing precipitation.
	Savings of **$13M** (2050s) to **$25M** (2080s) annually from a net decrease in building energy costs (increasing cooling costs are more than offset by declining heating costs) due to rising seasonal temperatures.
	Losses of **$28M** (2050s) to **$53M** (2080s) annually from damage to natural assets and lost ecosystem services from high temperatures, drought, and increased storms.
	Increases in farmland values of **$0.7M** (2050s) to **$0.3M** (2080s) annually from rising agricultural productivity due to seasonal warming, a longer growing season, and increases in total annual precipitation.

The above projected losses in Red Deer will have wider macroeconomic implications for the regional and provincial economy. By 2055, for example, employment income and Gross Domestic Product (GDP) are estimated to reduce by $53M and $90M per year, respectively. Estimated losses rise to $138M (employment income) and $226 (GDP) per year by 2085. Tax revenues are also adversely affected.

The magnitude of expected losses, which are already being incurred and expected to rise rapidly in the near term, suggests an urgency to accelerate the allocation of resources to adapt to anticipated climate change impacts.

11 Total economic costs in the 2050s and 2080s are given by the sum of losses (e.g., for the 2050s, $101M + $6M + $9M + $12M + $15M + $9M + $36M + $28M) less the building energy cost savings ($13M) less the increase in farmland values ($0.7M). Note that these sums may not equal the totals reported in the main text due to rounding.

4.3 INVESTING IN CLIMATE ADAPTATION

Adapting municipalities for projected climate change and associated physical risks has been conservatively estimated by the Insurance Bureau of Canada (IBC) and the Federation of Canadian Municipalities (FCM) to require an annual investment equivalent to 0.26% of GDP. Over the next 10 years (2025-2035), this equates to a total investment of about $240M for Red Deer, shared between households, businesses, and all levels of government (per capita, this level of investment amounts to approximately $205 per resident per year for 10-years). Fortunately, evidence from other jurisdictions shows that the majority of strategies and actions to mitigate climate-related physical risks provide strong returns on investment: up to $12 in benefits (avoided costs and co-benefits) per $1 dollar invested.

To shed light on the potential returns from different levels of investment in climate adaptation in Red Deer, different investment scenarios were examined. The results show that a shared investment roughly double that suggested by the IBC and FCM (i.e., $480M instead of $240M over the next 10 years) is needed to reduce the projected costs of climate change for Red Deer under the high climate change scenario by at least 70%. This level of investment by households, businesses, and all levels of government will avoid $1.0B-$2.7B in projected losses in Red Deer over the next 35-40 years. The analysis of adaptation investment scenarios also suggests that successful international efforts to limit (mitigate) climate change will reduce adaptation costs for households, businesses, and government in Red Deer.

5
CLIMATE ADAPTATION STRATEGY

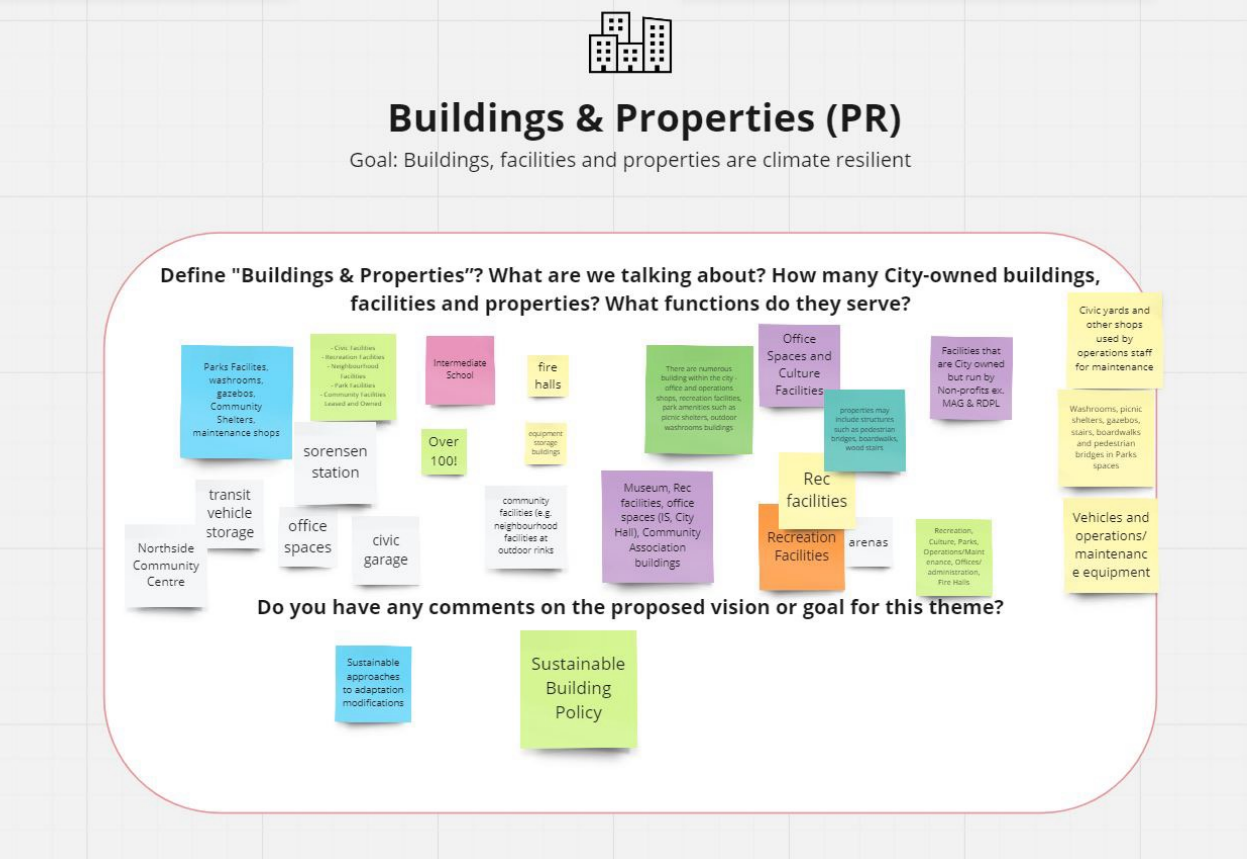
Informed by the results of the climate risk assessment, the next step in the process was to develop a climate adaptation plan (the "Strategy") to address priority climate change risks facing The City's assets, services, and operations.

This involved a series of facilitated climate adaptation action planning sessions with City staff. At these sessions, staff from across all City departments worked collaboratively to brainstorm appropriate actions to better manage the priority climate risks facing The City.

Six virtual sessions were held between December 6 and December 15, 2023; each session focused on one of the climate impact-consequence category (see Table 1).

Results of the climate adaptation action planning sessions were compiled into a list of concrete and potentially feasible actions to adapt The City for future climate change. The list was refined through a collaborative process involving input from City staff across all departments. A total of 62 potential climate adaptation actions were identified.

Figure 4. Screen capture of online collaborative whiteboard software, Miro, that was used during the action planning sessions. Photo taken December 6, 2023.



The refined list of actions was evaluated using a simplified, multi-criteria, cost-benefit analysis. Due to human resource and financial constraints, as well as competing priorities, it is unlikely that The City could implement all identified adaptation actions. Consequently, it was necessary to evaluate and prioritize actions to determine those that are expected to perform best with respect to key decision criteria. The decision criteria and results of the action evaluation are provided in Appendix C: Climate Adaptation Action Prioritization.

The City's Corporate Climate Adaptation Strategy is outlined below.

Vision: Red Deer is taking collaborative action and building on existing initiatives to enhance the climate resilience of The City's assets, services, and operations to best serve our community.

To achieve this vision, the Strategy has six goals, one for each theme:

Health & Safety (HS)	Natural Assets (NA)	Buildings, Facilities, and Properties (PR)	Municipal Utilities & Critical Services (UC)	Municipal Assets and (non-critical) Services (AS)	Emergency Management (EM)
					
Red deer staff enjoy a safe and healthy work environment	Red deer's natural assets are protected from climate impacts	Buildings, facilities, and properties are climate resilient	Critical municipal utilities and services are safe, efficient, and reliable	Municipal assets and services are climate resilient	Emergency resources are prepared to respond and recover from climate-related events

To achieve these six goals, the Strategy outlines **20 actions** for The City under **seven themes**:

THEME	ACTION
Bylaws & Governance	▪ Natural Areas Policy ▪ Tree Protection Bylaw ▪ Update Land Use Bylaw ▪ Source Water Protection Plan
City Administration	▪ Procurement Policy ▪ Outdoor Worker Rotations
City Operations & Projects	▪ Urban Heat Island Assessment ▪ Electrical Grid Assessment ▪ Tree Planting
Climate Resilient Natural Landscapes	▪ Green Infrastructure Guidelines ▪ Ecological Goods and Services
Disaster Resilience & Emergency Preparedness	▪ Water Shortage Response Plan ▪ Neighbourhood Resilience Program ▪ Wildfire Management Program
Enhanced Stormwater Management	▪ Adopt a Storm Drain Program ▪ Stormwater Master Plan Update ▪ Stormwater Utility
Sustainable Buildings & Assets	▪ Sustainable Building Policy ▪ Climate Lens Tool ▪ Asset Management Plan

Each action is summarized below, by theme, and includes the following details:

The climate **risks** that the action addresses:

The priority (Very High and High) **risk(s)** that the action addresses, with reference to the 'Rank' of the risk within the climate risk assessment results in Table 6 in Appendix B.

The climate adaptation **goal** that the action seeks to achieve:

	Red Deer staff enjoy a safe and healthy work environment
	Red Deer's natural assets are protected from climate impacts
	Buildings, facilities, and properties are climate resilient
	Critical municipal utilities and services are safe, efficient, and reliable
	Municipal assets and services are climate resilient
	Emergency resources are prepared to respond and recover from climate-related events

The **timeframe** for recommended implementation of the action:

Short term	Implemented in 1-3 years
Mid term	Implemented in 3-5 years
Long term	Implemented in 5+ years

The estimated total **cost** to implement the action[12]:

$	Less than $10,000
$$	$10,000 to $74,999
$$$	$75,000 to $249,999
$$$$	Greater than $250,000

12 Note that some actions have annual recurring (operating) costs associated with implementation. In these cases, the estimated cost is based on an assumed 1-year of implementation. Actions with annual recurring costs are denoted with an asterisk (*) in the tables below.

5.1 BYLAWS & GOVERNANCE

Natural Areas Policy

DESCRIPTION	RISKS[13]	GOAL	TIMEFRAME	COST
Revise the Natural Areas Policy to consider future climate changes, impacts and climate adaptation measures.	2, 3, 9, 10		Short term	$

Tree Protection Bylaw

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Develop a Tree Protection Bylaw or Policy that includes items around tree retention, valuation, and replacement.	2, 3, 9, 10, 29		Short term	$

Update Land Use Bylaw

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Update the Land Use Bylaw with climate resilience requirements for new development, for example increased stormwater absorption, natural areas protection, and tree coverage and structures for shade.	2, 10, 14, 15, 19, 21		Mid term	$$

Source Water Protection Plan

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Support the development of a source water protection plan for The City's drinking water supply which considers climate-related risks (e.g., wildfires, flooding, drought).	21, 22, 23, 30, 34		Mid term	$$

13 Detailed descriptions of related risks can be found in the climate risk assessment results in Table 6 in Appendix B.

5.2 CITY ADMINISTRATION

Procurement Policy

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Update City procurement policy to ensure consideration of climate risks and resilience features in all City projects.	ALL	ALL	Mid term	$$

Outdoor Worker Rotations

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Modify staffing/human resourcing allocations to ensure more frequent rotations for outdoor work to minimize heat and wildfire smoke exposure.	11, 19		Mid term	$$

5.3 CITY OPERATIONS & PROJECTS

Urban Heat Island Assessment

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Conduct an urban heat island assessment to identify and map vulnerability to heat extremes and provide recommendations for mitigation.	15, 19, 24	ALL	Short term	$$$

Electrical Grid Assessment

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Conduct a climate change resiliency assessment of the electrical grid to determine future loads and impacts associated with extreme heat and other climate events and ensure the grid can handle increased/changing loads.	4, 13, 33		Long term	$$$

Tree Planting

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Enhance tree planting across The City focused on providing shade protection and stormwater management, plant more trees, and ensure planted trees are suitable for the future climate of Red Deer.	2, 3, 9, 10, 29		Short term	$$$*

5.4 CLIMATE RESILIENT NATURAL LANDSCAPES

Green Infrastructure Guidelines

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Develop guidelines/policy for the implementation of green infrastructure / low impact development, including contractor specifications, to protect landscapes and people from heat, heavy rainfall and flooding and extreme weather. For example, increase minimum soil depth from 6" to 12", soil protection during construction, greenspaces for cooling, permeable pavement, natural area protection, bioswales, xeriscaping/ drought tolerant plants shading structures, etc.	10, 16, 19, 26		Mid term	$$

Ecological Goods and Services

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Conduct research to inventory and quantify the benefits of ecological goods and services across The City to support the management of natural assets.	2, 8, 10		Short term	$$$

5.5 DISASTER RESILIENCE & EMERGENCY PREPAREDNESS

Water Shortage Response Plan

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Support the Provincial Government to develop a Water Shortage Response Plan which considers potential future alternative water sources, mutual aid agreements and water supply for firefighting.	30, 31		Short term	$$

Neighbourhood Resilience Program

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Develop a Neighbourhood Resilience Program to facilitate social connection, information sharing, climate awareness, and emergency response activities amongst City residents at the neighborhood scale.	1, 15, 17, 31, 32		Mid term	$$*

Wildfire Management Program

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Develop a wildfire management program to provide specific training and direct staff and resources towards wildland fire mitigation activities.	1, 3, 4, 6, 20, 22, 23		Mid term	$$$*

5.6 ENHANCED STORMWATER MANAGEMENT

Adopt a Storm Drain Program

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Develop and implement an 'Adopt a Storm Drain' program to encourage citizens to support The City in clearing debris from storm drains.	21, 26, 28		Short term	$*

Stormwater Master Plan Update

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Update the Stormwater Master Plan to include stormwater system modelling with consideration of the climate change impacts on heavy rainfall events and aquatic invasive species management (monitoring and response) at stormwater management facilities.	8, 21, 25, 26		Long term	$$$

Stormwater Utility

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Create and fund a City-wide stormwater utility to provide additional resources for the management of The City's stormwater system and prevention of overland flooding.	8, 21, 25, 26, 28		Short term	$$$$*

5.7 SUSTAINABLE BUILDINGS & ASSETS

Sustainable Building Policy

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Develop a Sustainable (Climate Resilient) Building Policy which includes new guidelines and requirements for climate resilience features for new buildings and major renovation projects to protect buildings and assets from heat, wildfire smoke and extreme weather. For example, including insulation, air tightness, filtration systems, impact resistant roofing and siding materials, shade trees for buildings, etc.	5, 14, 16, 18, 20, 25, 35		Short term	$$

Climate Lens Tool

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Develop climate lens tool for new municipal infrastructure projects to identify climate issues the project must address during development.	ALL		Mid term	$$$

Asset Management Plan

DESCRIPTION	RISKS	GOAL	TIMEFRAME	COST
Develop an Asset Management Plan that considers future climate changes and potential implications for asset management and renewal, including enhanced GIS modelling and consideration of green natural features and infrastructure.	ALL		Mid term	$$$

6
CLIMATE CHANGE AND THE ENVIRONMENTAL MASTER PLAN

The 2019 Environmental Master Plan (EMP) was developed as part of The City of Red Deer's ongoing commitment to understanding, protecting, and improving its environmental performance and public services. To meet this commitment, the 2019 EMP includes clear goals and measurable environmental targets, as well as suggested actions for The City of Red Deer to undertake.

