Town of CANMORE

Climate Emergency Action Plan

Climate Risk and Vulnerability Assessment Report

January 2024

Territory Acknowledgement

The Town of Canmore is located within Treaty 7 region of Southern Alberta. In the spirit of respect, reciprocity and truth, we honour and acknowledge the Canmore area, known as "Chuwapchipchiyan Kudi Bi" (translated in Stoney Nakoda as "shooting at the willows") and the traditional Treaty 7 territory and oral practices of the Îyârhe Nakoda (Stoney Nakoda)—comprised of the Bearspaw First Nation, Chiniki First Nation, and Goodstoney First Nation—as well as the Tsuut'ina First Nation and the Blackfoot Confederacy comprised of the Siksika, Piikani, and Kainai. We acknowledge that this land is also home to the Rocky View Métis District 4 within the Battle River Territory. We acknowledge all Nations who live, work, and play and help us steward this land and honour and celebrate this territory. We commit to working to live in right relations and to advance Truth and Reconciliation.

Table of Contents

Territory Acknowledgement 1
Disclaimer | Purpose of Document 3
Key Terms 4
Introduction 7
The Future of Canmore 7
Previous Climate Change Work 10
Policy Context 10
Mitigation and Adaptation Working Together 12
Climate Risk and Vulnerability 13
Detailed Hazard Modelling Approach 33
Climate Risk and Vulnerabilities Analysis 41
Ecoregion Changes 41
Wildfire and Smoke 46
Steep Creeks 54
Extreme Heat 61
Riverine Flooding 75
Water Security 92
Conclusion 96
Appendix 1: Data, Methods, and Assumptions 97
Appendix 2: Historic Hazard Scan 98
Appendix 3: Hazard Assessment 101
Timescale of Assessment 101
Scope of Boundaries for Assessment 101
Data Gaps 102
Hazard Assessment 102
Appendix 4: Vulnerability Assessment 109
Appendix 5: Consequences Assessment 113

Disclaimer

Reasonable skill, care, and diligence have been exercised to assess the information acquired during the preparation of this analysis, but no guarantees or warranties are made regarding the accuracy or completeness of this information. This document, the information it contains, the information and basis on which it relies, and the associated factors are subject to changes that are beyond the control of the authors. The information provided by others is believed to be accurate but has not necessarily been verified.

This analysis includes strategic-level estimates of climate risk and vulnerability that should not be relied upon for design or other purposes without verification. The authors do not accept responsibility for the use of this analysis for any purpose other than that stated below and do not accept responsibility to any third party for the use, in whole or in part, of the contents of this document. This analysis applies to the Town of Canmore, and cannot be applied to other jurisdictions without analysis. Any use by the Town of Canmore, its sub-consultants, or any third party, or any reliance on or decisions based on this document, are the responsibility of the user or third party.

Purpose of This Document

This document summarizes the climate hazards and risks in Canmore, and the vulnerability of the people, businesses, infrastructure, and natural spaces in Canmore to those climate hazards. Using climate change modelling for the region, Sustainability Solutions Group (SSG) completed a review of current and projected climate impacts and growth and development in Canmore to compare the damages incurred now and in the future from climate hazards. Appendix 1 provides a detailed description of the modelling methodology, data sources, and assumptions. This risk and vulnerability analysis focuses on the specific climate hazards that impact Canmore currently and in the future.

Key Terms

Adaptive capacity: The ability of built, natural, human, and social systems to adjust and/or cope with climate change.

Climate: The long-term weather patterns of a given location averaged over a period of time, typically 30 years.

Climate adaptation: The process by which built, natural, social, and human systems adjust to actual or expected climate change. Adaptation seeks to manage unavoidable harm and leverage beneficial opportunities that result from the changing climate.

Climate change: Changes in long-term weather patterns caused by natural phenomena and exacerbated by human activities that alter the chemical composition of the atmosphere by the build-up of greenhouse gases, which trap heat and reflect it back to Earth's surface.

Climate change impacts (also commonly referred to as consequences or outcomes): The effects of climate hazards on natural, built, and human systems. This includes the effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure. Impacts generally manifest in some form of damage, disruption, or complete loss and can be generally categorized as physical, social, or economic. Impacts can be considered direct (e.g., damage to a building) or indirect (e.g., loss of a job or income as a result of damage to a building). Impacts result from the interaction of climate events or trends (occurring within a specific time period) and the vulnerability of an exposed society or system.

Climate change mitigation: Any activities (e.g., policy, program, regulation, infrastructure, activity, other project-based measures) that contribute to the reduction of greenhouse gas concentrations in the atmosphere.

Climate hazards: The potential occurrence of climate-related physical events (e.g., heat waves, floods) that may result in loss of life, injury, or other health impacts, as well as damage to natural, built, or human systems.

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected by climate-related events (e.g., assets located in a floodplain are more exposed to the impacts of climate change than those outside of the floodplain).

Equity: The principle of recognizing that fairness and justice in processes and outcomes requires recognizing and addressing the role of race, gender, socioeconomic status, sexuality, and other characteristics of individuals and communities. In regards to climate change, some communities and individuals experience disproportionate impacts from climate change and climate emergencies. Equity helps us understand how the impacts of climate change, including the costs and benefits, are distributed across society and ensures that all people share the benefits of climate action.

No net loss/Net gain: A goal for a development project, policy, plan, or activity in which the impacts on biodiversity are balanced or outweighed by measures taken to avoid and minimize the impacts, restore affected areas, and offset the residual impacts so that no loss remains. Where the gain exceeds the loss, the term 'Net Gain' may be used instead.

Representative Concentration Pathway (RCP): A GHG atmospheric concentration pathway used by the Intergovernmental Panel on Climate Change to estimate potential trajectories out to 2100. These pathways are used to model how climate change will be modified by various human activities over time.

Resilience: The capacity of a system, either social, economic, or environmental, to cope with hazardous events or disturbances. This can involve responding to hazards or reorganizing systems in ways that allow them to maintain their essential function, identity, and structure.

Risk: The potential for negative consequences where something of value is at stake and where the outcome is uncertain. It is often represented as the probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. This mathematical approach requires the consideration of vulnerability and exposure intrinsically for it to be valuable, as risk results from the interaction of vulnerability, exposure, and hazard. In this context, the term primarily refers to the risks of climate change impacts. A risk assessment evaluates the vulnerabilities, exposure, and climate change hazards for a particular sector or community and identifies the likelihood of these risks occurring as well as their possible consequences.

Sensitivity: The extent to which rising levels of greenhouse gases will affect Earth's temperature. A high sensitivity to climate change means more adaptation actions will need to be implemented to avoid large climate impacts, while a lower sensitivity would mean we have more time to adapt.

Standardized Precipitation Evapotranspiration Index (SPEI): A multidimensional variable to measure drought.

Vulnerability: The likelihood of being adversely affected due to characteristics of human or social-ecological systems that are exposed to hazardous climatic events or trends. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (low adaptive capacity). Ecosystems, geographic areas, assets, humans, etc. can be classified as vulnerable. This is of concern if a vulnerability in one area (e.g., humans) increases as a result of potential impairment or increased vulnerability in other areas (e.g., assets). A vulnerability assessment is a quantitative and/or qualitative assessment of potential adverse social, economic, and ecological impacts due to hazard exposure.

Introduction

The Future of Canmore

Canmore is a beautiful, vibrant community nestled in the Rocky Mountains. It draws millions of visitors each year, with people coming to enjoy the incredible natural beauty the area has to offer. As a community with such a large tourism industry, Canmore experiences unique pressures to accommodate the influx of visitors while maintaining the quality of life for Canmore residents.

Canmore has a growing population but limited areas in which to develop. Balancing this growth with the increased risks from climate change requires careful planning, using anticipated climate risks to shape current decisions. Understanding what climate hazards are the most pressing for both the Town and the community of Canmore is essential to developing the tools and processes needed to prepare for these hazards.

A Growing Community

Canmore is a growing community, with the population expected to increase from 16,100 permanent residents in 2021 to 27,000 people by 2050—a growth of 63%.[1] This growth comes with the need to house, employ, transport, and support the additional population, with added pressures to developable land within the town boundary.

Canmore currently sees 3–5 million visitors annually, and 26% of total dwellings are second homes (about 4,000 semi-permanent residents). The importance of tourism in Canmore's economy highlights the need to consider those who do not live permanently in the town in climate action planning.

To accommodate this growth, development for both residential and commercial purposes will be required. Figures 1 and 2 show the proposed development in Canmore by 2070.

[1] Population count from Statistics Canada (15,990 people in 2021) adjusted for the census undercount in the CIS model.

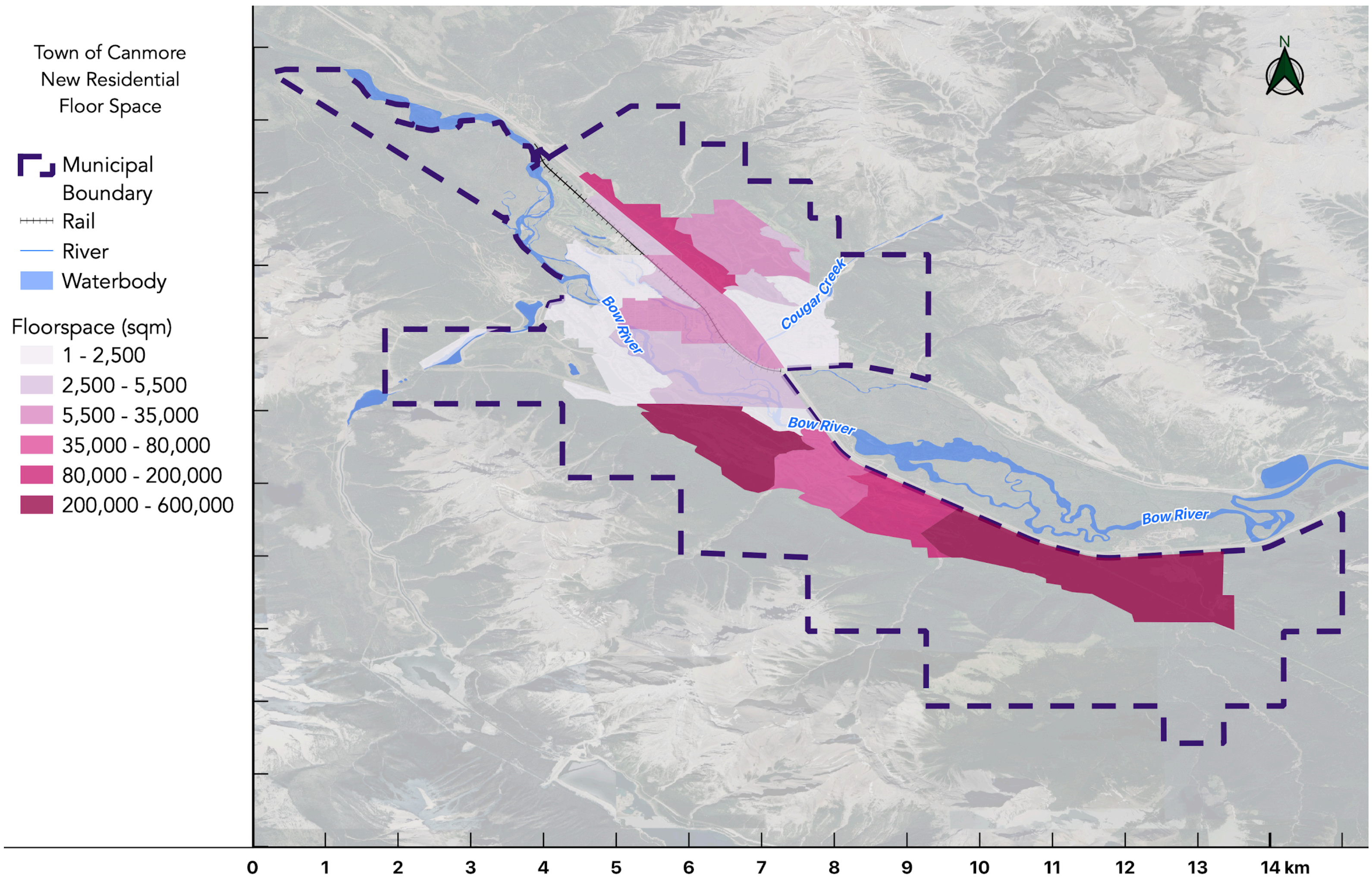


Figure 1. New residential development within Canmore between now and 2050.