Initiatives in the EMP are framed as targets with respect to a specific metric, which in turn collectively contribute to achieving a stated goal. In this section, links between climate change impacts on The City's assets, services, and operations and the EMP goals and metrics are highlighted. Actions in the EMP that support The City's climate resilience vision are also identified; similarly, actions in this Strategy that contribute to achievement of the EMP's goals are identified. Graphics are used to summarize the cross-linkages between this Strategy and the EMP[14].

WATER

The impacts of climate change have potential to cause widespread and severe consequences for water resources. These anticipated changes can deplete the water supply and have significant negative impacts to water quality in Red Deer. Figure 5 outlines the connection between climate change and the impacts on the EMP water -related metrics. The City's three water-related metrics may be affected by the identified potential impacts in the following ways:

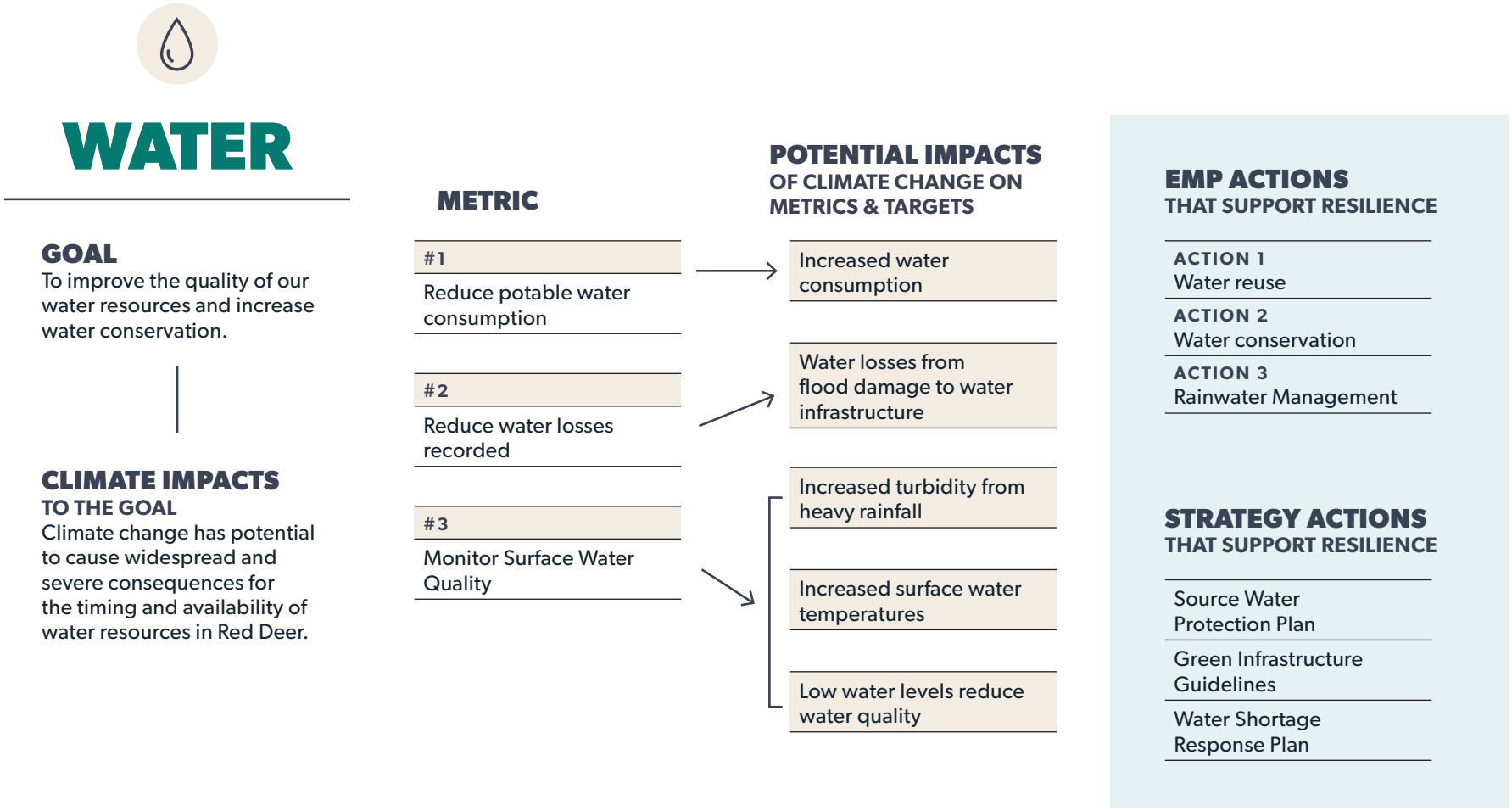
- Warmer summer temperatures and drier conditions will increase water consumption, thereby making it more difficult to achieve the target to reduce potable water consumption.
- Heavy precipitation events can cause localized flooding and road washouts which may affect underground water infrastructure and lead to water losses.
- The City's surface water quality may be affected by a number of climate impacts:
  - Heavy rainfall events and associated run-off/ discharge can increase turbidity in receiving waters causing a short-term reduction in water quality.
  - Warmer air temperatures will increase surface water temperature, adversely affecting water quality.
  - Changing seasonal precipitation patterns, including abnormally dry years can result in low water levels which will adversely affect water quality (surface water temperatures will serve to amplify impacts of low water levels).

The following actions in this Strategy will help to reduce the anticipated impacts of climate change on the EMP's water goal and associated targets:

- The Source Water Protection Plan.
- The Green Infrastructure Guideline.
- The Water Shortage Response Plan.

14 Note: EMP and Strategy actions are abbreviated to improve graphic readability in the Graphics

Figure 5 Climate Change Impacts and the Water Goal in the EMP[15]



WASTE

The City's waste management goal focuses on decreasing the amount of waste going to the landfill. Projected increases in extreme weather events (including wildfires and wildfire smoke), invasive pest outbreaks, and increases in heavy precipitation due to climate change have the potential to increase waste generation in the city—e.g., high winds or large hail may damage building exteriors producing debris requiring disposal, high winds or pests may result in broken branches or increased tree mortality, likewise increasing biomass for disposal. As a result, The City may encounter increasing difficulties achieving its waste diversion goal for 2035 or other future waste management targets (e.g., an updated target for waste generation per curbside account). Figure 6 outlines the connections between climate change and the EMP waste-related metrics.

Two of The City's three waste-related metrics may be affected by the identified climate change impacts which are anticipated to potentially increase waste generation:

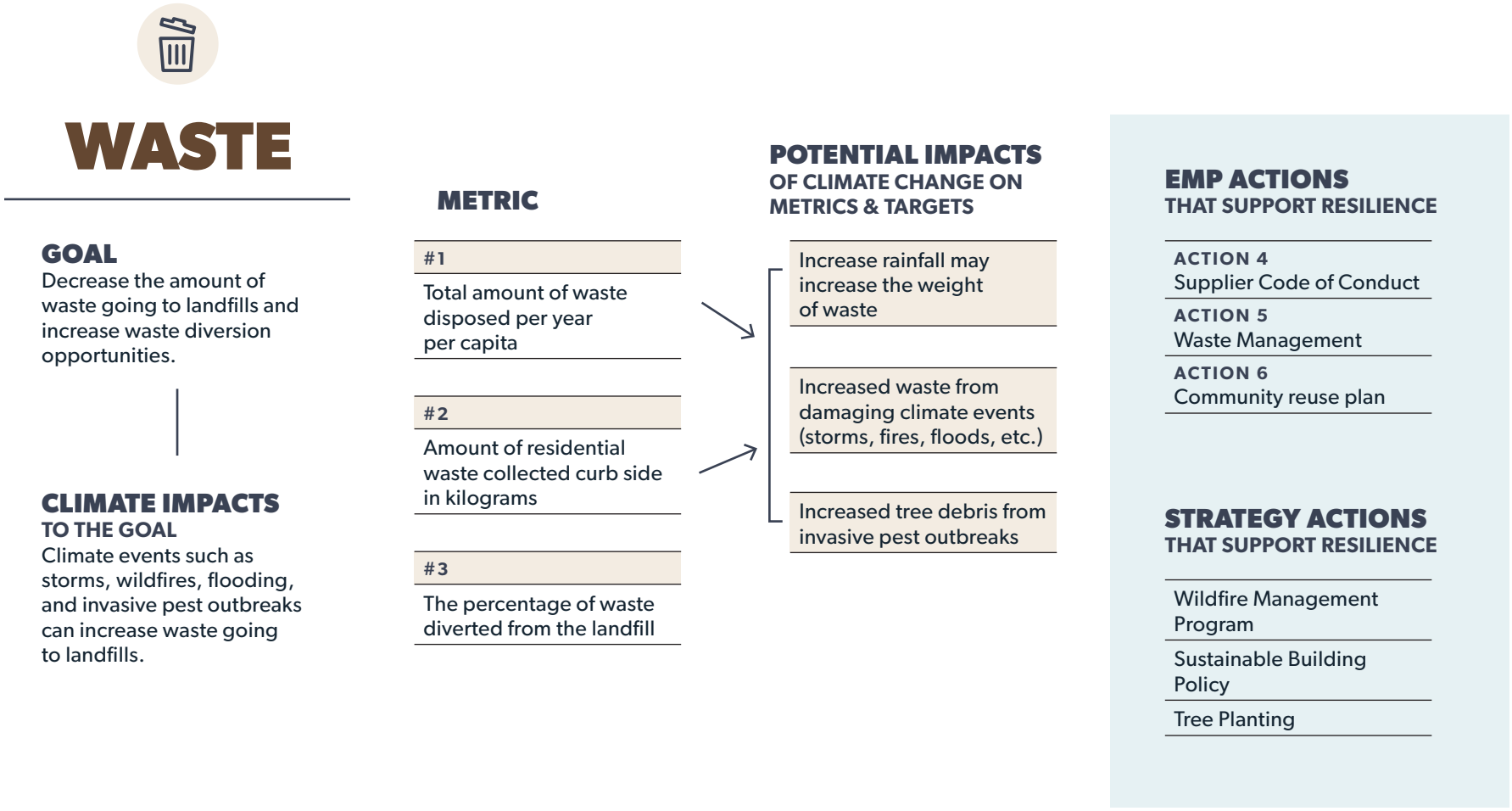
- The total weight of waste disposed per capita per year (the 2023 target has yet to be reached)
- The waste diversion target for the percentage of waste diverted from landfill by 2035.

The following actions in this Strategy will help to reduce the anticipated impacts of climate change on the EMP's waste goal and associated targets:

- The Wildfire Management Program.
- The Sustainable Building Policy.
- The Tree Planting Program[16].

16 Note: this assumes climatically suitable trees are planted which are more resilient, resulting in reduced tree mortality.

Figure 6 Climate Change Impacts and the Waste Goal in the EMP



ENERGY

Climate change is expected to increase summer and winter temperatures with implications for energy supply and demand in Red Deer. The impact of climate change on space cooling needs in Red Deer may affect The City's energy related metrics in the following ways.:

- Total energy (electricity) use in Red Deer is expected to rise as warmer summer conditions increase space cooling requirements throughout the growing building stock. Whether or not this jeopardizes achievement of the total community energy consumption target for 2035 depends on the magnitude of the anticipated reduction in space heating demand. Modelling suggests the net effect is a reduction in total annual energy consumption for space conditioning.
- The projected increase in electricity to meet growing space cooling needs should provide added impetus to meet the 2035 targets for the percentage of electricity demand met through renewable or alternative energy sources.

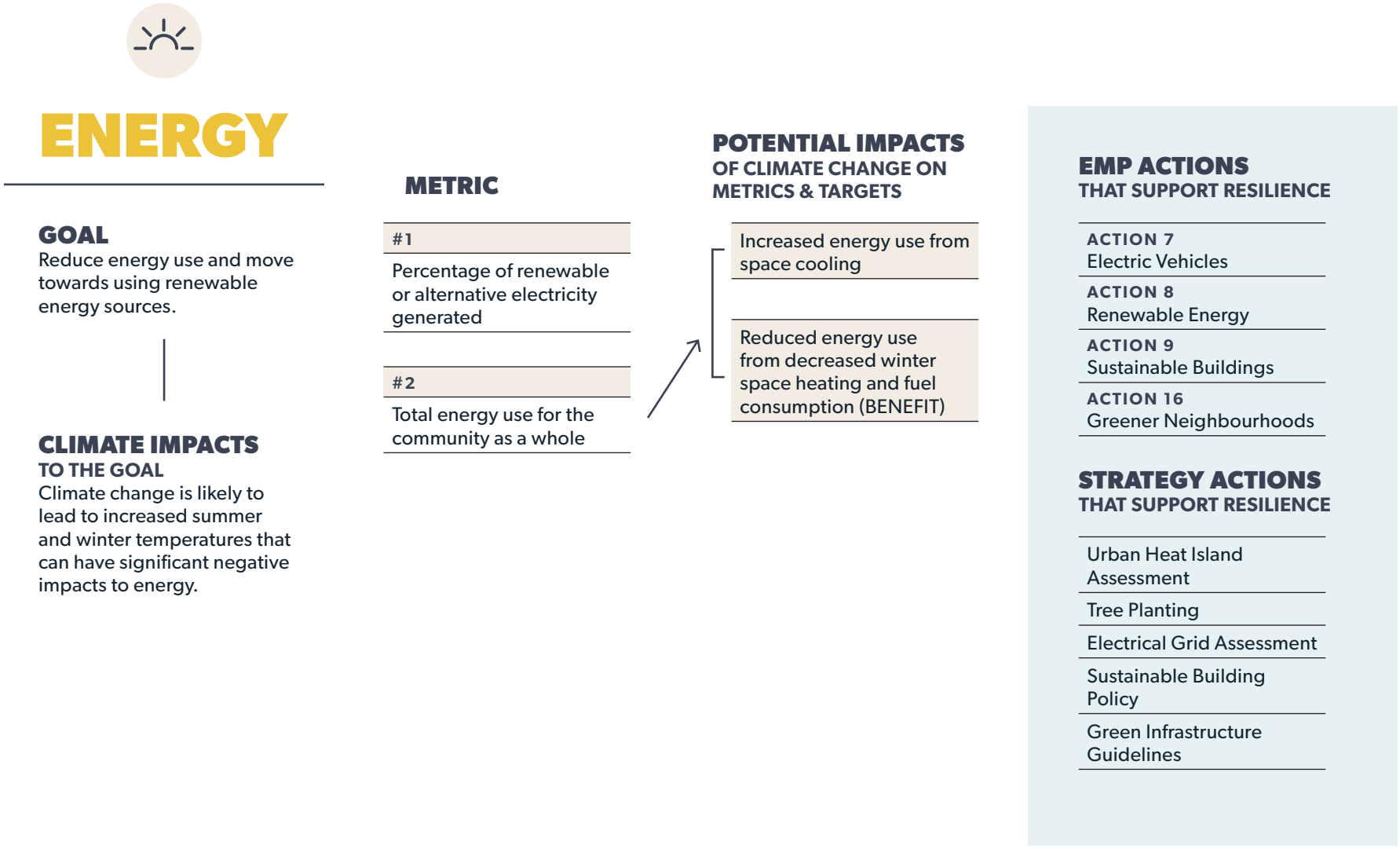
Figure 7 outlines the connections between climate change and the EMP energy-related metrics.

The following actions in this Strategy will help to ease the anticipated impacts of climate change on space cooling demand and the EMP's energy goal and associated targets:

- The Urban Heat Island Assessment.
- The Tree Planting Program.
- The Electricity Grid Assessment.
- The Sustainable Building Policy.
- The Green Infrastructure Guidelines.

There are also related impacts on the EMP's Air goals—in particular, the targets for GHG emissions.

Figure 7 Climate Change Impacts and the Energy Goal in the EMP



ECOLOGY

As growing seasons lengthen, precipitation patterns change and the climate envelope conducive to specific natural ecosystems begins to change, a number of impacts may arise for the terrestrial and aquatic health of Red Deer's natural heritage system. Two of the four ecological metrics in the EMP may be affected by the potential impacts of climate change:

- A longer growing season and other anticipated changes in Red Deer's climate may increase the prevalence of existing (and new) invasive species, pests, and disease. This may have implications for achieving The City's 2035 target for the use of non-chemical integrated pest management measures on City-owned and maintained area. Depending on the efficacy of alternative management options, The City may need to increase applications of chemical pest management measures.
- Tree species "suitable" for Red Deer's urban environment will change as climate change alters the composition of ecosystems across the province, shifting the climate envelope suitable to specific tree species. It is important that projected changes in the local climate are considered when defining "suitable" tree species for City-owned and managed lands to achieve the suitability target for 2035.

Figure 8 outlines the connection between climate change and the EMP ecology-related metrics.

The following actions in this Strategy will help to alleviate the anticipated risks that climate change presents on the EMP's ecology goal and associated targets:

- The Tree Planting Program.
- Tree Protection Bylaw.
- Natural Areas Policy.
- Ecological Goods and Services (inventory and quantification of benefits to strengthen case for resource allocation to Ecology goal).

Achieving the Ecology goal will contribute to the EMP's Air goal. For example, trees improve local air quality by trapping particulate matter in their leaves and needles; they also remove and store carbon dioxide from the atmosphere. Negative (removals) emission options are a crucial part of any ambitious strategy to reduce GHG emissions.

Figure 8 Climate Change Impacts and the Ecology Goal in the EMP

ECOLOGY

GOAL
Protect and enhance the terrestrial and aquatic health of the natural heritage system.

CLIMATE IMPACTS
TO THE GOAL
Climate change is likely to alter natural ecosystems in the Red Deer area, affecting terrestrial and aquatic health.

METRIC

#1	The share of protected areas within Red Deer
#2	The proportion of City-owned areas where non-chemical pest management measures are used
#3	Percentage of tree population suitable for Red Deer's urban environment
#4	The percentage of genetically diverse tree population

POTENTIAL IMPACTS
OF CLIMATE CHANGE ON METRICS & TARGETS

- Increase prevalence of invasive species, pests and diseases with increased pest management requirements
- Altered ecosystem compositions, shifting the climatic suitability of tree species

EMP ACTIONS
THAT SUPPORT RESILIENCE

- **ACTION 10** Biodiversity
- **ACTION 11** Urban Forest Management
- **ACTION 12** Inventoried City-owned trees
- **ACTION 13** Naturescaping
- **ACTION 14** Land conservation
- **ACTION 18** Urban Agriculture

STRATEGY ACTIONS
THAT SUPPORT RESILIENCE

- Natural Areas Policy
- Tree Protection Bylaw
- Tree Planting
- Ecological Goods and Services

COMMUNITY DESIGN

Anticipated changes in Red Deer's climate will likely affect community design related metrics of the EMP in the following ways:

- Warmer seasonal temperatures and a longer summer season will likely contribute to reduced fuel consumption in The City by a) decreasing the need for vehicle idling during cold temperatures, and b) increasing the modal share of active transportation, in turn reducing the use of private vehicles and total fuel (gas and diesel) consumed annually in The City. This may in turn increase public support (demand) to increase the length of bicycle and pedestrian routes per hectare of urban development.
- A longer growing season should increase the productivity of community garden plots increasing the number of residents who benefit from (can be supported by) garden produce.; however, anticipated increases in the intensity and frequency of extreme weather events (drought, storms, and flooding) may adversely impact the productivity of garden plots—in the absence of adaptation measures.
- Increased river flooding and erosion of riverbanks may affect parks, green areas, or other natural assets around the city. Parts of the city may become undevelopable due to changing flood risk, or even lost from erosion of riverbanks, reducing the total land available for urban development with implications for the urban development target.

Increasing use of active transport modes and the productivity of community gardens will also contribute to the EMP's Energy (community energy use) and Air (community GHG emissions) goals. Figure 9 outlines the connections between climate change and the EMP community design-related metrics.

The following actions in this Strategy will help to manage the anticipated risks climate change presents the EMP's community design goal and associated targets:

- The Urban Heat Island Assessment (considerations given to the location and design of active transport infrastructure).
- The Tree Planting Program.
- Neighbourhood Resilience Program.
- The Green Infrastructure Guidelines.

Figure 9 Climate Change Impacts and the Community Design Goal in the EMP

COMMUNITY DESIGN

GOAL

Plan and build a well-connected, sustainable community that contributes to a quality of life for residents to live, work, move around, and enjoy recreational and cultural pursuits.

CLIMATE IMPACTS TO THE GOAL

Climate change such as severe storms, wildfires, heat waves, and flooding can have significant negative impacts to the quality of life of Red Deer residents.

METRIC

#1	Length of bicycle and pedestrian routes
#2	The total fuel (gas and diesel) consumed annual in the city
#3	Emissions attributed to transportation in Red Deer
#4	Annual transit trips per capita taken on Red Deer Transit
#5	Urban development in metres squared per person
#6	The number of garden plots and the number of residents who benefit from garden produce

POTENTIAL IMPACTS OF CLIMATE CHANGE ON METRICS & TARGETS

- Reduced winter fuel consumption from decreased vehicle idling and increased active transportation use (BENEFIT)
- Increased river flooding and erosion reduces land available for urban development
- Extreme weather events negatively affect garden productivity
- Longer growing season and increased productivity of garden plots (BENEFIT)

EMP ACTIONS THAT SUPPORT RESILIENCE

- **ACTION 9** Sustainable Buildings
- **ACTION 13** Naturescaping
- **ACTION 16** Greener Neighbourhoods
- **ACTION 17** Public and active transportation
- **ACTION 18** Urban Agriculture

STRATEGY ACTIONS THAT SUPPORT RESILIENCE

- Urban Heat Island Assessment
- Green Infrastructure Guidelines
- Neighbourhood Resilience Program
- Tree Planting Program

AIR

Projected changes in mean and extreme seasonal temperatures will impact energy consumption in Red Deer with implications for GHG emissions. In addition, heightened levels of wildfire smoke anticipated to accompany climate change will negatively affect the health and wellbeing of Red Deer residents. Figure 10 outlines the connections between climate change and the EMP air-related metrics. The City's air metrics may be impacted in the following ways:

- Wildfire smoke contains multiple air pollutants including fine particles and gases, such as carbon monoxide, nitrogen oxides, and volatile organic compounds—some compounds are known carcinogens. Anticipated increases in wildfire smoke with climate change will increase local air pollution levels, compromising achievement of the EMP's ambient concentration targets for nitrogen dioxide and fine particulate matter (PM2.5).
- Warmer summer temperatures are linked with increased concentrations of ground-level ozone. Projected increases in daily mean summer temperatures may thus compromise achievement of the EMP's ambient concentration target for ozone.
- Warmer (and extended) summer conditions are expected to increase space cooling requirements, increasing electricity use and associated GHG emissions (all else being equal)[17]. At the same time, warmer temperatures at other times of the year may reduce fuel consumption to meet space heating demand, with corresponding reductions in GHG emissions (primarily from natural gas use). Whether net annual emissions arising from space heating and space cooling increase or decrease depends on a complex mix of factors.

The following actions in this Strategy will help to manage the anticipated risks climate change presents the EMP's community design goal and associated targets:

- Wildfire Management Program.
- Outdoor Worker Rotations.
- The Sustainable Buildings Policy.

17 That is, assuming Alberta's electricity system does not achieve net-zero emissions anytime soon.

Figure 10 Climate Change Impacts and Air Goal in the EMP

AIR

GOAL
Improve air quality and reduce emissions.

CLIMATE IMPACTS
TO THE GOAL
Climate events such as wildfires and heat waves can have significant negative impacts to air quality in Red Deer.

METRIC

#1 Measure ambient concentrations of airborne pollutants	Increased concentrations of airborne pollutants from wildfire smoke
#2 Measure greenhouse gas emissions for the City of Red Deer and the community as a whole	Increased space cooling requirements and associated GHG emissions
	Reduced winter fuel consumption and associated GHG emissions (BENEFIT)

POTENTIAL IMPACTS
OF CLIMATE CHANGE ON METRICS & TARGETS

EMP ACTIONS
THAT SUPPORT RESILIENCE

- ACTION 7 Electric Vehicles
- ACTION 8 Renewable Energy
- ACTION 11 Urban Forest Management
- ACTION 14 Land conservation
- ACTION 20 Clean Air

STRATEGY ACTIONS
THAT SUPPORT RESILIENCE

- Outdoor Worker Rotations
- Wildfire Management Program
- Sustainable Building Policy

7
IMPLEMENTATION CONSIDERATIONS

In addition to the Climate Adaptation Strategy actions and recommendations outlined in Section 5, the following additional recommendations are provided to support implementation.

Strategy Implementation:

- The City climate adaptation project team and steering committee should be maintained and continue to meet regularly to work towards implementation of the Strategy
- Funding should be committed annually to support implementation activities, including funding for monitoring and evaluation of action implementation. Grant funding should be sought to support implementation projects where possible.
- The Strategy should be updated at least every five to 10 years to ensure it remains effective and relevant. Future updates and iterations of this Strategy should consider:
  - Lessons learned from the implementation of actions, both in terms of whether actions have been implemented as intended and the effectiveness of implemented actions in achieving the intended results.
  - New research and scientific information on climate projections and impacts, which may affect the understanding of risks and opportunities facing The City.
  - Changes to Corporate goals, or to social, economic, or environmental conditions, which likewise may affect the understanding of risks and/or opportunities for resilience action.

Future Considerations

- Develop a community-wide climate adaptation plan considering the effects of climate change across all aspects of The City of Red Deer, including climate change impacts directly affecting:
  - The health, safety, quality of life and wellbeing of residents, including vulnerable populations.
  - Critical infrastructure and services not managed directly by The City including natural gas and telecommunications.
  - The vibrancy or attractiveness of the city.
  - Private property, including residential, commercial, and industrial buildings.
  - Local businesses and secondary “ripple effects” throughout the economy.
  - The natural environment that does not directly affect City assets, services, and operations, such as impacts to air quality, ecosystems, wildlife, etc.