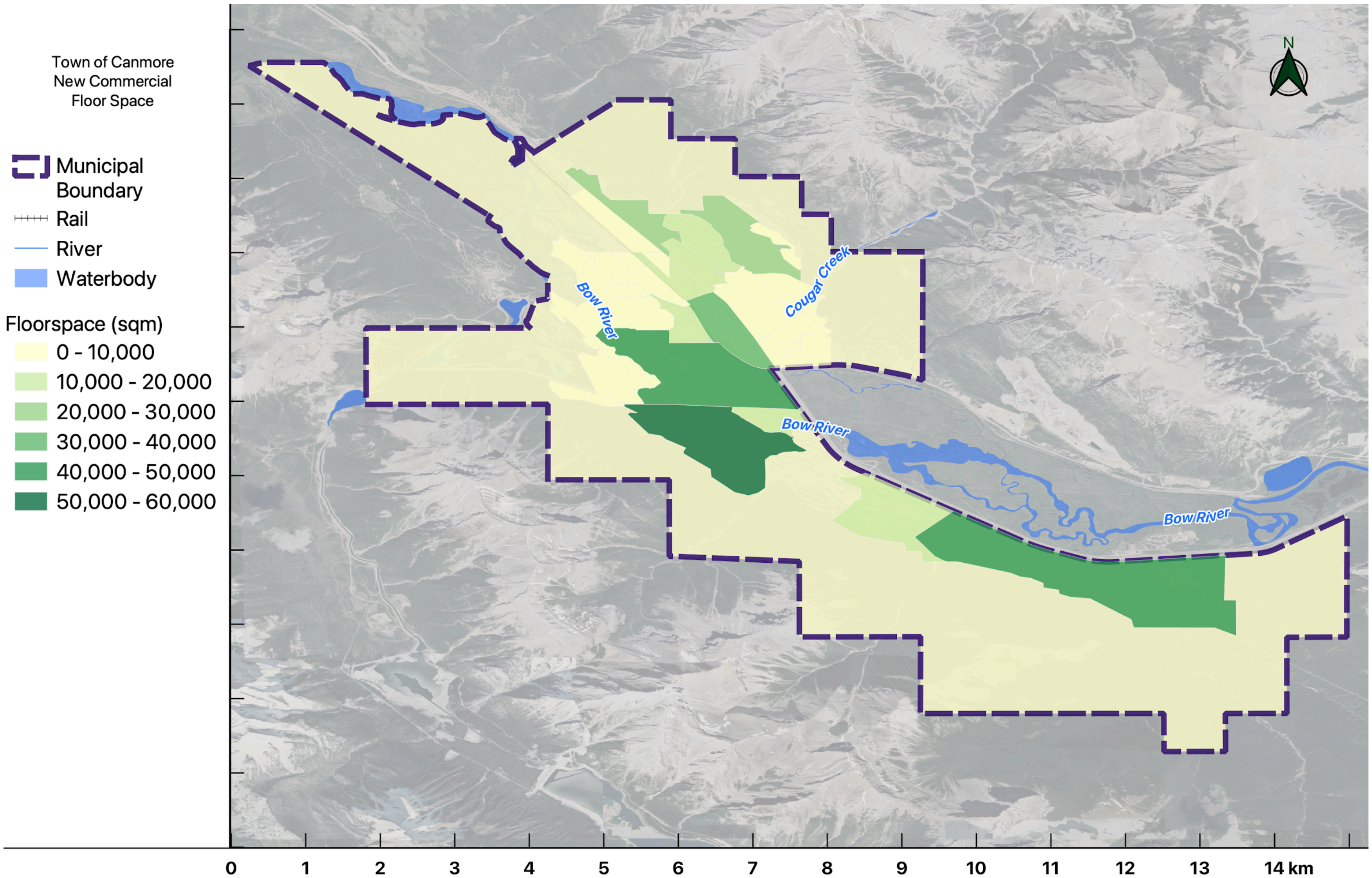


Figure 2. New commercial development in Canmore between now and 2050.

Previous Climate Change Work

In 2013, Canmore experienced a catastrophic flooding event when the seven mountain creeks surrounding the town overflowed due to torrential rain and rapid snow melt, causing extensive damages. This event prompted the Town to begin considering climate impacts in its planning, in order to strengthen its adaptation strategies and capabilities. The Town's *Climate Change Adaptation Background Report and Resilience Plan*, published in September 2016, identified seven priority climate risks facing Canmore over the next several decades: forest fires, Bow River flooding, creek flooding, localized flooding due to an overwhelmed stormwater system, extreme wind, heavy snowfall events, and freeze-thaw cycles. It also outlined three opportunities for action planning that Canmore could take: an increase in summer recreational opportunities, an extended construction season, and an increase in winter tourism competitive advantage.

In October 2019, the Town of Canmore officially declared a state of climate emergency, the second municipality in Alberta to do so after Edmonton. The declaration reaffirms Canmore's commitment to reduce its carbon footprint and waste generation. The Town is now updating its existing adaptation and mitigation plans and programs, to create a single, comprehensive Climate Emergency Action Plan (CEAP), to be released in 2024.

Wildfires and extreme heat are increasing concerns, and in April 2023, the Town released its report *Adapting to the Risks of Extreme Heat and Wildfire Smoke in Canmore*. This report reviews the risks that extreme heat and wildfire smoke poses to the community, as well as guidance on developing emergency response plans for heat and smoke, and recommendations to ensure long-term preparedness.

Policy Context

Climate adaptation efforts made in Canmore can be supported and informed by various national, provincial, regional, and local regulatory frameworks and programs. Historically, these elements have been considered under categorizations such as emergency and hazard management, environmental protection, and disaster mitigation and response. Current plans and strategies more precisely identify actions needed for adaptation and readiness.

- **Federal direction:** Adaptation is one of the four pillars of the *Pan-Canadian Framework on Clean Growth and Climate Change* (2016),[2] which commits Canada to meeting international climate change action obligations. Canada's recently released *National Adaptation Strategy*[3] focuses on an Assess-Prioritize-Plan-Implement-Adapt cycle for adaptation efforts. The Strategy identifies local governments as having primary responsibility for land-use planning and zoning, water supply and wastewater management, and flood and wildfire risk management.

- **Provincial direction:** Alberta municipalities developing climate adaptation and resiliency goals and services are governed by the Alberta *Municipal Government Act*, *the Alberta Land Stewardship Act*, and the *Alberta Emergency Management Act*.[4]

- **Regional direction:** Under Alberta's *Land-Use Framework*,[5] Canmore's location in the Bow Valley River Basin puts the municipality within the South Saskatchewan Region. The *South Saskatchewan Regional Plan*,[6] approved in 2014, sets environmental triggers and limits for surface water quality and air quality and commits the region to continued work on climate variability issues within the region.

These directions and support from other levels of governments provide a foundation on which Canmore can build local climate change adaptation action. Climate readiness will help to prevent infrastructure and property damages, prevent and reduce public and personal health impacts, and lower the costs of recovering from extreme weather events.

---

[2] Environment and Climate Change Canada. *Pan-Canadian Framework on Clean Growth and Climate Change: Canada's Plan to Address Climate Change and Grow the Economy.* 2016, http://www.deslibris.ca/ID/10065393

[3] Government of Canada. "Canada's National Adaptation Strategy: Building Resilient Communities and a Strong Economy." *National Adaptation Strategy*, Nov. 2022, https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan.

[4] Tyler, Mary-Ellen. "Climate Risk Assessment and Adaptation Considerations for Municipal Governance." University of Calgary School of Public Policy, *Future of Municipal Government Series Vol 15:43*, March 2023, http://dx.doi.org/10.11575/sppp.v16i1.76064

[5] Government of Alberta. *Land-use Framework*. December 2008, https://landuse.alberta.ca/LandUse%20Documents/Land-use%20Framework%20-%202008-12.pdf

[6] Government of Alberta. *South Saskatchewan Regional Plan 2014-2024*. Amended May 2018. https://landuse.alberta.ca/LandUse%20Documents/South%20Saskatchewan%20Regional%20Plan%202014-2024%20-%20May%202018.pdf

Mitigation and Adaptation Working Together

Mitigating and adapting to climate change are two interconnected approaches that are crucial for addressing the challenges posed by a changing climate. While they have distinct goals and strategies, their combined efforts are essential for effectively managing the impacts of climate change and ensuring the long-term sustainability of ecosystems, economies, and societies (see Figure 3).

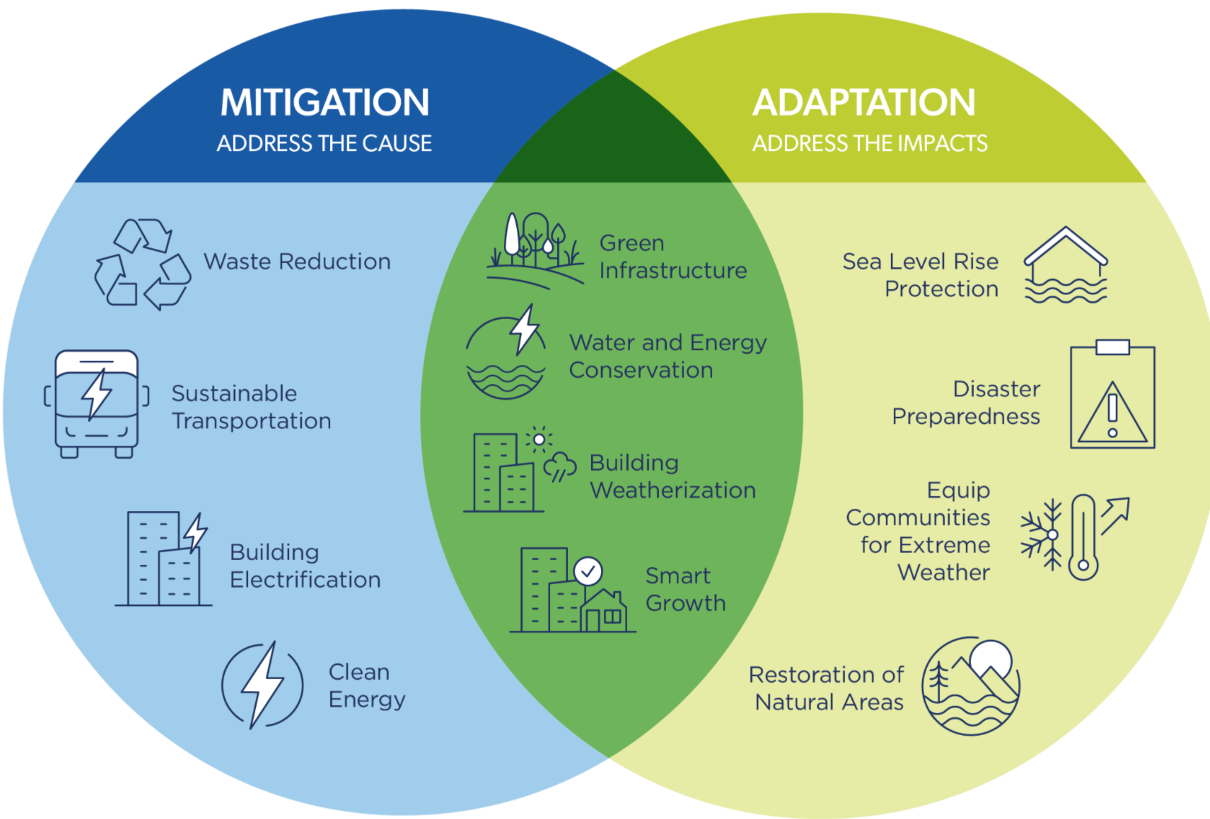


Figure 3. Climate change adaptation and mitigation actions.

Addressing climate adaptation and mitigation allows for efficiencies and co-benefits to be maximized while helping us avoid taking adaptive or mitigation actions that result in a co-harm to the other. These benefits include:

1. Identifying actions where adaptation and mitigation can work together to enhance the benefits, resulting in comprehensive benefits to the community.