Greenhouse Gas Mitigation Support

- Many actions within this Strategy have the potential to influence greenhouse gas (GHG) emissions. For example, actions that safeguard or enhance natural capital (e.g., Natural Areas Policy, Infrastructure Guidelines, etc.) could make important contributions to reducing GHG emissions in Red Deer. The negative emissions (removals) provided by natural capital help to offset positive emissions from energy consumption, which is crucial for achieving more ambitious emission reduction targets. In addition, several actions provide logical and cost-effective opportunities for the integration of GHG reduction considerations, such as the Procurement Policy and Neighbourhood Resilience Program. All actions under Sustainable Buildings & Assets theme (e.g., Sustainable Building Policy, Climate Lens Tool, and Asset Management Plan) should ideally be designed with the integration of GHG emissions reductions in mind.

APPENDIX A

DETAILED CLIMATE IMPACT SCENARIOS

The complete climate impact scenarios are provided below.
The structure for each scenario consists of the following components:

- A short name (heading).
- A description of the scenario or impact, corresponding with one of the 18 climate impact scenarios Each climate impact is defined using the same threshold and likelihood score.
- The climate driver(s) that result in the emergence of the climate impact, based on the climate projections identified for Red Deer.
- A threshold, defined as a point beyond which a system, because of physical damage or failure, is deemed to be no longer effective or safe, which is used to calculate the likelihood score, and to characterize the potential consequences of each climate impact.
- The likelihood method(s) used to calculate the historic and future likelihood of the scenario occurring (with reference to the methods discussed in Section 3.3).
- The historic likelihood (using the baseline period of 1981-2010 where possible) and future likelihood (the 2030s period of 2021-2050) of the scenario occurring, and the score (1-5) based on the likelihood scale (Figure 1).
- The potential consequences of each climate impact, which are assessed (scored) using the consequence scale (Figure 2). **Only consequences that have potentially significant impacts and pose a material threat to The City assets, services or operations were considered.** Each consequence includes a description, the consequence category, and a consequence score, which was determined through the September 28 workshop.
- An overall risk level corresponding to the placement of the climate-related consequence within the climate risk matrix—based on the combination of likelihood and consequence scores.
- Potential Vulnerabilities & Resilience. These are identified based on data and information gathered through a review of local documents, plans, policies, and bylaws, as well as research and literature on determinants of vulnerability and resilience to climate change.

A1
HEAT WAVE

DESCRIPTION	Multiple consecutive days of extreme heat		
CLIMATE DRIVER(S)	Hotter summer temperatures, more extreme heat		
THRESHOLD	8 heat warnings per year[18] [the projected number of heat warnings per year in the 2030s]		
LIKELIHOOD METHOD(S)	1 – Climate data analysis		
HISTORIC LIKELIHOOD	▪ 2 heat warnings per year (median) in the baseline period ▪ 5% annual probability of 8 heat warnings occurring in the baseline period		3 [Possible]
FUTURE LIKELIHOOD	▪ 8 heat warnings per year (median) are projected for the 2030s ▪ 49% annual probability of 8 heat warnings occurring		4 [Likely]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Potential public health emergency requiring a response	EM	3.3	3.3
Negative health impacts (e.g., heat exhaustion, heat stroke, etc.) and reduced productivity of workers	HS	3.1	3.1
Reduced participation in summer outdoor recreation activities, events, and programs	AS	2.9	2.9

POTENTIAL VULNERABILITIES & RESILIENCE

- The following groups have heightened risk of adverse health outcomes from heat: Older adults; Pregnant women; People with pre-existing health conditions (heart disease, respiratory disease, diabetes, obesity, mental illness, limited mobility); and Outdoor workers engaged in strenuous outdoor activity[19].
- Aging buildings and facilities with poor or lacking thermal protection (insulation, efficient doors and windows, etc.) and inadequate ventilation and air conditions systems for space cooling are more vulnerable.
- The presence, or lack thereof, of shade, shelter, water, and spaces for outdoor workers to cool and rehydrate during heat waves is a determinant of vulnerability

18 Based on Environment and Climate Change Canada criteria for public weather alerts due to heat in the Red Deer area: 2 or more consecutive days of daytime maximum temperatures above 29°C, and nighttime minimum temperatures above 14°C. Source: https://www.canada.ca/en/environment-climate-change/services/types-weather-forecasts-use/public/criteria-alerts.html#heat

19 Gosselin, P., Campagna, C., Demers-Bouffard, D., et al., 2022, ibid; Health Canada, Adapting to Extreme Heat Events: Guidelines for Assessing Health Vulnerability, Ottawa, ON.: Government of Canada; and Prepared BC, 2022, Extreme Heat Preparedness Guide, Victoria, BC: Government of British Columbia.

A2
OVERHEATING INFRASTRUCTURE

DESCRIPTION	Excessively hot summer temperatures cause heat damage to municipal infrastructure and assets		
CLIMATE DRIVER(S)	Hotter summer temperatures, more extreme heat		
THRESHOLD	14 very hot days (>30°C) per year [the projected number of very hot days per year in the 2030s]		
LIKELIHOOD METHOD(S)	1 – Climate data analysis		
HISTORIC LIKELIHOOD	▪ 3 very hot days per year (median) in the baseline period ▪ ~2% annual probability of 14 very hot days occurring in the baseline period		2 [Unlikely]
FUTURE LIKELIHOOD	▪ 14 Very Hot Days (median) are projected for the 2030s ▪ 51% annual probability of 14 very hot days occurring		5 [Almost Certain]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Heat stress on trees and green areas	NA	3.0	High
Accelerated degradation of buildings and facilities (roofing, siding, etc.)	PR	2.8	High
Reduced efficiency of power lines and potential power outages	UC	2.0	Moderate
Accelerated degradation of road and sidewalk infrastructure (e.g., concrete and asphalt buckling) and increased maintenance costs	AS	2.0	Moderate
Heat stress on sports fields and manicured spaces (planted grasses, landscaping, etc.)	AS	1.6	Moderate

POTENTIAL VULNERABILITIES & RESILIENCE

- Aging buildings and facilities with poor or lacking thermal protection (insulation, efficient doors and windows, etc.) and inadequate ventilation and air conditions systems for space cooling are more vulnerable to impacts.
- The Urban Forest Management Plan outlines numerous significant challenges facing The City's urban forest, including drought risks to urban trees.

18 Based on Environment and Climate Change Canada criteria for public weather alerts due to heat in the Red Deer area: 2 or more consecutive days of daytime maximum temperatures above 29°C, and nighttime minimum temperatures above 14°C. Source: https://www.canada.ca/en/environment-climate-change/services/types-weather-forecasts-use/public/criteria-alerts.html#heat

19 Gosselin, P., Campagna, C., Demers-Bouffard, D., et al., 2022, ibid; Health Canada, Adapting to Extreme Heat Events: Guidelines for Assessing Health Vulnerability, Ottawa, ON.: Government of Canada; and Prepared BC, 2022, Extreme Heat Preparedness Guide, Victoria, BC: Government of British Columbia.

A3
REDUCED NATURAL WATER QUALITY

DESCRIPTION	Gradual increase in average annual summer temperatures, increased water temperatures and reduced water quality in natural water bodies (lakes, rivers, etc.)		
CLIMATE DRIVER(S)	Hotter summer temperatures		
THRESHOLD	The average summer maximum temperature reaches 25°C [the projected summer maximum temperature in the 2030s]		
LIKELIHOOD METHOD(S)	1 – Climate data analysis		
HISTORIC LIKELIHOOD	▪ Average summer maximum temperature (median) in the baseline period is 22°C ▪ 5% annual probability of 25°C average summer maximum temperature		3 [Possible]
FUTURE LIKELIHOOD	▪ Average summer maximum temperature in the 2030s is projected to be 25°C ▪ 51% annual probability of 25°C average summer maximum temperature		5 [Almost Certain]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Increased surface water temperatures leading to degradation of surface water quality, with consequences for the treatment of water	UC	2.0	Moderate
Increased risk of algae blooms and management costs	NA	2.0	Moderate
Increased surface water temperatures affecting terrestrial and aquatic ecosystem health	NA	2.0	Moderate

POTENTIAL VULNERABILITIES & RESILIENCE

- Contamination of the water supply due to algal blooms as a result of 'changing weather patterns' is identified as a moderate source water risk in the Drinking Water Safety Plan.
- The City currently invests a minimal amount annually in management costs (staff time and resources) to identify algal blooms and educate the public through signage.

A4
REDUCED OUTDOOR RECREATION

DESCRIPTION	Gradual increase in average winter temperatures		
CLIMATE DRIVER(S)	Milder Winters		
THRESHOLD	The average number of non-winter days (above -5°C) increases to 245 days [the projected number of non-winter days in the 2030s][20]		
LIKELIHOOD METHOD(S)	1 – Climate data analysis		
HISTORIC LIKELIHOOD	▪ 228 non-winter days (median) in the baseline period ▪ 13% annual probability of 245 non-winter days occurring		4 [Likely]
FUTURE LIKELIHOOD	▪ 245 non-winter days (median) are projected for the 2030s ▪ 49% annual probability of 245 non-winter days occurring		4 [Likely]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Reduced quality and reliability of natural outdoor ice and snow, affecting winter recreation services (outdoor rinks, Nordic skiing, etc.)	AS	1.8	Moderate
POTENTIAL VULNERABILITIES & RESILIENCE			
▪ Determinants of vulnerability include: Participation rates in traditional winter activities and festivals; The number and accessibility of alternative indoor recreation options (e.g., indoor rinks); and the design and functionality of parks and outdoor recreation facilities for the cold season			

20 -5°C is the temperature where it becomes less desirable to engage in outdoor winter recreation activities and events as the quality of ice and snow conditions start to deteriorate

A5
INCREASED SPACE COOLING

DESCRIPTION	Gradual increase in average summer temperatures increases space cooling requirements in buildings and facilities		
CLIMATE DRIVER(S)	Hotter summer temperatures		
THRESHOLD	The number of Cooling Degree Days (CDDs)[21] increases to 137 [the projected CDDs in the 2030s]		
LIKELIHOOD METHOD(S)	1 – Climate data analysis		
HISTORIC LIKELIHOOD	▪ 42 CDDs (median) in the baseline period ▪ 5% annual probability of 137 CDDs occurring		3 [Possible]
FUTURE LIKELIHOOD	▪ 137 CDDs (median) are projected for the 2030s ▪ 45% annual probability of 137 CDDs occurring		4 [Likely]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Increased space cooling requirements and costs, including for the maintenance and upgrading of HVAC systems	PR	3.2	High
POTENTIAL VULNERABILITIES & RESILIENCE			
▪ Buildings and facilities with and without air conditioning is a determinant of vulnerability.			

21 CDDs are defined as the number of degree days accumulated above 18°C in a year. When the daily average temperature is hotter than the threshold temperature, CDDs are accumulated. Threshold values may vary, but 18°C is commonly used in Canada (Climate Data Canada, 2023)

A6
FREEZING PRECIPITATION

DESCRIPTION	Precipitation in the form of freezing rain or ice		
CLIMATE DRIVER(S)	Milder winters, Severe storms		
THRESHOLD	30mm freezing rain in a day[22]		
LIKELIHOOD METHOD(S)	3 – Existing research		
HISTORIC LIKELIHOOD	▪ 6-10 mm freezing precipitation in a day [1:20 year daily maximum freezing precipitation level][23] ▪ Unknown annual probability of 30 mm of freezing precipitation in a day, but less than 5%		2 [Unlikely]
FUTURE LIKELIHOOD	▪ 30 mm freezing precipitation in a day [1:20 year daily maximum freezing precipitation level] ▪ 5% annual probability of 30 mm of freezing precipitation in a day		3 [Possible]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Increased road and sidewalk maintenance costs (sanding, salting)	AS	3.6	High
Damage to tree branches, impacts to the urban tree canopy	NA	3.5	High
Damage to power lines and potential power outage	UC	3.0	Moderate
Damage to buildings and facilities, namely roof-mounted equipment (electrical, air conditioning, etc.)	PR	2.8	Moderate
Potential for falls, injuries, and traffic accidents due to slippery sidewalks and roads	HS	2.2	Low

POTENTIAL VULNERABILITIES & RESILIENCE

- Determinants of vulnerability include: The condition and age of buildings and infrastructure; The prevalence of outdoor, overhead electricity wires (versus underground); and the condition of the tree canopy, tree density and proximity to property and infrastructure.

22 Ice depth 1:20 year ice-thickness design standard for the 2030s

23 Historic and future likelihood assessment from: Jeong, D., et al., 2019: Projected changes to extreme freezing precipitation and design ice loads over North America based on a large ensemble of Canadian regional climate model simulations, Nat. Hazards Earth Syst. Sci., 19, 857–872; and Cannon, A., Jeong, D., Zhang, X. and Zwiers, F. 2020. Climate-Resilient Buildings and Core Public Infrastructure: An Assessment of the Impact of Climate Change on Climatic Design Data in Canada. Environment and Climate Change Canada, Gatineau, QC, 106 p.

A7 HAILSTORM

DESCRIPTION	Precipitation that is made up of ice and snow, and can range from pea size to golf ball size, and up		
CLIMATE DRIVER(S)	Severe storms		
THRESHOLD	A "very large hail day" with hailstones > 4cm in diameter		
LIKELIHOOD METHOD(S)	3 – Existing research		
HISTORIC LIKELIHOOD	▪ 1 large hail day every 6-7 years [3.5-5 large hail days over the period 1971-2000] ▪ ~14% annual probability of a large hail day occurring		4 [Likely]
FUTURE LIKELIHOOD	▪ Increasing likelihood. About 1 additional large hail day per season [1 large hail day every 5-6 years] ▪ ~18% annual probability of a large hail day occurring		4 [Likely]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Damage to buildings and facilities (roofing, cladding, etc.) including roof-mounted equipment (electrical, air conditioning, etc.)	PR	3.9	Very high
Flooding of roadways and disruption of transportation networks due to blocked catch basins	UC	2.7	High
Damage to tree branches, impacts to the urban tree canopy	NA	2.1	Moderate
Damage to vehicles and outdoor equipment and structures	AS	2.0	Moderate
POTENTIAL VULNERABILITIES & RESILIENCE			
▪ Determinants of vulnerability include the design, materials, condition and age of building envelopes and other external systems (e.g., roof top HVAC).			