2. Identifying and avoiding potential co-harms. For example, adaptation planning might identify the need for supplemental electricity generation, but mitigation planning shows that back-up diesel generators work against overall climate action.
3. Avoiding being locked-in to detrimental long-term choices by implementing adaptation measures to protect and secure current infrastructure, while simultaneously working to reduce the global impacts of climate change, reducing the need for the most expensive upgrades and adaptation measures. For example, without consideration of future flow rates and volumes, culverts due for replacement might not be correctly sized to accommodate climate change, increasing the likelihood of localized flooding.
4. Maximizing the economic benefits through job creation, efficient planning, and enhanced energy security.
5. Aligning policies and political energy, and avoiding duplication of efforts as much as possible. Climate plans, funding programs, and implementation strategies for both mitigation and adaptation can be developed together, maximizing efficiency and allowing the city to shift more quickly to implementing climate plans.

Climate Risk and Vulnerability

Future Climate Projections

The analysis in this report covers the period from the present day to 2070, but implementation planning will focus on immediate and medium-term opportunities. The 2070 end year is used to align with climate data projections which typically span projection periods with an end year between 2070 and 2100, with the largest weather changes typically projected to happen toward the end of this time span. Although a time span ending in 2070 is longer than typical community planning guidelines, many decisions made in the near-term will continue to determine the level of risk the community will face further into the future. For example, decisions around future development locations and infrastructure investments have resilience implications that will endure to the end of the century.

The change in hazards is driven by the underlying climate projections used in our analysis. For example, increased precipitation can drive flooding risks; similarly, projected increases in heat wave magnitude and frequency can drive heat-related risks.

Changing the people, places, infrastructure, built environment, and the hazards allows for the projection of their interactions to be modelled and resulting risks to the community to be estimated. It also allows for the estimation of long-term risks to the community and impacts of policy and infrastructure investment decisions. For example, changing zoning bylaws for flood-prone areas can have a significant impact on future flood damages. Also, investing in increasing urban tree canopy and cool roofs can significantly decrease long-term heat-related risks, especially in areas where the population is most vulnerable.

The United Nations Intergovernmental Panel on Climate Change (IPCC), the recognized global authority on advancing the understanding of global climate change, developed the Representative Concentration Pathways (RCPs) which describe different climate change scenarios, depending on the amount of greenhouse gases (GHGs) emitted over time.

With the IPCC's *Sixth Assessment Report* now in circulation, another set of pathways refine the RCPs, known as the Shared Socio-economic Pathways (SSPs). The SSPs explore the impacts of climate mitigation policies, technologies, and growth patterns on GHG emissions. RCPs describe the pathways for GHG concentrations in the atmosphere, whereas SSPs look at the impacts of global action on people, economies, and development, and how those impacts affect GHG emissions.

Modelling for this study uses RCP 8.5 values for its input assumptions as a precaution, as this is the scenario that shows the most serious impacts, despite commitments made by countries to lower emissions.

The RCP 8.5 (business-as-usual) scenario represents a future where GHG emissions continue to rise in the atmosphere, primarily due to continued use of fossil fuels. While the RCP 8.5 scenario (aligning with the SSP5) is considered unlikely due to global efforts to reduce GHG emissions, it is a scenario that the world cannot afford to allow to happen.[7] As planners, it is critical to evaluate and understand the implications of a case in which the world does not succeed in dramatically reducing emissions. In the event that emissions trend closer to the RCP 4.5 scenario, the conditions modelled for this project will be delayed but not eliminated entirely.

---

[7] Huard, D., Fyke, J., Capellán-Pérez, I., Matthews, H. D., & Partanen, A. (2022). Estimating the likelihood of GHG concentration scenarios from Probabilistic Integrated Assessment Model Simulations. *Earth's Future*, *10*(10). https://doi.org/10.1029/2022ef002715

Climate Hazards

Canmore will be getting **warmer** and **wetter**, with **less predictable** weather. Both the mean and maximum annual temperature is increasing. Minimum temperatures will increase throughout the century, and Canmore can expect to see multiple days above 30°C annually.

The total annual precipitation will also increase, but with less precipitation in the form of snow, and more in the form of rain, especially in the spring and fall. The number of frost-free days will increase dramatically. The combination of warmer weather and less predictable precipitation will have impacts on the snowpack and glaciers in the mountains around Canmore, which is discussed in more detail in later sections.

Table 1 shows specific changes to climate parameters from now to 2100, along with the trends of change in that parameter.

Table 1. Climate parameter changes in Canmore.[8]

Climate Indicator	Historical	RCP 8.5 2011–2040	RCP 8.5 2040–2070	RCP 8.5 2070–2100	Trend
Annual Temperature (°C)	0	3	5	8	Increasing
Summer Mean Temperature (°C)	12	15	19	22	Increasing
Humidex >30°C Occurrence (days)[9]	0	0	3	29	Increasing
Freeze/Thaw Cycle (cycles)	128	130	133	122	Decreasing
Frost Days (days)	248	231	213	190	Decreasing
Maximum 1-Day Precipitation (mm)	32	34	35	42	Increasing

[8] All climate data from https://climatedata.ca/ for Canmore Region.

[9] The humidex is a measure used to reflect the perceived temperature due to the combined effects of heat and humidity. It gives an indication of how hot and uncomfortable the weather feels to the average person. A humidex of 30 or above is considered uncomfortable.

Climate Indicator	Historical	RCP 8.5 2011–2040	RCP 8.5 2040–2070	RCP 8.5 2070–2100	Trend
Maximum 5-Day Precipitation (mm)	62	66	69	82	Increasing
Annual Precipitation (mm)	641	683	720	796	Increasing
Annual Growing Degree Days	707	1121	1622	2274	Increasing

Linking climate change with changes in hazards requires a multi-faceted analysis of the links between climate indicators and the physical assets, including both the built environment and the natural environment, of Canmore. The interrelated nature of these relationships is shown in Figure 4, where climate indicators are linked to hazards.

Translating climate change trends to hazards allows for a deeper understanding of how the warmer and wetter weather will shape the seasons, ecosystems, and risks to people, places, and spaces in Canmore.

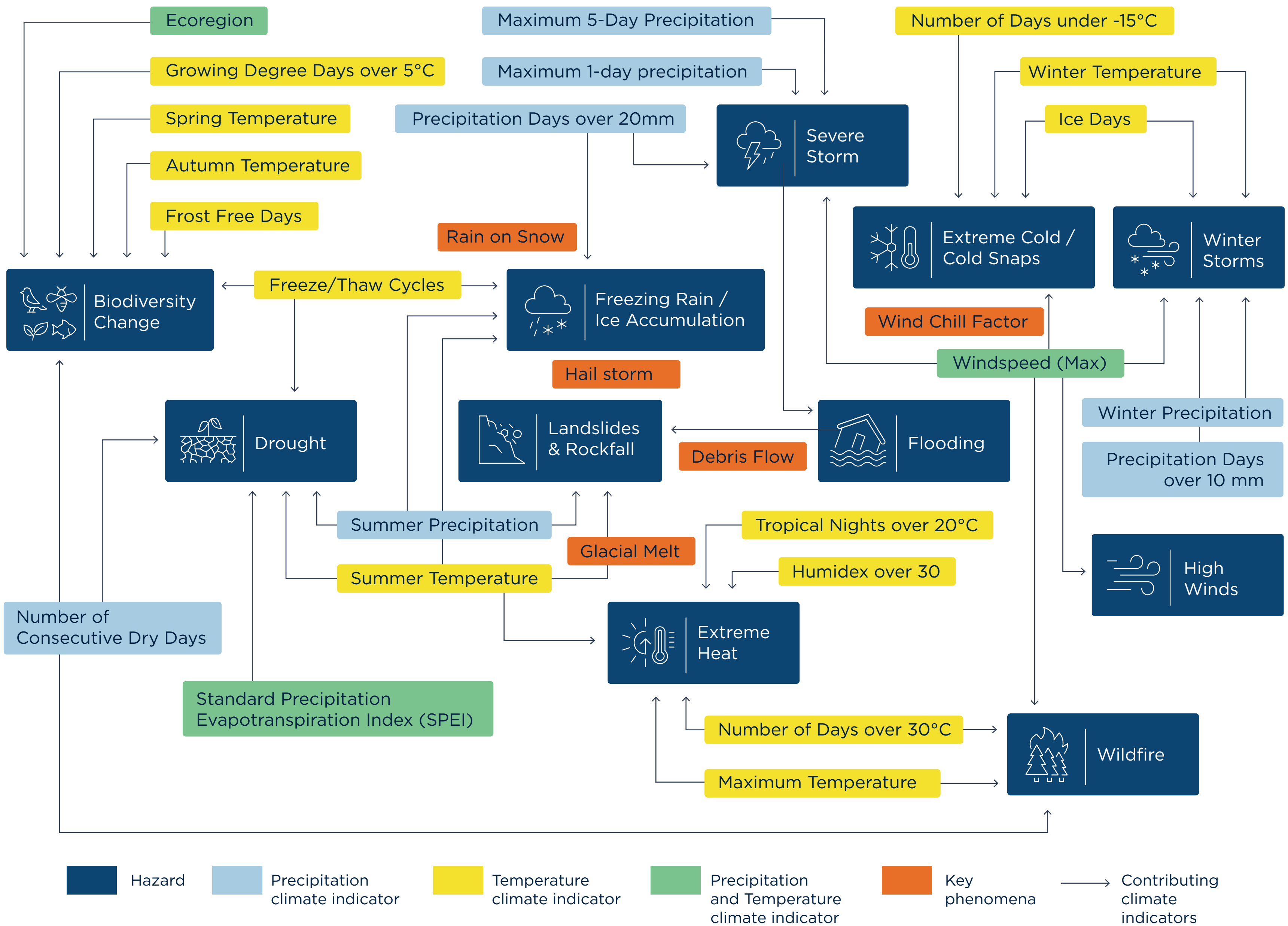


Figure 4. Relationship between climate indicators and hazards affecting Canmore.

Linking Hazards and Risk

Risk is defined as a function of three key components: the probability of a hazard threat, the vulnerability of a system to the hazard, and the consequences of the hazard (see Figure 5).

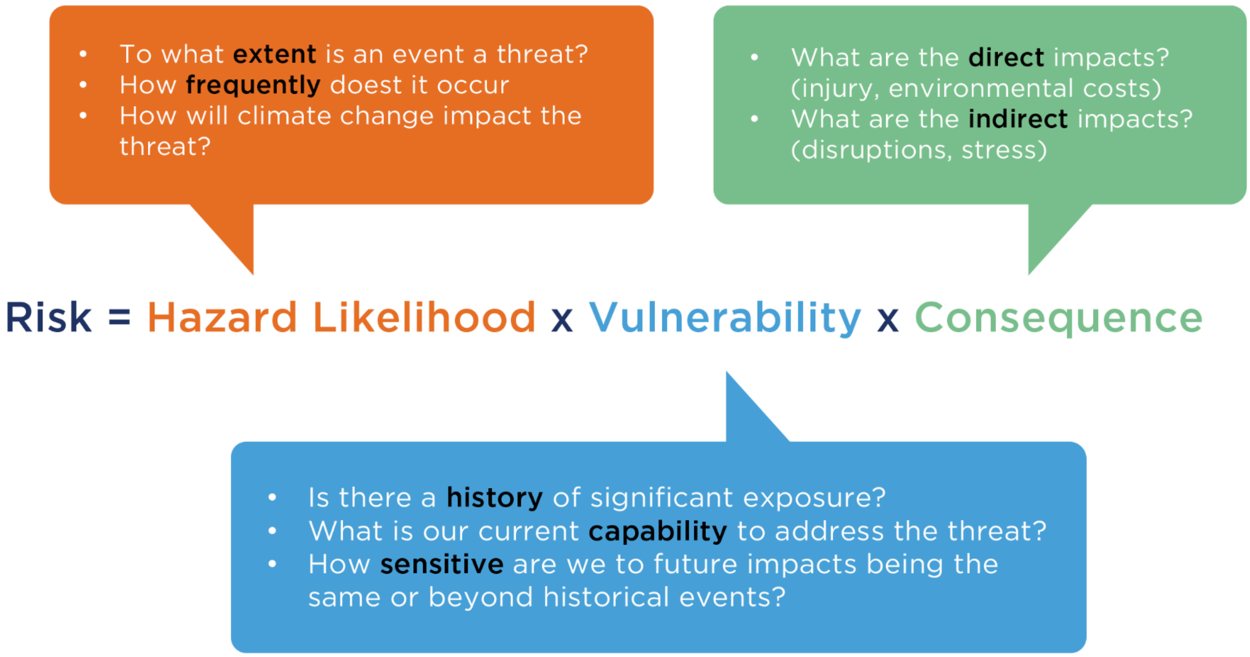


Figure 5. Conceptual formula of risk.

To understand the risk from climate hazards, three components are assessed:

- The hazard threat: What is the extent of the threat, how frequently does it occur, and how will it change over time?
- The vulnerability: What is the adaptive capacity of the system, and what is the sensitivity and susceptibility of the system to the hazard?
- The consequence: What are the direct and indirect consequences of the hazard to the system?

The risk score is the result of all three components combined. The following subsection describes each component in detail.

Hazard Threat Analysis

The hazard threat analysis examines the rate of change of underlying climate drivers for the different hazards in scope for different time horizons for an RCP 8.5 emissions scenario. It then assigns a threat level spanning five categories from minimal to very high threat from changing climate drivers. The hazard scores are determined using the relative change of climate parameters over time, to assess the scale of change over time. See Appendix 3 for details on the scoring for climate parameters based on the scale of change.

Hazard Score	Very High (5.0–4.1)	High (3.1–4.0)	Moderate (3.0–2.1)	Low (2.0–1.1)	Minimal (1.0–0)

The analysis for Canmore shows that in the mid-term (2050s–2070s), wildfire and ecoregion changes are projected to have the biggest increases in their respective underlying climate drivers, with some concerns about the rate of change for landslides, extreme heat, and droughts (see Table 2).

By the end of the century (2080s–2100), wildfire and ecoregion changes still show the highest hazard threat scores, but the increasingly unpredictable nature of storms increases the risk of landslides, and flooding, and extreme heat becomes more of a concern. Appendix 3 provides a full breakdown of the projected change in climate drivers and climate hazard threat scores.

Table 2. Climate hazards for Canmore.

Rank	Hazard	Near-Term Threat	Mid-Term Threat	Long-Term Threat	Average	Hazard
1	Ecoregion Changes	1.6	2.2	2.8	2.2	Low
2	Wildfire	1.3	2.3	2.8	2.1	Low
3	Steep Creeks[10]	0.8	1.5	2.3	1.5	Low

[10] While the hazard threat of steep creek flooding/debris flows is low, the risk is high. Steep creeks are a priority hazard because of the vulnerability and consequences, although the occurrence of steep creek floods/debris flows is still low based on climate parameters alone.

Rank	Hazard	Near-Term Threat	Mid-Term Threat	Long-Term Threat	Average	Hazard
4	Extreme Heat	0.5	1.3	2.3	1.3	Low
5	Riverine Flooding	0.3	0.8	1.5	1.1	Low
6	High Winds	1.0	1.0	1.0	1.0	Minimal
7	Freezing Rain/Ice Accumulation	1.0	0.6	1.1	0.9	Minimal
8	Dry Weather Conditions/Drought	0.4	1.1	0.8	0.8	Minimal
9	Extreme Cold/ Cold Snaps	0.6	0.8	0.8	0.8	Minimal
10	Snow Accumulation	0.4	0.8	0.9	0.7	Minimal

Vulnerability Assessment

Vulnerability is a qualitative measure of the adaptive capacity, susceptibility, and sensitivity of an asset to the hazard impact. Table 3 assigns thresholds for each score related to the three components of vulnerability. See Appendix 4 for a more detailed description of the methodology for the vulnerability assessment.

Adaptive capacity describes the institutional vulnerability to climate risk. It is defined as the ability of built, natural, human, and social systems to adjust to impacts of climate change.

Sensitivity is defined as a physical vulnerability to climate hazards (e.g., structural condition, available resources). A higher sensitivity means more adaptation actions will need to be implemented to avoid large climate impacts, while a lower sensitivity would mean we have more time to adapt.

Susceptibility describes the spatial vulnerability to a climate risk (the proximity of known hazardous zones or where historical impacts have occurred).

Vulnerability is assessed based on the scoring criteria shown in Table 3.

Table 3. Vulnerability Scoring Criteria.

Score		**Susceptibility** Is this area within direct impact if left unmitigated?	**Sensitivity** Is there adequate preparation to withstand hazard impacts?	**Adaptive Capacity** Is there adequate capacity to respond to this hazard?
1.0	Very High	• Very high likelihood the threat will translate to identified consequences • Within impact extent • History of impact	• Very high state of repair • Public resources overwhelmed	• Lack of capabilities to address hazard • Responses not implemented
0.8	High	• High likelihood the threat will translate to identified consequences. • Within/adjacent to impact extent • History of impact	• High state of repair • Public resources at capacity	• Low level of capabilities to address hazard • Responses partially implemented or not achieving control objectives
0.6	Medium	• Medium likelihood the threat will translate to identified consequences • Adjacent to impact extent[11] • History of impact	• No immediate repairs needed • Public resources at moderate capacity	• Medium level of capabilities to address hazard • Responses implemented and mostly achieving control objectives

[11] "Adjacent to impact extent" refers to the area that is next to or bordering the extent of an impact.

Score		**Susceptibility** Is this area within direct impact if left unmitigated?	**Sensitivity** Is there adequate preparation to withstand hazard impacts?	**Adaptive Capacity** Is there adequate capacity to respond to this hazard?
0.4	Low	• Low likelihood the threat will translate to identified consequences • Adjacent to impact extent	• Minimal repairs needed • Public resources available	• Medium to high level of capabilities to address hazard • Responses implemented and achieving control objectives except in extreme conditions
0.2	Very Low	• Very low likelihood that the threat event (if it occurs) will translate to identified consequences (adjacent to impact extent)	• System recently received adequate repairs/upgrades • Public resources readily available	• High level of capabilities to address hazard • Responses implemented and regularly tested for critical risks

Using the above criteria, we assessed the adaptive capacity, sensitivity, and susceptibility of Canmore relative to each of the climate hazards, based on historical data, engagement with staff and community members, and a review of the Town plans and policies. These results are summarized in Table 4, and more details are found in Appendix 4.

Table 4. Summary of vulnerability by hazard for Canmore.

Rank	Hazard	Vulnerability	Rationale/Comments
1	Ecoregion Changes	**0.7**	• Ecosystem changes are mostly forest changes; species composition will shift northward and higher with climate change • Forested areas will shift to a different type of forest, not an entirely different ecosystem • Pests, particularly those affecting trees, are expected to spread • Current systems to monitor and control may become stressed as ecosystem pressures increase
2	Wildfire	**0.9**	• Increasing stresses on forests from temperature shifts, pests, and other invasive species weaken the forest ecosystem, increasing susceptibility to fires • FireSmarting activities are not currently mandatory and monitored for continued compliance • FireSmarting focuses on buildings and assets, but wildfires can still occur and have ecological impacts • Wildfires are increasingly common in the region • Most of Canmore is classified as high risk for fire (see Wildfire and Smoke section)
3	Steep Creeks	**0.7**	• Debris flows are a known hazard across the steep creeks in Canmore, with historical floods causing damage • The Town's monitoring of conditions and investigation into mitigation activities are ongoing • Homes and businesses are situated in the debris flow risk areas • These flows are highly dangerous, and it is challenging to protect infrastructure from damages

Rank	Hazard	Vulnerability	Rationale/Comments
4	Riverine Flooding	**0.7**	● Flooding on the Bow River has occur historically, and is projected to increase with increased precipitation and more severe storm events ● Flood mitigation measures are deployed during flood events, but damages still occur ● Homes and businesses are found in the floodplain, and densification could put more people, homes, and assets within these flood risk areas.
5	Freezing Rain/Ice Accumulation	**0.2**	● Canmore has experience dealing with winter conditions and is prepared to manage icy conditions on roads, sidewalks, and other infrastructure ● The likelihood of freezing rain events is low ● Damage to urban forest canopy and forest ecosystem is possible from fallen branches, but clean-up systems currently exist within the community and Town to handle these events
6	High Winds	**0.3**	● Canmore's infrastructure and buildings can withstand strong storms and winter conditions, so serious consequences from high winds are unlikely ● Damage to trees or other infrastructure is possible, but clean-up and repair activities are currently in place for these events ● No large changes to the frequency or severity of these events are anticipated, so current systems are likely adequate to manage the events

Rank	Hazard	Vulnerability	Rationale/Comments
7	Extreme Heat	**0.4**	● Canmore is in a mountain valley and protected from the worst of extreme heat projected with climate change ● Building retrofits and high-efficiency buildings will improve the ability to maintain safe internal temperatures for homes and other buildings, and space cooling will be added with a conversion to electric heat pumps for thermoregulation in buildings ● Nighttime temperatures pose the highest risk of illness or death from heat, and many will be protected from these extreme temperatures through building improvements
8	Dry Weather Conditions/ Drought	**0.4**	● Canmore obtains its freshwater from a combination of groundwater, surface water, and minor snowpack/glacial melting. As this water supply has few upstream pressures, the Town has reliable access to freshwater resources ● Long-term drought conditions are unlikely to occur in Canmore, although periods of dry weather may result in short-term water shortages for parts of the community ● Water management restrictions may result from downstream drought conditions, as those communities will feel the effects of drought and water scarcity more intensely ● Climate projections show that drought conditions in Canmore should be short-lived and likely won't require large-scale changes to water management

Rank	Hazard	Vulnerability	Rationale/Comments
9	Snow Accumulation	0.2	• Canmore is prepared for winter storms, including snow accumulation, with snow-clearing infrastructure and processes in place • Climate projections suggest minimal changes to snow accumulation, so existing measures should be adequate to accommodate these events[12]
10	Extreme Cold/Cold Snaps	0.3	• Extreme cold temperatures are anticipated to be less frequent • Canmore is currently prepared for cold winter temperatures, so current systems should be adequate to accommodate cold snaps in the future

Consequence Assessment

Consequence is measured both quantitatively and qualitatively. The direct impacts are scored based on the data related to financial impact, environmental impact and human health impact. The indirect impacts are scored qualitatively using subject matter expert input on the disruption. Consequence is scored based on the criteria shown in Table 5.

Table 5. Consequence Scoring Criteria.

Consequence Scoring Criteria

Score	Definition	Impacts	
		Direct	Indirect
5.0	Severe	• Fatality • Catastrophic environmental impact • Catastrophic financial impacts (>$10M)	Loss of ability to meet business objectives based on severely impacted infrastructure or operations

[12] While less total annual snow is projected, changes in precipitation patterns could mean more larger snowfall events occur. In the near-term, rain on snow will persist and is anticipated during autumn (the wettest season in the year). Although we cannot predict when the freeze/thaw cycles will occur, the near-term will see an increased frequency of these cycles, which may increase the frequency of rain on snow events.

4.0	Major	• Long-term injuries and/or shock • Major environmental impacts • Major financial impacts ($1M–$10M)	Reduced ability to meet business objectives based on major impacts to infrastructure or operations
3.0	Moderate	• Short-term injuries and/or shock • Moderate environmental impacts • Moderate financial impacts ($100K–$1M)	Disruption to infrastructure or normal operations
2.0	Minor	• Minor injuries • Minor environmental impacts • Minor financial impacts ($10K–$100K)	Minimal impacts to infrastructure or normal operations
1.0	Insignificant	Costs of <$10K	Insignificant impact to infrastructure or operations

Using the above criteria, we assessed the direct and indirect consequences of climate hazards for Canmore based on modelling results, interviews with staff and community members, reviews of historic events, and reviews of Town plans and policies. These are shown in Table 6, and more details can be found in Appendix 5.

Table 6. Summary of consequences by hazard for Canmore.