A8
HIGH WINDS

DESCRIPTION	Severe wind gusts exceeding 90km/h		
CLIMATE DRIVER(S)	Severe storms		
THRESHOLD	Wind gusts of 90km/h of more[24]		
LIKELIHOOD METHOD(S)	2 – Historic event occurrences 3 – Existing research		
HISTORIC LIKELIHOOD	▪ 223 severe wind gusts between 1957-2022 [3-4 wind gusts per year][25] ▪ 99% annual probability of a severe wind gust occurring		5 [Almost Certain]
FUTURE LIKELIHOOD	▪ Projections for annual maximum wind pressures suggest little change in wind speeds[26] ▪ 99% annual probability of a severe wind gust occurring		5 [Almost Certain]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Damage to tree branches, impacts to the urban tree canopy	NA	3.0	High
Health and safety risks to municipal staff, including reductions in workforce productivity during storms	HS	3.0	High
Damage to power lines and potential power outage	UC	2.9	High
Damage to buildings and facilities (roofing, cladding, etc.)	PR	2.0	Moderate
Damage to municipal assets (vehicles, equipment, structures, etc.)	AS	1.9	Moderate
Potential for evacuations and displacement requiring emergency response	EM	1.0	Low

POTENTIAL VULNERABILITIES & RESILIENCE

- Determinants of vulnerability include: Construction materials (e.g., brick vs wood frames) and building design (e.g., addition of fasteners, ties, anchors); and, The condition of the tree canopy, tree density and proximity to property and infrastructure
- The City has an existing policy on Working in Severe Weather, designed to reduce health and safety risks

24 90km/h wind gusts are the threshold for an Environment Canada Wind Warning for Alberta (ECCC, 2023)

25 Data obtained from Red Deer weather station (ECCC, 2023)

26 See: Cannon, A., Jeong, D., Zhang, X. and Zwiers, F. 2020. Climate-Resilient Buildings and Core Public Infrastructure: An Assessment of the Impact of Climate Change on Climatic Design Data in Canada. Environment and Climate Change Canada, Gatineau, QC, 106 p

A9 TORNADO

DESCRIPTION	A severe tornado between EF2 to EF3 damages municipal infrastructure and puts the health and safety of staff at risk		
CLIMATE DRIVER(S)	Severe storms		
THRESHOLD	EF2-EF3 Tornado event with windspeeds between 178km/h to 265km/h[27]		
LIKELIHOOD METHOD(S)	2 – Historic event occurrences 3 – Existing research		
HISTORIC LIKELIHOOD	No known occurrences of EF2-EF3 Tornadoes touching down in Red Deer historically[28]		1 [Rare]
FUTURE LIKELIHOOD	Insufficient evidence to determine future trend[29]		1 [Rare]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Potential for evacuations and displacement requiring emergency response	EM	4.9	High
Damage to power lines and potential power outage	UC	4.8	High
Damage to water and wastewater infrastructure including treatment plants, lift stations, and reservoirs	UC	4.8	High
Damage to buildings and facilities (roofing, cladding, etc.)	PR	4.7	High
Damage to tree branches, impacts to the urban tree canopy	NA	4.4	Moderate
Health and safety risks to municipal staff, including emergency response personnel	HS	4.0	Moderate
Damage to municipal assets (vehicles, equipment, structures, etc.)	AS	3.6	Moderate

POTENTIAL VULNERABILITIES & RESILIENCE

- Determinants of vulnerability include: Construction materials (e.g., brick vs wood frames) and building design (e.g., addition of fasteners, ties, anchors); and The condition of the tree canopy, tree density and proximity to property and infrastructure
- The City has an existing policy on Working in Severe Weather, designed to reduce health and safety risks

27 EF2-EF3 tornadoes contain windspeeds that can produce significant damage to The City.

28 Data retrieved from Red Deer Weather Related Emergency Events document (2023). The closest severe tornado to Red Deer was recorded in 2000. A tornado touched down West of Pine Lake moving east for 24.5kms spending 30mins on the ground. Mostly F2 (winds >250kph) were recorded but at its strongest was F3 (winds>330kph).

29 There is currently no evidence to support either an increasing or decreasing trend in tornado activity over Alberta in particular. See: Khandekar, M. L. (2002). Trends and changes in extreme weather events: An assessment with focus on Alberta and Canadian Prairies

A10
INVASIVE SPECIES & PESTS

DESCRIPTION	An outbreak of different varieties of plant or animal species which are not native to Red Deer		
CLIMATE DRIVER(S)	Changing seasons and ecosystems, milder winters, hotter temperatures.		
THRESHOLD	The frost-free season is extended to 145 days [the projected number of frost-free days per year in the 2030s][30]		
LIKELIHOOD METHOD(S)	1 – Climate data analysis		
HISTORIC LIKELIHOOD	▪ 126 frost free days (median) in the baseline period ▪ 2% annual probability of 145 frost-free days occurring		3 [Possible]
FUTURE LIKELIHOOD	▪ 145 frost free days (median) are projected for the 2030s ▪ 50% annual probability of 145 frost-free days occurring		5 [Almost Certain]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Damaged trees or diminished urban tree canopy from insect pests (e.g., Emerald Ash Borer)	NA	3.5	Very high
Increased weeds and maintenance of stormwater management system (ponds)	UC	3.0	High
Increased weeds and maintenance of sports fields, manicured spaces (planted grasses, landscaping, etc.), and transportation corridors (ditches, trails, etc.)	AS	2.2	Moderate

POTENTIAL VULNERABILITIES & RESILIENCE

- Determinants of vulnerability include: The condition of the urban tree canopy; and the prevalence (or lack thereof) of weed management and maintenance staff and invasive species and pest detection programs.
- The Urban Forest Management Plan has a series of recommended actions focused on protecting The City's urban forest.

30 The frost-free season is defined as the number of consecutive days during the 'summer' without any daily minimum temperatures below 0°C (Climate Data Canada, 2023)

A11
INCREASED WASTE

DESCRIPTION	Increased annual precipitation causes waste to become heavier		
CLIMATE DRIVER(S)	More total precipitation		
THRESHOLD	Annual total precipitation increases to 471mm [projected level of annual total precipitation in the 2030s]		
LIKELIHOOD METHOD(S)	1 – Climate data analysis		
HISTORIC LIKELIHOOD	▪ Historic total annual precipitation (median): 461mm[31] ▪ 49% annual probability of 471 mm of total annual precipitation [return interval = 2.1]		4 [Likely]
FUTURE LIKELIHOOD	▪ Projected future total annual precipitation (median): 471mm[32] ▪ 52% annual probability of 471 mm of total annual precipitation [return interval = 1.9]		5 [Almost Certain]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Increased weight (kilograms) of waste, additional waste management costs	UC	1.4	Low

POTENTIAL VULNERABILITIES & RESILIENCE

- The Environmental Master Plan has a goal (and metrics) to decrease waste going to the landfill, measured in weight (kilograms) of waste.
- Note: Damaging climate events such as severe storms, wildfires and flooding have potential to generate significant amounts of waste. These impacts are secondary consequences associated with those events and were considered as part of the scoring of consequences associated with damages.

31 Source: www.ClimateData.ca.

32 Source: www.ClimateData.ca.

A12
OVERLAND FLOODING

DESCRIPTION	Flooding caused by a short-duration high-intensity rainfall event		
CLIMATE DRIVER(S)	Severe Storms, more extreme precipitation		
THRESHOLD	A 1:100-year 24-hour rainfall event[33]		
LIKELIHOOD METHOD(S)	1 – Climate data analysis		
HISTORIC LIKELIHOOD	▪ Historic 1:100 24-hour rainfall event was 101mm[34] ▪ 1% annual probability of a 1:100 24-hour rainfall event occurring		2 [Unlikely]
FUTURE LIKELIHOOD	▪ Projected future 1:100 24-hour rainfall event is 118mm[35] ▪ ~3% annual probability of a 1:100 24-hour rainfall event occurring		3 [Possible]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Flooding including from landslides and erosion, and damage to underground critical infrastructure (water, sewer, stormwater, telecommunications, etc.)	UC	4.0	High
Flooding of roadways due to culvert failure or road washout, and disruption of transportation networks	AS	3.6	High
Flooding and erosion of parks, green areas, or other natural assets, including from landslides and erosion	NA	2.6	Moderate
Flooding (water inundation) of buildings and facilities	PR	2.3	Low
Increased runoff, with potential adverse impacts on water quality (turbidity) and resultant increased treatment costs	UC	2.0	Low
Flooding of sports fields	AS	1.7	Low

POTENTIAL VULNERABILITIES & RESILIENCE

- Determinants of vulnerability include: Engineering design standards for the stormwater management system (pipes, culverts, stormwater ponds, drainage areas, etc.); and the age and condition of drainage systems, and the level of maintenance

33 1:100 24-hour rainfall event is a standard design parameter for stormwater infrastructure

34 Source: www.ClimateData.ca. Note: the historic period is different for each weather station (Red Deer Regional Airport) from which the IDF statistics are estimated; for Red Deer it is 1959-2014 (it can't be changed).

35 Source: www.ClimateData.ca.

A13
RIVER & CREEK FLOODING

DESCRIPTION	Flooding of the Red Deer River, Waskasoo Creek and/or Piper Creek		
CLIMATE DRIVER(S)	More severe weather, more extreme precipitation		
THRESHOLD	The 1:100-year flood peak discharge rate on the Red Deer River below Waskasoo Creek [A flow rate of 1,870 m3/s on the], Waskasoo Creek above Piper Creek [37.1m3/s], and Piper Creek above Waskasoo Creek [19.3m3/s][36]		
LIKELIHOOD METHOD(S)	3 – Existing research		
HISTORIC LIKELIHOOD	▪ 1:100-year maximum flow = 1,870m3/s [Red Deer River] ▪ 1% annual probability		2 [Unlikely]
FUTURE LIKELIHOOD	▪ Possible increase in likelihood as a result of climate change[37] ▪ 1:100-year discharge = 1,870m3/s [Red Deer River]		3 [Possible]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Flooding and damage to major roadways and bridges, and disruption of supply chains	UC	4.8	Very high
Flooding and damage to municipal buildings and facilities	PR	3.7	High
Erosion of riverbanks and flooding of parks, green areas, or other natural assets	NA	3.4	Moderate
Flooding and damage to critical utility infrastructure (e.g., water treatment plant, etc.)	UC	3.0	Moderate
Increased runoff with potential adverse impacts on water quality (turbidity) and resultant increased treatment costs	UC	2.9	Moderate
Potential for evacuations and displacement requiring emergency response	EM	2.3	Low
Flooding of roadways and disruption of transportation networks (trails, pedestrian paths, low-lying roadways etc.)	AS	2.1	Low
Flooding of sports fields and other outdoor recreation assets (park equipment, skating rinks, etc.)	AS	1.1	Low

POTENTIAL VULNERABILITIES & RESILIENCE

- The City has a Flood Response and Recovery Plan (2019), and the Province of Alberta has conducted comprehensive hydraulic modelling and flood inundation mapping of river and flood hazards along the Red Deer River, Waskasoo Creek, and Piper Creek
- The City has a project underway to construct a berm to protect the wastewater treatment plan from a 1:400-year flood. The water treatment plant is designed to withstand a 1:100-year flood.
- The Province of Alberta is in the process of completing capacity enhancements at Dickson Dam to improve flood resilience .

36 Based on data from: Golder, 2022. Hydraulic Modelling and Flood Inundation Mapping Report: Red Deer River Hazard Study; and Alberta Flood Hazard Maps: https://floods.alberta.ca/

37 See: Wobus, C., Porter, J., Lorie, M., Martinich, J., & Bash, R. (2021). Climate change, riverine flood risk and adaptation for the conterminous United States. Environmental Research Letters, 16(9), 094034; Bush, E. and Lemmen, D.S. (Eds.) Canada's Changing Climate Report. Government of Canada, Ottawa, Ontario, pp 112-193; Muzik, I (2001) Sensitivity of Hydrologic Systems to Climate Change. Canadian Water Resources Journal, 26, 2.

38 See: Province of Alberta Dickson Cam Capacity Enhancements (Phase 2): https://majorprojects.alberta.ca/details/Dickson-Dam-Capacity-Enhancements-Phase-3/10607

A14 DROUGHT

DESCRIPTION	A lack of adequate precipitation, and drier than normal conditions, over a few months or longer		
CLIMATE DRIVER(S)	Hotter summers, drier summer conditions		
THRESHOLD	The 3-month summer (June-August) Standardized Precipitation Evapotranspiration Index (SPEI) drops to -1.5[39]		
LIKELIHOOD METHOD(S)	1 – Climate data analysis		
HISTORIC LIKELIHOOD	▪ ~1 drought event occurs every 10 years [0.1 drought events per year][40] ▪ <1% annual probability of a drought occurring historically		1 [Rare]
FUTURE LIKELIHOOD	▪ ~2.2 drought events projected to occur every 10 years [0.22 drought events per year][41] ▪ 3% annual probability of a drought occurring in the 2030s		3 [Possible]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Drying out of trees and green areas	NA	3.1	Moderate
Increased water demand	UC	3.0	Moderate
Drying out and increased maintenance of sports fields and manicured spaces (planted grasses, landscaping, etc.)	AS	1.9	Low
POTENTIAL VULNERABILITIES & RESILIENCE			
▪ Determinants of vulnerability include the existence (or lack thereof) of drought management plans and strategies (e.g., drought planning and preparedness, water management planning)			

39 The Standardized Precipitation Evapotranspiration Index (SPEI) is a water balance index based on the monthly difference between precipitation and potential evapotranspiration. The SPEI defines the value of -1.5 as 'Severely dry'

40 Source: www.ClimateData.ca

41 Source: www.ClimateData.ca

A15
SEVERE MULTI-YEAR DROUGHT[42]

DESCRIPTION	Persistent dry conditions over multiple years		
CLIMATE DRIVER(S)	Hotter summers, drier summer conditions		
THRESHOLD	The 12-month SPEI drops to -1.5 for 2 consecutive years[43]		
LIKELIHOOD METHOD(S)	1 – Climate data analysis		
HISTORIC LIKELIHOOD	▪ <1 multi-year drought event occurs every 10 years [<0.1 drought events per year][44] ▪ <1% annual probability of a multi-year drought occurring historically		1 [Rare]
FUTURE LIKELIHOOD	▪ ~1.7 multi-year drought events projected to occur every 10 years [0.17 drought events per year][45] ▪ 2% annual probability of a multi-year drought occurring in the 2030s		2 [Unlikely]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Potential loss of water supply	UC	4.9	High
Potential for public emergency requiring a response due to water shortage	EM	4.8	High

POTENTIAL VULNERABILITIES & RESILIENCE

- Determinants of vulnerability include the existence (or lack thereof) of drought management plans and strategies (e.g., drought planning and preparedness, water management planning)
- Insufficient raw water quantity as a result of 'drought' is identified as a moderate source water risk in the Drinking Water Safety Plan.