Rank	Hazard	Consequence	Rationale/Comments
1	Ecoregion Changes	2.5	• The natural beauty of Canmore and its surrounding areas are central to the tourism economy of the town. Damage to the forest and other ecosystems could affect the economic stability of the community. • Environmental damage from pests and invasive species could be devastating to the environment, especially when those come with an increased likelihood of wildfire

Rank	Hazard	Consequence	Rationale/Comments
2	Wildfire	4.5	• Wildfire has the potential to cause severe damage to buildings, infrastructure, and other assets within the town • Disruption from wildfire can result in evacuations, lasting days to weeks, and then recovery from fire damage can take months to years
3	Steep Creeks	4.0	• Debris flows on some steep creeks in Canmore have the risk of serious injury or death • Damage from debris flows is limited in geographic scope to those areas within the flow path, but damage within those areas can be severe • Recovery can last days to weeks for clean-up, and months to years to rebuild damaged homes, businesses, and other infrastructure
4	Riverine Flooding	4.0	• Damage from riverine flooding depends on the severity of the flood event, but can result in millions to hundreds of millions of dollars in damages • Disruptions from flooding can last days to weeks, and recovery from damages can take months to years, depending on the severity of the damage
5	Freezing Rain/Ice Accumulation	1.5	• Damages from ice accumulation and freezing rain are not anticipated to result in expensive costs or repairs, as most of the damages will be to trees or electrical infrastructure • Disruptions from these events will be minimal, lasting hours to days
6	High Winds	1.5	• Damages from high winds are not anticipated to require costly repairs and clean-up; most damage will be minor, including fallen branches and damage to electrical infrastructure • Disruptions from these events will be minimal

Rank	Hazard	Consequence	Rationale/Comments
7	Extreme Heat	2.0	• People exposed to extreme high heat, particularly those outdoors, will be at higher risk of heat-related illnesses • Vulnerable people, including the very young and the elderly, as well as those without access to cooled spaces, will be at higher risk of heat-related illnesses • These events typically last days and require little recovery to infrastructure or systems
8	Dry Weather Conditions/ Drought	1.5	• Canmore relies on freshwater for community and commercial use, but has no major industrial or agricultural demands for water • Water efficiency upgrades to reduce water use and water loss will further reduce disruptions felt by water scarcity events
9	Snow Accumulation	1.0	• No serious damages or disruptions are anticipated from snow accumulation
10	Extreme Cold/Cold Snaps	1.0	• No serious damages or disruptions are anticipated from extreme cold, as long as emergency warming locations are available as needed

Risk Assessment

The final risk scores for each hazard are a product of vulnerability and consequence scores. The classification matrix to assess risk is shown in Table 6.

Table 6. Risk classification based on vulnerability and consequence scores.

Risk Characterization

Consequence	0.2 Very Low	0.4 Low	0.6 Medium	0.8 High	1.00 Very High
5 Severe >$10M	1	2	3	4	5
4 Major $5M - $10M	0.8	1.6	2.4	3.2	4
3 Moderate $1M - $5M	0.6	1.2	1.8	2.4	3
2 Minor $100K - $1M	0.4	0.8	1.2	1.6	2
1 Insignificant < $100,000K	0.2	0.4	0.6	0.8	1
	Vulnerability				

Risk	Insignificant 0.20 - 0.59	Minor 0.60 - 0.99	Moderate 1.00 - 1.99	High 2.00 -3.99	Very High 4.00 - 5.00

Canmore's Climate Risk Assessment

When we consider the vulnerability of Canmore to various climate hazard threats and their consequences, we can develop risk scores for each of those hazards. Table 7 lists the climate hazards in Canmore and the risk scoring for each.

Table 7. Risk assessment scores for climate hazards in Canmore.

Rank	Hazard	Hazard Threat	Vulnerability	Consequence	Risk
1	Ecoregion Changes	2.2	0.7	2.5	1.67
2	Wildfire	2.1	0.9	4.5	3.90
3	Steep Creeks	1.5	0.7	4.0	2.93
4	Extreme Heat	1.3	0.4	2.0	0.80
5	Riverine Flooding	1.1	0.7	4.0	2.67
6	High Winds	1.0	0.3	1.5	0.50
7	Freezing Rain/Ice Accumulation	0.9	0.2	1.5	0.30
8	Dry Weather Conditions/Drought	0.8	0.4	1.5	0.60
9	Extreme Cold/ Cold Snaps	0.8	0.3	1.0	0.27
10	Snow Accumulation	0.8	0.2	1.0	0.20

This risk assessment allows us to identify the greatest threats posed by climate change to the people, places, assets, and infrastructure of Canmore. We can prioritize actions to increase Canmore's resilience to climate change by considering the existing systems, strengths, and vulnerabilities of the town's infrastructure and systems, as well as the ability of the Town and community to withstand and recover from both emergency events and slower changes.

The assessment shows that wildfire poses the most serious risk to Canmore. This is not surprising given the community is surrounded by forests and in an area prone to wildfires, and has an economy dependent on the natural beauty of the town and surrounding areas. Climate pressures, with increasing temperatures, changes in precipitation, and increased presence of pests and invasive species all act as stressors on the forest ecosystem.

Debris flows and flooding also pose a serious risk to Canmore, as these can result in serious damages to homes and other infrastructure, and put people at risk of injury or even death. Flooding is not new to Canmore but will continue to be a priority risk into the future.

Extreme heat and ecosystem changes are moderate risks to the town. Canmore is protected from the worst of extreme heat by its geography, and severe health risks can be reduced with access to space cooling and emergency cooling centres. Ecosystem changes—including shifting composition of forest species and the larger threat from insects and pests—pose a threat to forest health, human health, and the economy.

Detailed Hazard Modelling Approach

Modelled Hazards

While the identification of hazards for inclusion in this assessment was completed based on a review of local climate change parameters, not all hazards are appropriate for detailed spatial and temporal modelling. Hazards included in the model were determined based on the following factors (see Appendix 1 for details about the model used):

- **Historical risk** associated with the hazard for the community;
- **Anticipated risk** of the hazard in the future for the community;
- **Spatial variance** in the interaction between the hazard and potentially affected assets; and
- **Data availability** of the hazard parameters.

Table 8 summarizes the hazards for Canmore, and the type of analysis completed for each hazard. A detailed assessment for each hazard follows.

Table 8. Hazard scope and definitions.

Hazard	Definition	Hazard Risk	Spatial Variance	Data Availability	Assessment Type	Rationale
Ecoregion Changes	Ecoregion changes refer to shifts in the species composition or type of ecosystem or ecoregion found in the area. This analysis focused on invasive species and diseases, as well as stresses to the forest ecosystem.	Moderate	Medium	Low	Qualitative	Data are not available to track potential ecoregion shifts or the spread of new species at the scale of Canmore. Regional shifts can be tracked, but these are harder to scale down to the level of a town. Impacts from ecoregion changes are included in wildfire, as the primary concern is with stresses to forest ecosystems.

Hazard	Definition	Hazard Risk	Spatial Variance	Data Availability	Assessment Type	Rationale
Wildfire	Wildfire is the unplanned spread of fire caused by natural events or human activity. Smoke from wildfires can affect locations far away from the actual fire. As Canmore is a valley, smoke can become trapped in the area, resulting in health problems and impacts to recreation and tourism.	High	Medium	Medium	Qualitative	Wildfire risk is elevated across all of Canmore, so specific high-risk areas cannot be isolated in the analysis. The value of assets at risk from fire in the present and future can be assessed, based on the elevated fire risk across the town. As smoke from wildfires cannot be tracked spatially at the scale of the town, this is assessed qualitatively.

Hazard	Definition	Hazard Risk	Spatial Variance	Data Availability	Assessment Type	Rationale
Steep Creeks	Landslides and debris flows, also known as steep creek flooding, are caused by large precipitation events in mountainous areas. These floods can be unpredictable and dangerous, causing extensive damage downstream.	High	High	Medium	Quantitative[13]	Detailed assessments of the risk and potential damages from steep creek flooding were completed by BCG Engineering (2014–2018, depending on the creek). These studies form the basis of our qualitative assessment of risk, but spatial data from these analyses were not available to include in our spatial modelling.

[13] The quantitative analysis for steep creek flooding was completed by BGC Engineering between 2014 and 2018.

Hazard	Definition	Hazard Risk	Spatial Variance	Data Availability	Assessment Type	Rationale
Extreme Heat	Extreme heat is a period of high heat. This analysis specifically looked at the effect of such conditions as they relate to heat stress and the effect of periods of high heat on Canmore's residents.	Minor	High	High	Quantitative	Data are readily available to assess the spatial variation of high heat across Canmore.
Riverine Flooding	Riverine flooding occurs when excessive rainfall occurs over an extended time period, causing rivers or creeks to overflow.	High	High	High	Quantitative	The geographic extent of flooding across Canmore is highly variable, and data are available on flood depth, return intervals of floods, and the assets found within floodplains.

Hazard	Definition	Hazard Risk	Spatial Variance	Data Availability	Assessment Type	Rationale
High Winds	Strong winds result from shifting atmospheric pressures, and can damage trees, buildings, electrical infrastructure, and other assets.	Insignificant	Low	Low	Not Included	This hazard is not expected to have a significant impact on Canmore, nor is it expected to change from current conditions.
Freezing Rain/Ice Accumulation	Freezing rain and the accumulation of ice on surfaces, trees, and other infrastructure are caused by winter storms that occur with temperatures around the freezing point.	Insignificant	Low	Low	Not Included	This hazard is not expected to have a significant impact on Canmore, nor is it expected to change from current conditions.

Hazard	Definition	Hazard Risk	Spatial Variance	Data Availability	Assessment Type	Rationale
Dry Weather Conditions/ Drought	Droughts are caused by extended warm periods. Stresses to surface and subterranean water supplies threaten potable water availability.	Minor	Low	Low	Qualitative	The impacts of droughts have low spatial variability, and data are not available to assess this in detail.
Extreme Cold/Cold Snaps	Periods of extreme cold, or periods with a rapid drop in temperature outside of the normal temperatures expected for a given time	Insignificant	Low	Low	Not Included	This hazard is not expected to have a significant impact on Canmore, nor is it expected to change from current conditions.

Hazard	Definition	Hazard Risk	Spatial Variance	Data Availability	Assessment Type	Rationale
Snow Accumulation	Snow accumulation refers to the gradual buildup of snow on the ground over a specific period, such as hours or days.	Insignificant	Low	Low	Not Included	This hazard is not expected to have a significant impact on Canmore, nor is it expected to change from current conditions.

Climate Risk and Vulnerabilities Analysis

Ecoregion Changes

Summary of Impacts

Category	Impacts
Changes to hazard due to climate change	• Stresses to ecosystem health from increased heat and precipitation changes, particularly forested areas • Increased presence of invasive species, including pest species like the mountain pine beetle, and vectors of diseases • Decreased biodiversity • Increased climate hazard potential
Infrastructure/ Critical infrastructure	• Increased stress on forest ecosystems, which can increase vulnerability to climate hazards like landslides, flooding, and wildfire which all pose substantial risk to infrastructure
Services	• Impacts changing the regulatory functions of the natural environment will put more stress on human systems (e.g., increased need for air conditioning if the cooling effect of local plants is reduced).
People	• Invasive insects and increased insect populations, such as mosquitos, pose a nuisance risk as well as a vector-borne disease risk.
Environment	• Ecosystem biodiversity may deteriorate, with negative outcomes for ecosystem functions including cooling and flood mitigation. • Spread of species like the mountain pine beetle
Economy	• Disruptions to the tourism industry from forest fires, forest death, and spread of vector-borne disease

Context

Climate change, particularly warmer temperatures and shifts in precipitation patterns, affects forests in numerous ways, resulting in ecoregion changes. For example, as the temperature warms, species adapted for cooler temperatures may no longer be able to thrive in their current locations, and be driven northward and to higher elevations. Depending on the ability and speed at which a species can shift their location, some species may not be able to adapt quickly enough to persist in the face of changing environmental conditions. These environmental changes can bring pest species to new locations where they previously were not found. Additionally, these changing conditions can stress an ecosystem, reducing its ability to defend against pests. Many pest species infect stressed or damaged trees, and shifting climatic conditions can contribute to the rapid growth of ecosystem-wide infections.

Invasive species typically do not have specialized food or habitat needs, making them adaptable to various environments. They also lack predators in their introduced environments, and are often better able to exploit disturbances than their native competitors. Climate change impacts (e.g., hotter temperatures, wildfires, droughts) will produce more disturbances, and thus may further facilitate the establishment and spread of invasive species.[14] Species will migrate as climate change impacts make geographies more hospitable for them.

Human activities (e.g., development, transportation infrastructure, altering land uses, agriculture) change, degrade, and fragment habitats. These impacts can make it challenging for flora and fauna species to move elsewhere in response to climate-related disturbances. Human responses to natural disasters can also exacerbate impacts of climate change. For example, extensive tree salvage harvest following insect infestations can create hotter microclimates that encourage wildfire; overgrazing and trampling change the plant community in grasslands and forest understory, destroying the biological crust and opening soil to invasive plants.[15]

---

[14] "Invasive Species." *U.S. Climate Resilience Toolkit*, 6 Aug. 2021, https://toolkit.climate.gov/topics/ecosystem-vulnerability/invasive-species

[15] Government of British Columbia. "Adapting Forest and Range Management to Climate Change in the Skeena Region:" *Adapting to Climate Change*, https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nrs-climate-change

Human Health and Safety

There is widespread concern in Canada that warmer weather caused by climate change is encouraging ticks to spread, increasing the risk of Lyme disease.[16] Deer ticks can be found in Alberta, including in populous places. They typically feed on rodents, deer, and other mammals in these regions, not humans. Milder winters and the spread of host animals can increase the population and range of deer ticks.

Mosquito populations and instances of mosquito-borne disease (MBD) contraction—such as West Nile Virus—are expected to increase under climate change impacts.[17] MBD contractions have already risen 10% over the past 20 years in Canada, largely due to climate change effects.[18] Mosquito habitat ranges are expected to expand north as the climate changes. Mosquito seasonal activity is also expected to expand from three to five months of the year in certain parts of Canada, including much of southern Alberta.[19] Several climate change factors contribute to these increases:

- Early wet seasons allow mosquitoes to hatch earlier in the year, providing them with more breeding time;
- Increased precipitation expands mosquito breeding grounds (standing water); and
- Warmer temperatures increase mosquito activity, encouraging them to breed more and to feed more frequently.

Other Impacts

Critical Infrastructure

Invasive plant species can outcompete native species that stabilize the environments and ecosystems in which critical infrastructure is built. As these areas are destabilized, the ability of the environments and ecosystems to buffer that infrastructure against extreme

[16] *Lyme Disease Under Climate Change*. https://climateatlas.ca/lyme-disease-under-climate-change

[17] Climate Atlas of Canada. *Mosquito-Borne Diseases and Climate Change*. https://climateatlas.ca/mosquito-borne-disease

[18] Ludwig, Zheng, Vrbova, Drebot, Iranpour, and Lindsay. 2019. Increased Risk of Endemic Mosquito-Borne Diseases in Canada Due to Climate Change. Canada Communicable Disease Report 45:91–97. https://doi.org/10.14745/ccdr.v45i04a03

[19] Chen CC, Jenkins E, Epp T, Waldner C, Curry PS, Soos C. Climate change and West Nile virus in a highly endemic region of North America. Int J Environ Res Public Health 2013 Jul;10(7):3052–71. https://doi.org/10.3390/ijerph10073052

weather events is decreased. As invasive species change landscapes to be more prone to wildfires, floods, or landslides, for example, any infrastructure located within the potential geographic range of a fire or flood, or downstream from landslides or debris flows, will be at risk of damage.

Invasive plant and insect species themselves also pose threats to infrastructure. For example, the strong root systems of plants like knotweed and the behaviour of insects including various ant species can damage sidewalks, roadways, and buildings, and interfere with waterways.

Services

Invasive species may require increased maintenance costs for their removal from parks, roads, and water systems. Certain species grow quickly, requiring frequent maintenance.

The Town of Canmore is responsible for the management of mountain pine beetles in the town itself. Thus, increased spread of this insect would increase the costs of beetle management for the Town.

Environment

Climate change is enhancing the ability of some native species to negatively affect their ecosystems. Perhaps the most prominent example of this is the mountain pine beetle. Pine beetles can survive temperatures from −20°C during autumn up to −35°C in deep winter, depending on the beetle’s life stage. Warming winters and a reduction in very cold days mean that pine beetle populations have exploded and are taking a toll on lodgepole, western white, whitebark, and ponderosa pine species.

The mountain pine beetle is found in the forests surrounding Canmore and, if left untreated, could cause significant damage to all species of pine trees in those forests, and spread eastward. Warming winters mean these beetles can survive the winters, increasing their populations. The beetle kills the trees, increasing their vulnerability to wildfires. Forest management practices for controlling the mountain pine beetle must consider current research in ensuring the health of waterways and the ecosystem while also working to reduce the beetle’s spread.

Other invasive plant species in the Canmore area are the Canada thistle, scentless chamomile, common tansy, yellow toadflax, tall buttercup, yellow clematis, white cockle, ox-eye daisy, and spotted knapweed.[20] Educating the public about how to identify and remove these species can help prevent their spread across the environment.

The spread of invasive plant species is a concern in wildfire-prone areas. After a wildfire, plant nutrients can change, encouraging the growth of species that take advantage of those nutrients. Cheatgrass, or downy brome, spread is one such concern in Alberta.[21] Cheatgrass can change the way wildfire starts and spreads, providing a readily flammable substance with great horizontal coverage.[22] It also has been shown to decrease the time between fire events.[23]

Economy

Invasive plant, animal, and insect species can have a variety of potential financial impacts, including:

- Interference of tourism and recreational activities due to plant species changing biodiversity and environmental conditions, and from insect and animal species presenting nuisances;
- Infrastructure damage resulting from changed environmental conditions that promote more frequent and/or severe flooding, hot microclimates, wildfire, landslides, etc.;
- Increased forest pest management, monitoring, and intervention activities;
- Natural resource industries may be affected as changes occur to the environments in which the resources are located or to the resources themselves;
- Elevated health costs from increased allergic reactions and foreign diseases; and
- Decreased property values from negative aesthetic and recreational value of land.

---

[20] Town of Banff, 2023. Invasive Plants. Accessed: https://banff.ca/707/Invasive-Plants

[21] Alberta Invasive Species Council, 2014. Downy brome. Accessed: https://abinvasives.ca/wp-content/uploads/2020/07/N_FS-DownyBrome.pdf

[22] Brooks et al. (2004). Effects of invasive alien plants on fire regimes. BioScience, 54(7), 677-688.

[23] J. Chambers, B. Roundy. What makes Great Basin sagebrush ecosystems invisible by Bromus tectorum? Ecol. Monogr., 77 (2007), pp. 117-145.

Wildfire and Smoke

Summary of Impacts

Category	Impact
Changes to hazard due to climate change	• Drier landscape from warmer weather • Longer fire season • Increased fuel from dead trees weakened by invasive species and heat stress
Infrastructure/Critical infrastructure	• Disruption to transportation network • Disruption to electricity grid infrastructure
Services	• Increased strain on emergency services • Contaminated drinking water • Increased strain on medical systems from poor air quality from smoke
People	• Elevated risk of wildfire for all of Canmore • Health concerns from poor air quality due to smoke
Environment	• Decreased tree canopy • Soil erosion • Poor air quality
Economy	• Decreased tourism • Unhealthy working conditions due to poor air quality • Reduced productivity from extended periods of poor air quality

Context

Wildfire risk is high across all of Canmore. The town is situated in a forested valley surrounded by intact forests and grasslands, which are environments susceptible to fire..

Fire risk is impacted by a variety of climate conditions. For example, warmer temperatures, changes to precipitation, and the spread of invasive species all contribute to an elevated fire risk.

Smoke from wildfires outside of Canmore can drift into the community, resulting in increased air pollution, extended periods of poor air quality, and health concerns to those exposed to the smoke.

Careful monitoring and management of natural spaces, as well as the built environment are essential to protect the health and safety of the community, as well as the natural systems in the region.

FireSmart for Wildfire Management

Watershed areas serve as the source of clean water for many communities. Uncontrolled wildfires can lead to erosion, sediment runoff, and contamination, resulting in severe consequences for water supplies. The intense heat and ash generated by wildfires can degrade water quality, making it unsafe for consumption.

To protect the water supply of a town from the devastating impacts of wildfires, implementing fuel management practices in these areas is critically important. These practices help create defensible buffers that reduce the risk of intense wildfires reaching the watershed. By strategically thinning vegetation, removing dead trees, and conducting controlled burns, the amount of flammable material is reduced, decreasing the intensity and severity of potential wildfires. These activities require coordination between all levels of government, as the areas surrounding Canmore include both provincial parkland and federal crown lands.

Implementing building and landscape modifications according to FireSmart guidelines is a highly effective approach to protecting communities from the dangers of wildfires. Research shows that structural modifications alone can reduce wildfire risk by up to 40%.

When combined with landscape modifications, the risk reduction potential increases significantly to about 75%.[24]

FireSmart activities in Canmore are planned and prioritized in the Town's *FireSmart Mitigation Strategy*. This strategy was developed in 2010 and is regularly updated to reflect completed work and changes to the landscape. As of 2023, more than 230 hectares of land had been FireSmarted in Canmore to reduce the risk of wildfire.

Human Health and Safety

Figure 5 illustrates the wildfire risk across Canmore. This map shows that no area of Canmore is excluded from the potential risk of wildfire, and that areas on the outskirts of the town are at highest risk.

[24] National Association of Insurance Commissioners, 2020. Application of Wildfire Mitigation to

Insured Property Exposure. Retrieved from: https://content.naic.org/sites/default/files/cipr_report_wildfire_mitigation.pdf

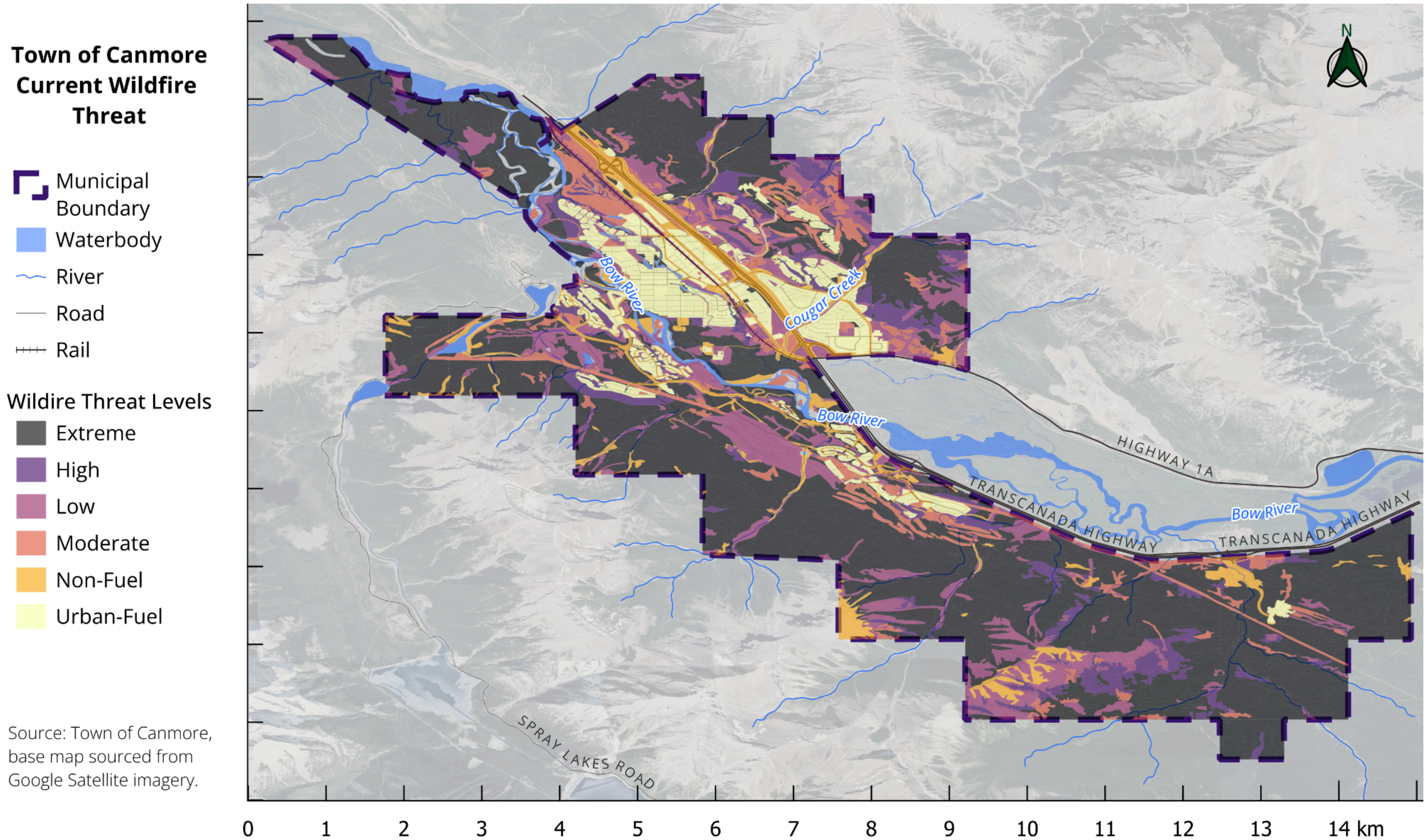


Figure 5. Wildfire threat levels for Canmore, present day.[25]

[25] Modified from: Walkinshaw, Stew, 2020. Wildfire Risk Assessment. Three Sisters Mountain Village. Montane Forest Management Ltd.