42 Note: the consequences of a severe multi-year drought would include the same consequences as the drought scenario at A14 - increased water demand, drying out of tree and green areas, and drying out and increased maintenance of sports fields and manicured spaces. For practical reasons, those impacts were only assessed once, under scenario A14.

43 The Standardized Precipitation Evapotranspiration Index (SPEI) defines the value of -1.5 as 'Severely dry'

44 Source: www.ClimateData.ca

45 Source: www.ClimateData.ca

A16
WILDLAND-URBAN INTERFACE FIRE

DESCRIPTION	An uncontrolled wildfire enters or starts in The City and causes damage[46]		
CLIMATE DRIVER(S)	Hotter temperatures, drier summer conditions		
THRESHOLD	The projected summer maximum (90th percentile) temperature [31°C][47]		
LIKELIHOOD METHOD(S)	1 – Climate data analysis		
HISTORIC LIKELIHOOD	▪ Summer maximum (90th percentile) temperature in the baseline period is 28°C ▪ 2-3% annual probability of 31°C summer maximum temperature		3 [Possible]
FUTURE LIKELIHOOD	▪ Summer maximum (90th percentile) temperature in the 2030s is projected to be 31°C ▪ 10% annual probability of 31°C summer maximum temperature		4 [Likely]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Potential for evacuations and displacement requiring emergency response	EM	4.9	Very high
Damage to trees and diminished urban tree canopy	NA	4.2	Very high
Damage to power lines and potential power outage	UC	3.9	Very high
Health and safety risks to municipal staff, including emergency response personnel	HS	3.8	Very high
Damage to buildings and facilities	PR	3.0	High
Damage to water and wastewater infrastructure including treatment plants, lift stations, and reservoirs	UC	3.0	High
Degradation of surface water quality, with consequences for the treatment of water	UC	3.0	High
Damage to sports fields and manicured spaces (planted grasses, landscaping, etc.)	AS	1.9	Moderate

POTENTIAL VULNERABILITIES & RESILIENCE

- Natural areas of high wildfire exposure and risk are based on local topography (slope, aspect, and elevation all influence fire risk) and the presence of fuels (trees, shrubs, etc.)
- The City has completed a Wildfire Hazard and Risk Assessment (2020) which identifies wildfire risk within the community, particularly within the wildland-urban interface.
- Red Deer Emergency Services conducted a Wildfire Hazard Assessment (2022) to identify hazardous areas in The City's forested areas in line with the FireSmart Program.
- FireSmart practices, such as the removal of woody forest debris, buffers/fire breaks, and fire-resistant construction materials on buildings can help reduce risk

46 Scenario as described in the Prometheus Wildfire Model developed through the Wildfire Hazard and Risk Assessment (2020)

47 Threshold consistent with Prometheus Wildfire Model developed through the Wildfire Hazard and Risk Assessment (2020)

A17
WILDFIRE SMOKE

DESCRIPTION	Smoke caused by wildfires enters into municipal boundaries		
CLIMATE DRIVER(S)	Hotter temperatures, drier summer conditions		
THRESHOLD	Visibility is reduced to 2 km or less due to wildfire smoke[48]		
LIKELIHOOD METHOD(S)	2 – Historic event occurrences 3 – Existing research		
HISTORIC LIKELIHOOD	▪ Between 1953-2023, there were 32 days where visibility was reduced to 2km or less from wildfire smoke (Average = 2 days of poor visibility per year) ▪ Annual probability = 99%		5 [Almost Certain]
FUTURE LIKELIHOOD	▪ Increasing[49]. For example: Projected 45% increase in the number of wildfire spread days and 200% increase in the area burned in surrounding "fire zones"[50]		5 [Almost Certain]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Negative health impacts (e.g., respiratory issues) and reduced productivity of workers	HS	3.0	High
Potential public health emergency requiring a response	EM	2.5	High
Impacts to building filtration (HVAC) systems and potential for increased maintenance and operating costs (e.g., filter replacement), and/or HVAC system upgrades	PR	2.5	High

POTENTIAL VULNERABILITIES & RESILIENCE

- The City of Red Deer has previously exceeded Canadian standards for air quality (fine particulate matter) as a result pollution from transportation, industrial and other emissions sources
- The following people are at a higher risk of health problems when exposed to wildfire smoke: Seniors, pregnant people, people who smoke, infants and children, outdoor workers, and people with existing illnesses or chronic health conditions[51].
- Aging buildings and facilities with poor or lacking ventilation systems are more vulnerable
- The presence (or lack thereof) of spaces for outdoor workers to seek refuge from smoke is a determinant of vulnerability.

48 Reduced visibility was chosen as the threshold for wildfire smoke, rather than fine particulate matter measurements as the major sources of nitrogen dioxide and volatile organic compounds in The City are the result of transportation, upstream oil and gas facilities, chemical manufacturing, and residential and commercial heating.

49 Reference: Boulanger, Y., et al., 2014: A Refinement of Models Projecting Future Canadian Fire Regimes using Homogeneous Fire Regime Zones, Can. J. For. Res. 44: 365–376; Wotton, B., et al., 2017: Potential Climate Change Impacts on Fire Intensity and Key Wildfire Suppression Thresholds in Canada, Environ. Res. Lett. 12 (2017) 095003; and Wang, X., et al., 2020: Projected Changes in Fire Size from Daily Spread Potential in Canada Over the 21st Century, Environ. Res. Lett. 15 (2020) 104048.

50 A "spread day" measures of the number of days suitable for active fire growth within the potential or observed lifetime of a fire. They are conditional on the joint occurrence of a drying period where fuel moisture is expected to support fire ignitions and survival, b) extensive fuels to support fire spread, c) extreme fire weather (hot, dry, and windy).

51 See: Health Canada – Wildfire smoke, air quality and your health: https://www.canada.ca/en/environment-climate-change/services/air-quality-health-index/wildfire-smoke.html#toc5

A18
SHIFTING NATURAL ECOREGIONS

DESCRIPTION	Alberta's grasslands, parkland and boreal regions are anticipated to shift northward with climate change. The natural regions that surround communities around the Red Deer area will no longer look the same in the future, providing different ecosystem services, and making them a different place to live.		
CLIMATE DRIVER(S)	Changing seasons, changing environmental conditions		
THRESHOLD	A shift from mainly Dry Mixedwood Forest to Mixed Grassland ecosystems[52]		
LIKELIHOOD METHOD(S)	3 – Existing research 5 – Professional judgment		
HISTORIC LIKELIHOOD	n/a		
FUTURE LIKELIHOOD	Unknown, as it depends on disturbances to the landscape (to create windows for change) as well as changes to the climate envelope of each ecoregion		3 [Possible]
POTENTIAL CONSEQUENCES	**CATEGORY**	**CONSEQUENCE SCORE**	**RISK LEVEL**
Changing suitability of tree species	NA	2.7	Moderate
Ecological impacts affecting terrestrial and aquatic health	NA	2.1	Low

POTENTIAL VULNERABILITIES & RESILIENCE

- The Urban Forest Management Plan outlines numerous significant challenges facing The City's urban forest, including climate change impacts
- A goal of The City's Environmental Master Plan is to protect and enhance the terrestrial and aquatic health of the natural heritage system.

52 Schneider, R., 2013, Alberta's Natural Subregions Under a Changing Climate: Past, Present and Future, Report prepared by Department of Biological Sciences, University of Alberta for the Biodiversity Management and Climate Change Adaptation Project, 97p.

APPENDIX B

DETAILED CLIMATE RISK ASSESSMENT RESULTS

There are generally five methods that can be used to assess the likelihood of a scenario occurring. These includes, from highest to lowest priority:

1. **Climate data analysis:** Download daily or annual time-series data from climate databases (e.g., Climate Data Canada) and approximate the likelihood of a defined threshold or intensity level occurring using statistical techniques;
2. **Historic event occurrences:** Analyze historical data obtained from nearby weather stations or other records of historic event occurrences;
3. **Existing research:** Existing assessments or research may contain relevant likelihood estimates, or data from which estimates can be generated or extrapolated. This includes for example, impacts with known return intervals such as a 1-100-year river flow level;
4. **Local sources:** Use local reports or news articles to estimate likelihoods for events that have affected the community in the past (e.g., wildfires); or
5. **Professional judgment:** The professional judgment of staff and local experts in the community can be used to estimate the likelihood of events occurring today and, in the future.

Table 6: Climate risk assessment results

RANK	CATEGORY	IMPACT	CONSEQUENCE	LIKELIHOOD SCORE	CONSEQUENCE SCORE	RISK LEVEL	RISK SCORE
1	EM	Wildland-Urban Interface Fire	Potential for evacuations and displacement requiring emergency response	4	4.9	Very high	19.6
2	NA	Invasive Species & Pests	Damaged trees or diminished urban tree canopy from insect pests (e.g., Emerald Ash Borer)	5	3.5	Very high	17.5
3	NA	Wildland-Urban Interface Fire	Damage to trees and diminished urban tree canopy	4	4.2	Very high	16.8
4	UC	Wildland-Urban Interface Fire	Damage to power lines and potential power outage	4	3.9	Very high	15.6
5	PR	Hail	Damage to buildings and facilities (roofing, cladding, etc.) including roof-mounted equipment (electrical, air conditioning, etc.)	4	3.9	Very high	15.6
6	HS	Wildland-Urban Interface Fire	Health and safety risks to municipal staff, including emergency response personnel	4	3.8	Very high	15.2
7	UC	River & Creek Flooding	Flooding and damage to major roadways and bridges, and disruption of supply chains	3	4.8	Very high	14.4
8	UC	Invasive Species & Pests	Increased weeds and maintenance of stormwater management system (ponds)	5	3.0	High	15.0

RANK	CATEGORY	IMPACT	CONSEQUENCE	LIKELIHOOD SCORE	CONSEQUENCE SCORE	RISK LEVEL	RISK SCORE
9	NA	High Winds	Damage to tree branches, impacts to the urban tree canopy	5	3.0	High	15.0
10	NA	Overheating Infrastructure	Heat stress on trees and green areas	5	3.0	High	15.0
11	HS	Smoke	Negative health impacts (e.g., respiratory issues) and reduced productivity of workers	5	3.0	High	15.0
12	HS	High Winds	Health and safety risks to municipal staff, including reduced workforce productivity during storms	5	3.0	High	15.0
13	UC	High Winds	Damage to power lines and potential power outage	5	2.9	High	14.5
14	PR	Overheating Infrastructure	Accelerated degradation of buildings and facilities (roofing, siding, etc.)	5	2.8	High	14.0
15	EM	Heat Wave	Potential public health emergency requiring a response	4	3.3	High	13.1
16	PR	Increased Space Cooling	Increased space cooling requirements and costs, including for the maintenance and upgrading of HVAC systems	4	3.2	High	12.8
17	EM	Smoke	Potential public health emergency requiring a response	5	2.5	High	12.5
18	PR	Smoke	Impacts to building filtration (HVAC) systems and potential for increased maintenance and operating costs (e.g., filter replacement), and/or HVAC system upgrades	5	2.5	High	12.5
19	HS	Heat Wave	Negative health impacts (e.g., heat exhaustion, heat stroke, etc.) and reduced productivity of workers	4	3.1	High	12.4
20	PR	Wildland-Urban Interface Fire	Damage to buildings and facilities	4	3.0	High	12.0
21	UC	Overland Flooding	Flooding, including from landslides and erosion, and damage to underground critical infrastructure (water, sewer, telecommunications, etc.)	3	4.0	High	12.0
22	UC	Wildland-Urban Interface Fire	Damage to water and wastewater infrastructure including treatment plants, lift stations, and reservoirs	4	3	High	12.0
23	UC	Wildland-Urban Interface Fire	Degradation of surface water quality, with consequences for the treatment of water	4	3	High	12.0
24	AS	Heat Wave	Reduced participation in summer outdoor recreation activities and programs	4	2.9	High	11.6