Future development is slated to occur both as infill in the central, more densely developed sections of Canmore and along the outskirts of the community. New buildings, both residential and commercial, should be built with wildfire safety considerations, including FireSmart practices. Existing infrastructure should be retrofitted for fire safety, and fire safety measures should be inspected regularly to ensure they remain in compliance with current best practices.

Other Impacts

Critical Infrastructure

Wildfires can be extremely destructive and disruptive to a town's infrastructure. Electrical infrastructure can be damaged by wildfires, and electric service may be temporarily suspended along lines found in the highest-risk locations to reduce the potential for sparking. Disruptions to a town's electricity supply pose a significant risk to the wellbeing of the population, as wildfires tend to occur in the hottest periods of the year when demand for electricity for cooling peaks. A significant disruption to the electrical grid occurring at the same time as an extreme heat event could be fatal. Additionally, wildfires can disrupt road infrastructure, preventing access to and from the areas where the fire is occuring. This could severely hinder evacuation and rescue efforts.

The main evacuation route for Canmore is eastward, using Highway 1, the TransCanada Highway. Wildfires along this route could pose a danger to the community, and could trigger evacuations of the town even if the town itself is not at an elevated risk of wildfire. Similarly, the mountainous terrain limits the town's ability to introduce redundancy in electrical infrastructure, meaning Canmore is at risk of losing electricity should wildfire impact areas southeast of the town, connecting to the Spray Lake generation station, or to the east of Canmore, where electricity infrastructure follows Highway 1.

Services

With more frequent and severe wildfires, emergency responders are required to be deployed more often and for longer periods of time, which can lead to exhaustion and burnout. The need for additional resources, including firefighting equipment, personnel, and infrastructure, also places a strain on emergency services. Moreover, the fires can threaten homes, businesses, and infrastructure, leading to evacuations and road closures that further complicate emergency response efforts.

Water quality can also be affected by wildfires. During and after a wildfire, ash, debris, and sediment can be carried into rivers, streams, and lakes by stormwater runoff, leading to water quality issues.[26] High levels of nutrients and organic matter from burned vegetation can also contribute to harmful algal blooms and decrease dissolved oxygen levels. In addition, wildfires can damage or destroy infrastructure, such as water treatment facilities, leading to disruptions in water supply and potential contamination.

Environment

Wildfires can lead to significant loss of tree canopy, which can have a significant impact on the surrounding environment. For example, reduced tree canopy can lead to increased soil erosion due to the loss of roots that hold soil in place, resulting in the runoff of sediment into nearby waterways which can have an added detrimental impact on water quality. Additionally, tree canopy provides much needed shading and cooling to the surrounding areas, which will be of increasing value as temperatures rise and extreme heat events occur more frequently.

Economy

Wildfires can also negatively impact the tourism industry, as smoke and other factors may deter visitors and disrupt travel plans. This can result in lost revenue for local businesses such as hotels, restaurants, and outdoor recreation companies. The impact of wildfires on tourism can have long-term effects, as negative publicity and ongoing concerns about air quality and other factors can discourage visitors from returning to the area.

Finally, increased wildfires can lead to unhealthy working conditions for people employed in outdoor industries. The smoke and other particulate matter from wildfires can reduce air quality, which can have negative health consequences for workers who are exposed to these conditions for extended periods. This can result in lost productivity, increased healthcare costs, and other economic impacts.

[26] HealthLink BC. (2021). Wildfire and its Effects on Drinking Water Quality. Retrieved February 24, 2023.

Smoke and Air Quality

As of Spring 2023, Canmore developed emergency response plans (ERPs) for extreme heat and wildfire smoke as part of its Municipal Emergency Management Plan. At the time of writing the ERPs, the Calgary air quality monitoring station was the closest station to the town. Since then, the Banff monitoring station has become operational, allowing Canmore to access more localized data to help emergency management teams monitor air quality and determine actions to protect residents as needed.[27]

Primary air quality indicators identified include fine particulate matter (PM2.5), carbon monoxide, nitrogen oxides, and volatile organic compounds (VOCs). PM2.5 is a public health indicator because it poses health risks as it can be inhaled deep within the lungs.

Wildfire smoke may impact a healthy human by causing irritation in the eyes, nose, or throat, leading to coughing or difficulty breathing. These impacts are exacerbated for those with existing respiratory or cardiovascular conditions. The following populations were identified as vulnerable to wildfire smoke:

- Older adults (aged 65 years and older);
- Infants and young children;
- Pregnant women and foetuses;
- Smokers;
- People with pre-existing health conditions (e.g., respiratory disease, lung infections, heart disease, diabetes, obesity, mental illness);
- Materially deprived and socially disadvantaged and isolated people, including homeless and unsheltered individuals and people who live alone;
- Newcomers and transient populations, including tourists; and
- Outdoor workers and others engaged in strenuous outdoor activity.

The 2023 ERP identified several interventions to address wildfire smoke health risks with a focus on reaching vulnerable populations. These include establishing clean air centres, coordinating transportation to these locations, and providing the community with multilingual information about the health risks and available resources.

---

[27] Many local residents use a third-party air quality monitoring map system, Purple Air, to gather localized information on air quality. This system allows users to share air quality data from Purple Air sensors with the public, providing many data points and detailed information on real-time air quality.

Critical Infrastructure and Emergency Management

Clean air centres have been proposed to help Canmore's residents during smoke events or other times of poor air quality. The Elevation Place and the Canmore Recreation Centre are recommended as feasible locations for clean air centres, with several other locations identified as possible candidates.[28]

Clear emergency response plans are set out in Canmore's Wildfire Smoke Emergency Response Plan.[29] The implementation of these plans during smoke events will help protect community members, particularly those who are most vulnerable to air quality issues, including the children, the elderly, pregnant people, those with health conditions or limited mobility, those who are socially isolated, and outdoor workers.

The addition of the Banff air quality monitoring station will assist the Town in monitoring for smoke and other air quality concerns, allowing for timely communication with emergency services and the community as a whole.

[28] AllOneSky Foundation, Associated Engineering, and The Resilience Institute, 2023. Adapting to the Risks of Extreme Heat and Wildfire Smoke in Canmore. Final Report.

[29] Ibid.

Steep Creeks

Summary of Impacts

Category	Impact
Changes to hazard due to climate change	• Increased total precipitation annually and seasonally in spring and fall • Higher average temperatures in winter and spring affect peak flows and timing of spring freshet
Infrastructure/Critical infrastructure	• Potential damages to electrical infrastructure • Potential damages to other critical service buildings including the hospital, RCMP building, and municipal government buildings. • Damage to and disruption of roads
Services	• Increased need for emergency shelters • Support for repairs and clean-up after flooding
People	• Risk of death or injury from debris flows/floods • Disruption and displacement from debris flows/floods
Environment	• Damage to forests and other ecosystems from debris flows/floods • Increased sedimentation in down-stream water bodies
Economy	• Potential damages to homes, businesses, roads, and other infrastructure • Loss of visitor industry in affected areas

Context

Flooding along steep creeks in mountainous areas behaves differently than riverine flooding. The combination of intense precipitation and loose sediment along streambeds can produce fast-moving flows with entrained debris, including mud, soil, rocks, boulders, trees and other debris, which increases the hazard compared to riverine flooding.

Between 2014 and 2019, Canmore undertook assessments of the hazard and risks associated with debris flows and debris floods on the steep creeks in the town. These assessments were completed by BGC Engineering, and include an evaluation of the potential damages to buildings and infrastructure, as well as an assessment of the risk to lives for people located within the buildings. These assessments also include recommendations to reduce the risks associated with debris flows and debris floods along these creeks. The creeks included in this assessment were:

- Stone Creek;
- Pigeon Creek;[30]
- Stoneworks Creek;
- Three Sisters Creek;
- Cougar Creek; and
- X, Y and Z Creeks.

[30] The Pigeon Creek assessment was a joint project between the Town of Canmore and the Municipal District of Bighorn. Approximately 95% of the expected damages, as well as all the potential fatalities, fall within the geographic boundary of Bighorn.

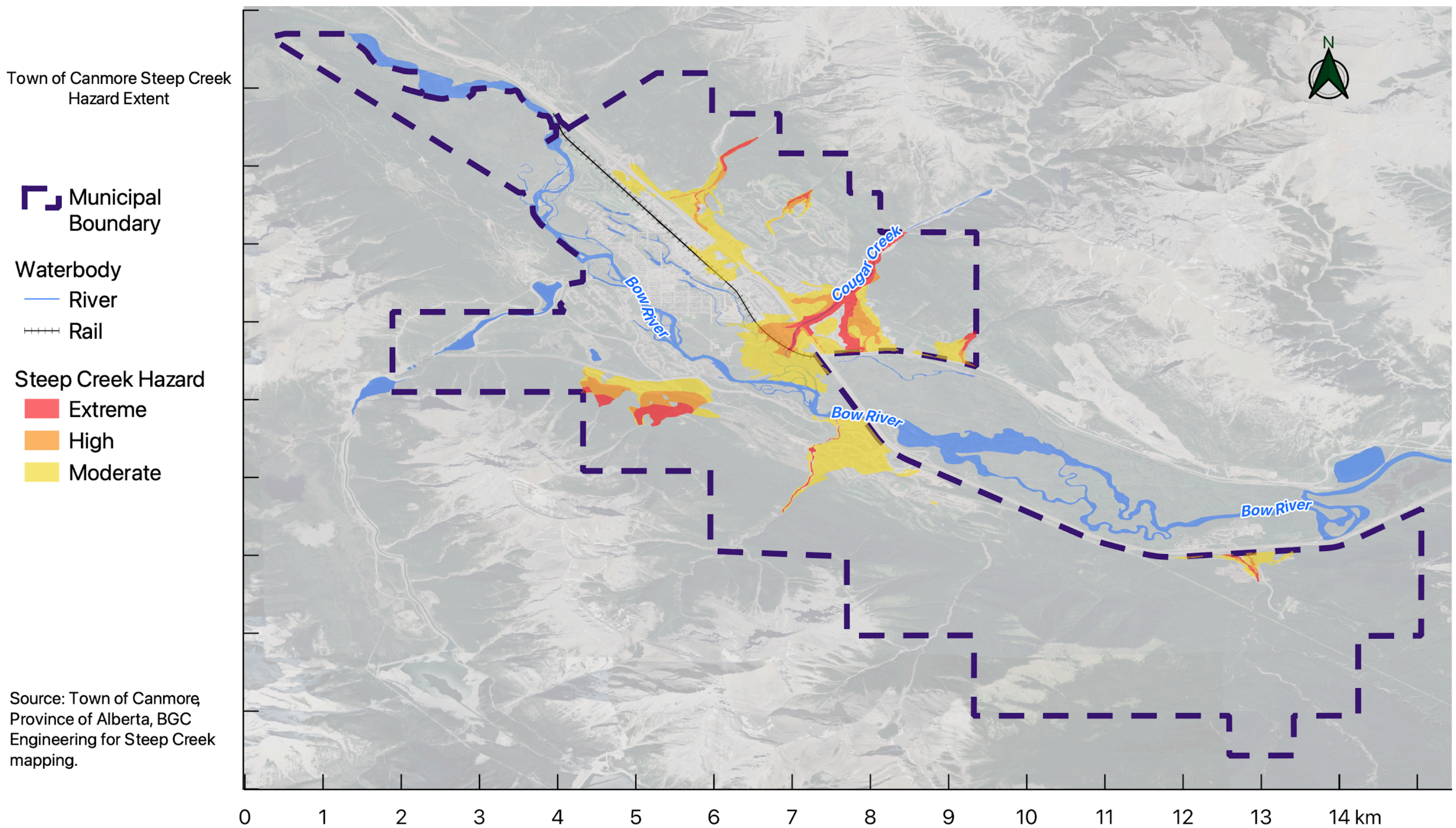


Figure 6. Extent of Steep Creek Hazard Zones for the creeks included in the risk assessments completed between 2015 and 2018 by BGC Engineering, Ltd. Hazard level increases from yellow to red in severity, based on the steep creek risk assessment analysis.

Financial Impacts

Unmitigated steep creeks pose the greatest risk of both damage to buildings and loss of life. Unmitigated damages to buildings are summarized in Table 9.