RANK	CATEGORY	IMPACT	CONSEQUENCE	LIKELIHOOD SCORE	CONSEQUENCE SCORE	RISK LEVEL	RISK SCORE
25	PR	River & Creek Flooding	Flooding and damage to municipal buildings and facilities	3	3.7	High	11.0
26	AS	Overland Flooding	Flooding of roadways due to culvert failure or road washout, and disruption of transportation networks	3	3.6	High	10.8
27	AS	Freezing Precipitation	Increased road and sidewalk maintenance costs (sanding, salting)	3	3.6	High	10.8
28	UC	Hail	Flooding of roadways and disruption of transportation networks due to blocked catch basins	4	2.7	High	10.8
29	NA	Freezing Precipitation	Damage to tree branches, impacts to the urban tree canopy	3	3.5	High	10.5
30	UC	Severe Multi-Year Drought	Potential loss of water supply	2	4.9	High	9.8
31	EM	Severe Multi-Year Drought	Potential for public emergency requiring a response	2	4.8	High	9.6
32	EM	Tornado	Potential for evacuations and displacement requiring emergency response	1	4.9	High	4.9
33	UC	Tornado	Damage to power lines and potential power outage	1	4.8	High	4.8
34	UC	Tornado	Damage to water and wastewater infrastructure including treatment plants, lift stations, and reservoirs	1	4.8	High	4.8
35	PR	Tornado	Damage to buildings and facilities (roofing, cladding, etc.)	1	4.7	High	4.7
36	AS	Invasive Species & Pests	Increased weeds and maintenance of sports fields, manicured spaces (planted grasses, landscaping, etc.), and transportation corridors (ditches, trails, etc.)	5	2.2	Moderate	11.0
37	NA	River & Creek Flooding	Erosion of riverbanks and flooding of parks, green areas, or other natural assets	3	3.4	Moderate	10.2
38	UC	Reduced Natural Water Quality	Increased surface water temperatures leading to degradation of surface water quality, with consequences for the treatment of water	5	2.0	Moderate	10.0
39	UC	Overheating Infrastructure	Reduced efficiency of power lines and potential power outages	5	2.0	Moderate	10.0
40	AS	Overheating Infrastructure	Accelerated degradation of road and sidewalk infrastructure (e.g., concrete and asphalt buckling) and increased maintenance costs	5	2.0	Moderate	10.0

RANK	CATEGORY	IMPACT	CONSEQUENCE	LIKELIHOOD SCORE	CONSEQUENCE SCORE	RISK LEVEL	RISK SCORE
41	PR	High Winds	Damage to buildings and facilities (roofing, cladding, etc.)	5	2.0	Moderate	10.0
42	NA	Reduced Natural Water Quality	Increased risk of algae blooms and management costs	5	2.0	Moderate	10.0
43	NA	Reduced Natural Water Quality	Increased surface water temperatures affecting terrestrial and aquatic health	5	2.0	Moderate	10.0
44	AS	High Winds	Damage to municipal assets (vehicles, equipment, structures, etc.)	5	1.9	Moderate	9.5
45	NA	Drought	Drying out and increased watering requirements and maintenance of trees and green areas	3	3.1	Moderate	9.3
46	UC	River & Creek Flooding	Flooding and damage to critical infrastructure (e.g., water treatment plant)	3	3.0	Moderate	9.0
47	UC	Freezing Precipitation	Damage to power lines and potential power outage	3	3.0	Moderate	9.0
48	UC	Drought	Increased water demand	3	3.0	Moderate	9.0
49	UC	River & Creek Flooding	Increased runoff with potential adverse impacts on water quality (turbidity) and resultant increased treatment costs	3	2.9	Moderate	8.7
50	PR	Freezing Precipitation	Damage to buildings and facilities, namely roof-mounted equipment (electrical, air conditioning, etc.)	3	2.8	Moderate	8.4
51	NA	Hail	Damage to tree branches, impacts to the urban tree canopy	4	2.1	Moderate	8.4
52	NA	Shifting Natural Ecoregions	Changing suitability of tree species	3	2.7	Moderate	8.1
53	AS	Hail	Damage to vehicles and outdoor equipment and structures	4	2.0	Moderate	8.0
54	NA	Overland Flooding	Flooding and erosion of parks, green areas, or other natural assets, including from landslides and erosion	3	2.6	Moderate	7.8
55	AS	Overheating Infrastructure	Heat stress on sports fields and manicured spaces (planted grasses, landscaping, etc.)	5	1.6	Moderate	7.8
56	AS	Wildland-Urban Interface Fire	Damage to sports fields and manicured spaces (planted grasses, landscaping, etc.)	4	1.9	Moderate	7.6
57	AS	Reduced Outdoor Recreation	Reduced quality and reliability of natural outdoor ice and snow, affecting winter recreation services (outdoor rinks, Nordic skiing, etc.)	4	1.8	Moderate	7.2

RANK	CATEGORY	IMPACT	CONSEQUENCE	LIKELIHOOD SCORE	CONSEQUENCE SCORE	RISK LEVEL	RISK SCORE
58	NA	Tornado	Damage to tree branches, impacts to the urban tree canopy	1	4.4	Moderate	4.4
59	HS	Tornado	Health and safety risks to municipal staff, including emergency response personnel	1	4.0	Moderate	4.0
60	AS	Tornado	Damage to municipal assets (vehicles, equipment, structures, etc.)	1	3.6	Moderate	3.6
61	UC	Increased Waste	Increased weight (kilograms) of waste, additional waste management costs	5	1.4	Low	7.0
62	EM	River & Creek Flooding	Potential for evacuations and displacement requiring emergency response	3	2.3	Low	6.9
63	PR	Overland Flooding	Flooding (water infiltration) of buildings and facilities	3	2.3	Low	6.9
64	HS	Freezing Precipitation	Potential for falls, injuries, and traffic accidents due to slippery sidewalks and roads	3	2.2	Low	6.6
65	AS	River & Creek Flooding	Flooding of roadways and disruption of transportation networks (trails, pedestrian paths, low-lying roadways etc.)	3	2.1	Low	6.3
66	NA	Shifting Natural Ecoregions	Ecological impacts affecting terrestrial and aquatic health	3	2.1	Low	6.3
67	UC	Overland Flooding	Increased runoff, with potential adverse impacts on water quality (turbidity) and resultant increased treatment costs	3	2.0	Low	6.0
68	AS	Drought	Drying out and increased watering requirements and maintenance of sports fields and manicured spaces (planted grasses, landscaping, etc.)	3	1.9	Low	5.7
69	AS	Overland Flooding	Flooding of sports fields	3	1.7	Low	5.1
70	EM	High Winds	Potential for evacuations and displacement requiring emergency response	5	1.0	Low	5.0
71	AS	River & Creek Flooding	Flooding of sports fields and other outdoor recreation assets	3	1.1	Low	3.4

Figure 11 through 16 provide risk matrices for each impact-consequence category: Health and Safety (HS), Natural Assets (NS), Buildings and Properties (PR), Critical Utilities and Services (UC), Municipal Assets and Services (AS), and Emergency Management (EM).

Figure 11 Health, Safety, Productivity and Wellbeing of Municipal Staff Climate Risk Matrix

CONSEQUENCE	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost certain (5)
Very high (5)					
High (4)	Health and safety risks from tornado (59)			Health and safety risks from wildfire (6)	
Medium (3)				Negative health impacts from heat waves (19)	Negative health impacts from wildfire smoke (11) Health and safety risks from high winds (12)
Low (2)			Health and safety risks from freezing rain (64)		
Very low (1)					

LIKELIHOOD

Figure 12 Natural Assets Climate Risk Matrix

CONSEQUENCE	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost certain (5)
Very high (5)					
High (4)	Damage to trees from tornado (58)		Damage to trees from freezing rain (29) River flooding impacts to parks and green areas (37)	Damage to trees from wildfire (3)	Damage to trees from invasive pests (2)
Medium (3)			Drying out of trees and green areas from drought (45) Changing suitability of tree species (52) Overland flooding impacts to parks and green areas (54)		Damage to trees from high winds (9) Heat stress on trees (10)
Low (2)			Impacts to terrestrial and aquatic health from shifting ecoregions (66)	Damage to trees from hail (51)	Increased risk of algal blooms from reduced water quality (42) Impacts to terrestrial and aquatic health from reduced water quality (43)
Very low (1)					

LIKELIHOOD

Figure 13 Buildings and Properties Climate Risk Matrix

CONSEQUENCE						
	Very high (5)	Damage to buildings from tornado (35)				
	High (4)			Damage to buildings from river flooding (25)	Damage to buildings from hail (5)	
	Medium (3)			Damage to buildings from freezing rain (50)	Increased space cooling (16) Damage to buildings from wildfire (20	Accelerated degradation of buildings from heat (14) Impacts to building filtration (HVAC) systems from smoke (18)
	Low (2)			Overland flooding of buildings (63)		Damage to buildings from high winds (41)
	Very low (1)					
		Rare (1)	**Unlikely (2)**	**Possible (3)**	**Likely (4)**	**Almost certain (5)**
		LIKELIHOOD				

Figure 14 Critical Utilities and Services Climate Risk Matrix

CONSEQUENCE	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost certain (5)
Very high (5)	Tornado damage to power lines (33) Tornado damage to water and wastewater infrastructure (34)	Loss of water supply from severe drought (30)	River flooding damage to critical infrastructure (7)		
High (4)			Overland flooding damage to underground critical infrastructure (21)	Wildfire damage to power lines (4)	
Medium (3)			Flooding damage to critical infrastructure (46) Freezing rain damage to power lines (47) Increased water demand from drought (48) Increased turbidity from river flooding (water quality) (49)	Flooding of roads from hail (blocked catch basins) (28) Wildfire damage to water and wastewater infrastructure (22) Wildfire degradation of surface water quality (23)	Invasive weeds impact stormwater management system (8) High wind damage to power lines (13)
Low (2)			Increased turbidity from overland flooding (water quality) (67)		Reduced efficiency of power lines from heat (39) Increased surface water temperatures, degradation of water quality (38)
Very low (1)					Increased weight of waste from precipitation (61)

LIKELIHOOD

Figure 15 Municipal Assets and Services Climate Risk Matrix

CONSEQUENCE	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost certain (5)
Very high (5)					
High (4)	Asset damage from tornado (60)		Overland flooding damage to roadways and transportation disruption (26) Increased road and sidewalk maintenance from freezing rain (27)		
Medium (3)				Reduced participation in summer recreation from heat waves (24)	
Low (2)			River flooding of transportation networks (65) Drying out of sports fields and landscaped areas from drought (68) Overland flooding damage to sports fields and landscaped areas (69)	Hail damage to vehicles and outdoor equipment (53) Damaged to landscaped areas from wildfire (56) Reduced winter recreation (57)	Increased maintenance of landscaped areas from weeds (36) Accelerated degradation of roads and sidewalks from hotter summers (40) Asset damage from high winds (44) Heat stress on sports and manicured spaces from hotter summers (55)
Very low (1)			River flooding damage to sports fields and landscaped areas (71)		

LIKELIHOOD

Figure 16 Emergency Management Climate Risk Matrix

CONSEQUENCE						
	Very high (5)	Evacuations from tornado (32)	Drought and water shortage emergency (31)		Evacuations from wildfire (1)	
	High (4)					
	Medium (3)				Heat wave health emergency (15)	Wildfire smoke health emergency (17)
	Low (2)			Evacuations from river flooding (62)		
	Very low (1)					Evacuations from high winds (70)
		Rare (1)	**Unlikely (2)**	**Possible (3)**	**Likely (4)**	**Almost certain (5)**
		LIKELIHOOD				

APPENDIX C

CLIMATE ADAPTATION ACTION PRIORITIZATION

The framework and decision criteria used to evaluation climate adaptation actions for The City of Red Deer is provided below in Table 7 and Table 8. On the cost side, in addition to total costs (i.e., any required capital expenditures and ongoing annual expenses), the potential for negative side-effects—for example, increasing greenhouse gas emissions—is captured. Feasibility considers whether implementation is possible, given technological, legal and/or economic constraints. Acceptability captures whether the public and elected officials would accept and implement the action.

On the benefit side, the effectiveness of the action in achieving the stated adaptation goals is clearly important. But it is also important to capture equity and whether the action provides benefits across The City and across Departments. To help manage uncertainty about future levels of climate change, a higher priority is given to actions that offer greater flexibility to be modified or scaled-up or down over time in response to new information. Finally, the potential for the action to generate co-benefits for The City in addition to reducing risk is captured.

As some criteria are deemed to be more important than others, several factors on both the cost and benefit side are weighted differently, as noted in Table 7 and Table 8. The following calculations were used to determine the cost-benefit score for each potential action:

- Weighted average costs = [Total Capital Cost score x 2 + Feasibility score x 2 + Negative side-effects score x 1 + Acceptability score x 1] / 6
- Weighted average benefits = [Effectiveness score x 3 + Co-benefit score x 1 + Equity score x 1 + Flexibility score x 1] / 6
- Benefit-cost ratio = weighted average benefits / weighted average costs

The results of the multi-criteria, cost-benefit analysis for each action is provided in Table 9.

Table 7: Criteria for evaluating potential costs of climate adaptation actions

	DECISION CRITERIA [WEIGHT]	DESCRIPTION	SCORE = 1	SCORE = 3	SCORE = 5
COSTS	Capital costs [2]	The total costs of the action including, for example, upfront investment (capital) costs and annual recurring (operation and maintenance) expenses. **Prioritize: actions with low total costs**	Upfront investment and annual cost of action represent minimal cost and have little to no impact on existing budgets Estimated costs of <$30,000	Upfront investment and annual cost of action is within existing budgets but require financial allocation and moderate increase in resource requirements. Estimated costs of $125,000 - $400,000	Upfront investment and annual cost of action represent a significant increase to existing budgets and require additional resources to implement. Estimated costs of >$1,500,000
	Feasibility [2]	The capacity of The City to successfully implement the action, including access to necessary knowledge, technologies, human resources, budgets etc., all of which could act as barriers to action. Feasibility is also influenced by local and regional political preferences and priorities, as well as the presence of entry points or windows of opportunity to adopt the action, like upcoming revisions to strategic plans or the construction of a new building. **Prioritize: the most feasible actions.**	No or minor technological, knowledge, staff, political, or financial barriers to action	Moderate technological, knowledge, staff, political, or financial barriers to action	Significant technological, knowledge, staff, political, or financial barriers to action
	Negative side-effects [1]	Unintentional negative impacts for other City economic, social, or environmental objectives. Examples include actions that increase GHG emissions, increase risks to other groups or sectors that are not the target of the action, or that limit future climate action. **Prioritize: actions that produce no or few negative side-effects.**	No or minor unintentional negative impacts or consequences for The City	Unintentional negative impacts with moderate consequences for The City	Unintentional negative impacts with significant consequences for The City
	Acceptability [1]	The likely degree of support for the action from City staff, decision-makers, and Council, as well as the public or other groups/organizations affected by the action. **Prioritize: actions with the broadest support across the community.**	The vast majority of City staff, decision-makers, Council, as well as the public and other groups/ organizations would support the action	Most City staff, decision-makers, Council, as well as the public and other groups/organizations would support the action, but there may be some opposition	Most City staff, decision-makers, Council, as well as the public and other groups/organizations would not support the action

Table 8: Criteria for evaluating potential benefits of climate adaptation actions

	DECISION CRITERIA [WEIGHT]	DESCRIPTION	SCORE = 1	SCORE = 3	SCORE = 5
BENEFITS	Effectiveness [3]	The degree to which the action achieves the goal(s) of the Climate Change Action Plan—i.e., reduces anticipated adverse consequences of a climate risk. **Prioritize: actions that provide the largest reduction in risk.**	Minor reduction in a priority climate risk	Moderate reduction in one or more priority climate risks	Significant reduction in one or more priority climate risks
	Co-benefits [1]	Intentional or unintentional positive side-effects of the action for other City economic, social, or environmental objectives. Examples include actions that provide recreation opportunities, improve ecosystem services, support employment opportunities, improve physical or mental health, reduce greenhouse gas emissions, support social interactions, and build social capital. **Prioritize: actions the contribute positively to multiple other City economic, social, or environmental objectives.**	No or minor positive contribution to other City economic, social, or environmental objectives	Modest positive contribution to other City economic, social, or environmental objectives	Significant positive contribution to other City economic, social, or environmental objectives
	Equity [1]	The fair and equitable distribution of the net benefits of an action. Ideally, actions should benefit the broadest possible range and number of City staff, Departments, and/or community members. **Prioritize: actions that benefit a broad range and number of City staff, Departments, and community members, and provide benefits across The City.**	Benefits accrue to a narrow segment of City staff, Departments, and/or community members, and provide benefits at a very specific site	Benefits accrue to a wide segment of City staff, Departments, and/or community members, or provide benefits across multiple areas of The City	Benefits accrue to a wide segment of City staff, Departments, and/or community members, and provides benefits across The City
	Flexibility [1]	Adjustable actions that can be implemented incrementally and readily adapted (i.e., scaled up or down, or brought forward or deleted at minimal additional costs) if future climate and socioeconomic conditions change or turn out to be different from those expected today. **Prioritize: actions that are readily adjustable to changing climate and socioeconomic conditions and City priorities, with minimal transition costs.**	Action has no to limited scope to be modified	Action can be partially modified, but at moderate additional costs	Action can be fully adjusted at minimal additional costs

Table 9: Climate adaptation action evaluation results

ACTION	AVERAGE COSTS	AVERAGE BENEFITS	BENEFIT-COST RATIO	RANK
Revise the Natural Areas Policy to consider future climate changes, impacts and climate adaptation measures	1.0	3.7	3.7	1
Identify and designate one or more public facilities to act as refuge areas during extreme weather events, including heat and wildfire smoke, and considering the needs of vulnerable populations. These facilities should be well communicated to the public	1.0	3.7	3.7	1
Update The City Extreme Weather Policy to ensure clear guidelines for City staff and residents related to wildfire smoke and heat, including go/no go recommendations for outdoor events	1.0	3.7	3.7	1
Update the "Floodplain Overlay Provision" in the Land Use Bylaw with new data from the Red Deer River Flood Hazard Study	1.0	3.7	3.7	1
Develop and implement an 'Adopt a Storm Drain' program to encourage citizens to support The City in clearing debris from storm drains	1.0	3.7	3.7	1
Integrate FireSmart considerations into existing and new City Bylaws where appropriate	1.2	3.7	3.1	6
Develop a Tree Protection Bylaw or Policy that includes items around tree retention, valuation, and replacement	1.2	3.7	3.1	6
Update City procurement policy to ensure consideration of climate risks and resilience features in all City projects	1.5	4.7	3.1	8
Develop a Sustainable (Climate Resilient) Building Policy which includes new guidelines and requirements for climate resilience features for new buildings and major renovation projects to protect buildings and assets from heat, wildfire smoke and extreme weather. For example, including insulation, air tightness, filtration systems, impact resistant roofing and siding materials, shade trees for buildings, etc.	1.7	4.7	2.8	9
Enhance FireSmart education and citizen engagement, for example through online resources, material development, and presence at community events	1.3	3.7	2.8	10
Assess backup power supplies and capabilities at City facilities to identify gaps and potential retrofitting requirements	1.3	3.7	2.8	10
Develop a corporate city-wide business continuity plan for city staff in response to extreme weather events	1.3	3.7	2.8	10
Support the Provincial Government to develop a Water Shortage Response Plan which considers potential future alternative water sources and storage options, mutual aid agreements and water supply for firefighting.	1.3	3.7	2.8	10
Develop a policy to prioritize the placement of electrical wires underground in new City developments/projects	1.3	3.3	2.5	14
Conduct research and develop local guidance on the climatic suitability of tree species in Red Deer	1.3	3.3	2.5	14

ACTION	AVERAGE COSTS	AVERAGE BENEFITS	BENEFIT-COST RATIO	RANK
Integrate climate risk and adaptation considerations into all City strategic plans when updating	1.7	4.2	2.5	16
Update the Land Use Bylaw with new climate resilience requirements for new development in including increased stormwater absorption, natural areas protection, and tree coverage and structures for shade	1.7	4.2	2.5	16
Update the Stormwater Master Plan to include stormwater system modelling with consideration of the climate change impacts on heavy rainfall events and aquatic invasive species management (monitoring and response) at stormwater management facilities	1.7	4.2	2.5	16
Conduct research on climate resilient building materials and infrastructure inputs, for example more appropriate concrete and asphalt mixes, vegetative (green) roofs, light coloured building materials, etc.	1.3	3.2	2.4	19
Develop guidelines/policy for the implementation of green infrastructure / low impact development to protect landscapes and people from heat, heavy rainfall and flooding and extreme weather. For example, greenspaces for cooling, permeable pavement, natural area protection, bioswales, raingardens, xeriscaping/drought tolerant plants, shading structures, etc.	1.5	3.5	2.3	20
Support the development of a source water protection plan for The City's drinking water supply which considers climate-related risks (e.g., wildfires, flooding, drought).	1.7	3.8	2.3	21
Expand the hybrid work policy to encourage staff to stay home and avoid travel during smoke/heat events/extreme weather	1.3	3.0	2.3	22
Modify staffing/human resourcing allocations to ensure more frequent rotations for outdoor work to minimize wildfire smoke exposure	1.3	3.0	2.3	22
Develop a Neighbourhood Resilience Program to facilitate social connection, information sharing, climate awareness, and emergency response activities amongst City residents at the neighborhood scale	2.0	4.5	2.3	22
Update the Emergency Management Plan and City-wide Evacuation Plans to account for the increased frequency and severity of some climate impacts and events	1.7	3.7	2.2	25
Enhance mental health supports for City staff, particularly following extreme weather and climate events	1.5	3.2	2.1	26
Work with sporting groups and other organizations to explore opportunities to move outdoor activities indoors (i.e. soccer, baseball practice, etc.)	1.3	2.7	2.0	27
Enhance funding and resources for The City's emergency management department, including additional staff and funding for emergency preparedness planning and for Emergency Social Services supplies and activities	1.7	3.3	2.0	27
Develop a wildfire management program to provide specific training and direct staff and resources towards wildland fire mitigation activities	2.0	4.0	2.0	27
Update (climate adjust) Intensity-Duration-Frequency (IDF) curves based on future heavy rainfall projections	2.0	4.0	2.0	27

ACTION	AVERAGE COSTS	AVERAGE BENEFITS	BENEFIT-COST RATIO	RANK
Install additional water features (e.g., fountains) at popular public spaces across The City	1.7	3.3	2.0	27
Enhance building inspections and maintenance schedules to account for the increased frequency and severity of some climate impacts and events	2.0	3.7	1.8	32
Increase maintenance and inspection of stormwater infrastructure.	2.0	3.7	1.8	32
Develop a program and provide fire safety training for individuals at urban encampments in public areas	2.0	3.7	1.8	32
Conduct an urban heat island assessment to identify and map vulnerability to heat extremes and provide recommendations for mitigation	2.0	3.7	1.8	32
Develop an Asset Management Plan that considers future climate changes and potential implications for asset management and renewal, including enhanced GIS modelling and consideration of green natural features and infrastructure	2.0	3.7	1.8	32
Assess the risks of climate change to The City's electricity distribution system, specifically to identify risks to the above ground network and prioritize the placement of wires underground in high-risk areas	2.0	3.7	1.8	32
Conduct research to inventory and quantify the benefits of ecological goods and services across The City	2.0	3.7	1.8	32
Develop climate lens tool for new municipal infrastructure projects to use to identify the climate considerations the project will include when being developed	2.5	4.5	1.8	39
Update and formalize The City Biodiversity Strategy to account for the impacts of climate change, including enhanced protection of natural areas (soils, grasslands, seasonal streams, natural treed areas, wetlands, terrestrial and aquatic species habitats, protected species management, etc.)	2.0	3.5	1.8	40
Update and formalize the Integrated Pest Management (IPM) program and manual to account for the potential effects of climate change on invasive species and pests, with both proactive and reactive strategies, to detect, prevent and control new and emerging invasive species and pests, including elm and ash trees. Strategies can include utilizing GIS to monitor and model the movement of invasive pests and diseases and integrating with the IPM program.	2.3	4.0	1.7	41
Update engineering design guidelines and contractor specifications with green infrastructure / low impact development, including landscaping requirements related to tree planting and soil protection (for example, increase minimum depth from 6" to 12" for turf areas. Ensure volume and depth suitable for trees, soil protection during construction, minimize transfer of weeds/ disease, increase areas around trees, etc.).	2.3	4.0	1.7	41
Upgrade the stormwater management system to protect The City from more heavy rainfall events	2.7	4.5	1.7	43
Conduct a climate change resiliency assessment of the electrical grid to determine future loads and impacts associated with extreme heat and other climate events and ensure the grid can handle increased/changing loads	2.0	3.3	1.7	44

ACTION	AVERAGE COSTS	AVERAGE BENEFITS	BENEFIT-COST RATIO	RANK
Increase tree management and maintenance across The City including watering, tree pruning and deadfall clearing in wooded areas, and removal of damaged/diseased trees	2.3	3.8	1.6	45
Purchase additional protective equipment for City staff (masks for smoke, cooling materials for uniforms, etc.)	1.7	2.7	1.6	46
Develop educational materials targeted at City staff and the public related to weather and climate-related risks (heat, smoke, flooding, extreme weather) and steps to stay safe (e.g., shelter-in-place locations). This should include messaging about how The City is adapting its assets, services, and operations to keep the community safe.	2.0	3.2	1.6	47
Update the Utility Bylaw to limit tree intrusion to underground (roots) and overhead infrastructure (tree height, etc.) [Plant deep rooted trees in parks spaces or places where there are no future conflicts, shallow rooting trees in shared spaces (with other utilities)]	1.5	2.3	1.6	48
Establish an internal communications system, across and within departments, to provide more consistent communications and real-time messaging to staff, including information about weather and climate-related risks (heat, smoke, flooding, extreme weather) and steps to stay safe and keep the community safe	2.0	3.0	1.5	49
Create and fund a City-wide stormwater utility to provide additional resources for the management of The City's stormwater system and prevention of overland flooding.	3.0	4.5	1.5	49
Identify an appropriate site (e.g., a vulnerable or high water use landscape) to implement a drought tolerant landscaping project to showcase the use of climate-resilient plants and grasses, and xeriscaping techniques	2.0	3.0	1.5	49
Identify a specific site (e.g., a high use, sun-exposed park) to install an outdoor covered space(s) to provide shading	1.7	2.5	1.5	49
Retrofit buildings to provide better protection from heat, wildfire smoke and extreme weather, for example back-up power systems, better insulation, air tightness, improved HVAC (Heating, Ventilation and Air Conditioning) and filtration systems, impact resistant materials, and re-enforcement of roof-mounted equipment to provide hail and wind protection	3.2	4.5	1.4	53
Establish sanitation process (policy) for regulated woody debris disposal (including post storm events and/or when a regulated pest comes through).	1.7	2.3	1.4	54
Enhance tree planting across The City focused on providing shade protection and stormwater management, plant more trees, and ensure planted trees are suitable for the future climate of Red Deer	2.8	3.8	1.4	55
Purchase additional wildland fire fighting equipment and supplies	2.0	2.7	1.3	56
Develop and implement a soil conservation strategy to protect soil across The City from degradation.	2.3	3.0	1.3	57
Purchase temporary flood mitigation solutions (tiger dams) for rapid deployment during flooding events	2.3	3.0	1.3	57

ACTION	AVERAGE COSTS	AVERAGE BENEFITS	BENEFIT-COST RATIO	RANK
Develop a new vector-borne disease monitoring program to better track mosquitoes and other new/potential vector borne diseases	2.3	2.8	1.2	59
Enhance funding and resources for The City's Parks department focused on enhanced tree planting, management, and maintenance	1.8	2.0	1.1	60
Install berms and other permanent flood mitigation measures as needed along the Red Deer River, Waskasoo Creek and Piper Creek.	3.2	3.3	1.1	61
Purchase new snow clearing equipment to more effectively clear and clean roads and pathways following freezing rain events	2.3	2.2	0.9	62

All One Sky
— FOUNDATION —

ALL ONE SKY FOUNDATION is a not-for-profit, charitable organization established to help vulnerable populations at the crossroads of energy and climate change. We do this through education, research, and community-led programs, focusing our efforts on adaptation to climate change and energy poverty. Our vision is a society in which ALL people can afford the energy they require to live in warm, comfortable homes, in communities that are resilient and adaptive to a changing climate.

THE CITY OF
Red Deer