The Three Sisters and Cougar Creeks pose the largest risk to buildings and infrastructure. Damages from steep creek are modelled to exceed $240 million in a 1,000-3,000 year event, affecting 1,320 parcels. Monitoring and flood mitigation measures for these creeks, as well as continuing stringent development planning to reduce the exposure to steep creek debris floods will be essential to protecting the buildings and infrastructure in these locations.

Further details on the potential impacts of steep creek debris floods and debris flows are found in the creek-specific reports completed by BGC Engineering, Ltd. for the Town of Canmore.[31]

[31] These studies are available for download from the Town of Canmore's website.

Table 9. Summary of unmitigated debris-flow damages to buildings for each steep creek for four debris-flow scenarios.

Creek	**30–100 yr**		**100–300 yr**		**300–1,000 yr**		**1,000–3,000 yr**		**Annualized Costs**
	# parcels	Buildings damages ($M)	# parcels	Buildings damages ($M)	# parcels	Buildings damages ($M)	# parcels	Buildings damages ($M)	
Stone	8	$10.3	11	$19.5	17	$20.4	22	$25.7	$300,000/yr
Pigeon[32]	15	$4.6	25	$4.6	25	$4.9	27	$7.9	$440,000/yr
Stoneworks	46	$7.8	46	$8.7	53	$16.8	57	$29.2	$790,000/yr
Three Sisters	211	$31.3	236	$37.1	257	$39.3	264	$40.3	$1,100,000/yr
Cougar[33]	37	$8.0	487	$40.0	707	$106.0	875	$129.0	$700,000/yr
X, Y and Z	0	$0.4	8	$2.56	34	$5.5	75	$9.4	$13,000/yr for X $16,000/yr for Y $21,000/yr for Z
Total	**317**	**$62.4**	**813**	**$112.5**	**1,093**	**$192.9**	**1,320**	**$241.5**	

[32] Pigeon Creek results include the 2b scenario for culvert blockage. This scenario shows the most severe damages and flooding.

[33] Cougar Creek results include the 3b scenario with ERBC blockage.

Human Health and Safety

Injury and death can occur from steep creek hazard, where people may be caught in the high-velocity flows, or debris flows cause damage to homes, businesses or other infrastructure. The risk of loss of life, shown as the number of fatalities, for each creek has also been assessed by BGC Engineering, and is shown in Table 10, below. All values shown in the table are based on the base case without any steep creek mitigation implemented.

Table 10. Estimated number of fatalities from unmitigated debris-flow scenarios for each steep creek.

Creek	30–100 yr	100–300 yr	300–1,000 yr	1,000–3,000 yr
Stone	<1	2	3	4
Pigeon[34]	0	0	0	2
Stoneworks	0	0	1	3
Three Sisters	0	0	<1	<1
Cougar[35]	<1	5	42	57
X, Y and Z	<1	<1	<1	3
Total	**<1**	**7**	**46**	**69**

Subsequent portions of this project will explore measures to reduce the potential for injury and death from debris flows in steep creeks.

Other Impacts

[34] Pigeon Creek consequences included the 2b scenario for culvert blockage. This scenario shows the most severe damages and flooding.

[35] These numbers are based on the unmitigated debris flow conditions. Mitigated flows will be assessed in the Adapted Scenario, including currently planned and future mitigation structures.

Critical Infrastructure

Debris floods and debris flows can cause serious damage to buildings, roads, railways, infrastructure, within a steep creek hazard zone. The risk assessments undertaken by BGC identify the parcels with the highest risk of damages.

Services

Flooding along steep creeks can result in the need to evacuate homes in high-risk areas, and damages to homes and infrastructure can result in costly and intensive repairs. Emergency shelter during evacuations, as well as longer-term housing for people displaced by debris floods and debris flows, will be needed to ensure those impacted by steep creek flooding are safe and can remain in their community during repairs and clean-up.

Environment

Debris floods/flows can cause significant damage to creek ecosystems, through bank erosion and sedimentation in shallow areas and down-stream water bodies. High-velocity flows can uproot trees and damage creek-side habitats, destabilizing these environments, and increasing the risk of slope failures and even landslides along these areas.

Disturbances like landslides, debris flows, and wildfires can open up new niches within an ecosystem, with opportunities for new species and microhabitats to flourish.

Economy

Economic impacts from debris floods/flows come from disruptions to buildings and transportation infrastructure. Potential damages to buildings are summarized in Table 9, but these values don’t include the costs associated with displacement, clean-up, repairs, business interruption, or other indirect damages. Impacts to tourism from damages associated with debris floods/flows, including damages to accommodations, businesses, roads, and other infrastructure, are also not included in these estimates.

Extreme Heat

Summary of Impacts

Category	Impact
Changes to hazard due to climate change	• Higher average temperatures • More heat waves • Hotter nights
Infrastructure/Critical infrastructure	• Increased importance of grid stability • Decreased hours available for road and other infrastructure repairs
Services	• Increased peak electricity demand • Increased hospitalizations • Increased demand for cooling centres
People	• Increased risk of heat-related health impacts and diseases • Increased demands on health services, with added stresses to healthcare workers and emergency services
Environment	• Decreased air quality • Tree canopy loss • Changes in water availability from glacial and snowpack melt • Heat stress on vegetation and changes in species composition as the climate warms • Changes in water quality from algal blooms and reduction in dissolved oxygen in warmer waters
Economy	• Increased energy costs for households, businesses, and institutions for space cooling • Loss of productivity due to heat-related illnesses • Reduced tourism from long-term impacts to glaciers and mountain snowsports

Context

Increasing annual average temperatures, as well as higher maximum temperatures, mean that heat will affect Canmore more and more over the coming century. Canmore is protected from the most extreme heat by its geography, with the compounding effects of shading from surrounding mountains, nighttime cooling from chilled air settling in the valley, and wind patterns bringing cool air into the town. As the climate changes, increasing global temperatures will impact the community in various ways. Canmore can expect warmer summers and longer periods above freezing. Increased heat impacts the changes in snowpack at elevation, and increases the potential for warmer winters. Canmore's drinking water comes from both surface and groundwater sources, and changes in precipitation and snowpack can alter the recharge and quality of these water sources. A longer growing season and warmer winters impact biodiversity and natural spaces, resulting in changes in species composition in forests and in waterways, and can result in the spread of invasive species.

This section will focus on the impacts of increasing temperatures on the people and supporting infrastructure in Canmore. Water security and invasive species and disease are discussed later on in this report.

Using satellite data for the region, the variation in average temperatures across Canmore can be more fully understood. Figure 7 shows the impacts of land use on surface temperatures, with cooler blues indicating treed and vegetated areas, while hotter reds show more densely developed areas. The variation in temperature by neighbourhood, relative to the Banff National Park weather station, shows the community-level variation in temperature across the town. Satellite imagery for 12:45 p.m. MT on August 7, 2022 was used as the basis of this analysis, and then adjusted to nighttime temperatures. Appendix 1 outlines the full details of this analytical method.

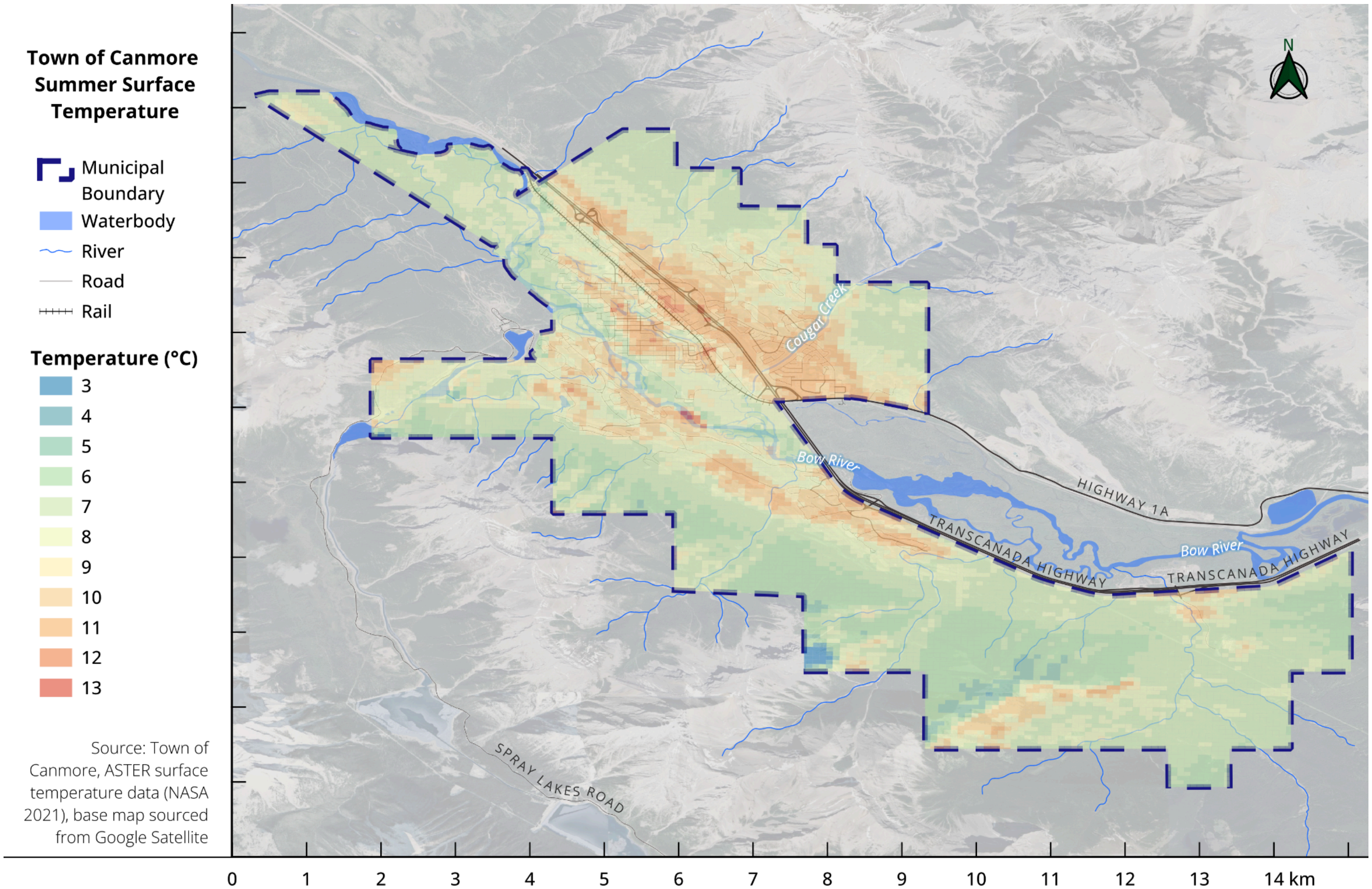


Figure 7. Nighttime land surface temperature in Canmore on August 7, 2022.[36]

[36] Modified from: NASA, 2021. ASTER surface temperature data. EarthData Open Access for Open Science. Accessed July 2023.

Urban Heat Island Effect

Land use greatly impacts the average temperature fluctuations of an area. Spaces that are heavily vegetated or treed, or are near water bodies, are typically cooler than those with hard, dry surfaces. Buildings, roads, sidewalks, and parking lots absorb heat from the sun and reflect it back, concentrating heat in densely developed areas. These areas, known as urban heat islands (UHIs), are pockets of landscape with elevated temperatures that are made worse by human activities (e.g., driving), or internal space cooling, that release more heat into the environment. UHIs show elevated average temperatures—an issue of particular concern during heat events. Areas with lots of vegetation and natural cooling may be within a safe temperature range for humans, while UHIs are pushed into an unsafe range, increasing the risk of serious health impacts on people within those locations.

Figure 7 shows the role land use plays in the variation of heat. For example, the more developed areas in the downtown areas of Canmore show higher temperatures than the less developed areas on the outskirts of the town. Note that while Figure 8 shows the heat variation based on current land use, it shows the mean temperature value across an entire neighbourhood. The Stewart Creek neighbourhood, in the east of the town, shows a high temperature based on the mean value derived from the mix of currently developed land and land that is slated for development in the near future.

Future temperatures across Canmore will be influenced by climate change and land use decisions such as densification of urban areas. Replacing treed and vegetated areas with urban materials such as concrete and asphalt can lead to an increase in the UHI effect and increased heat risk for the population living in these areas.

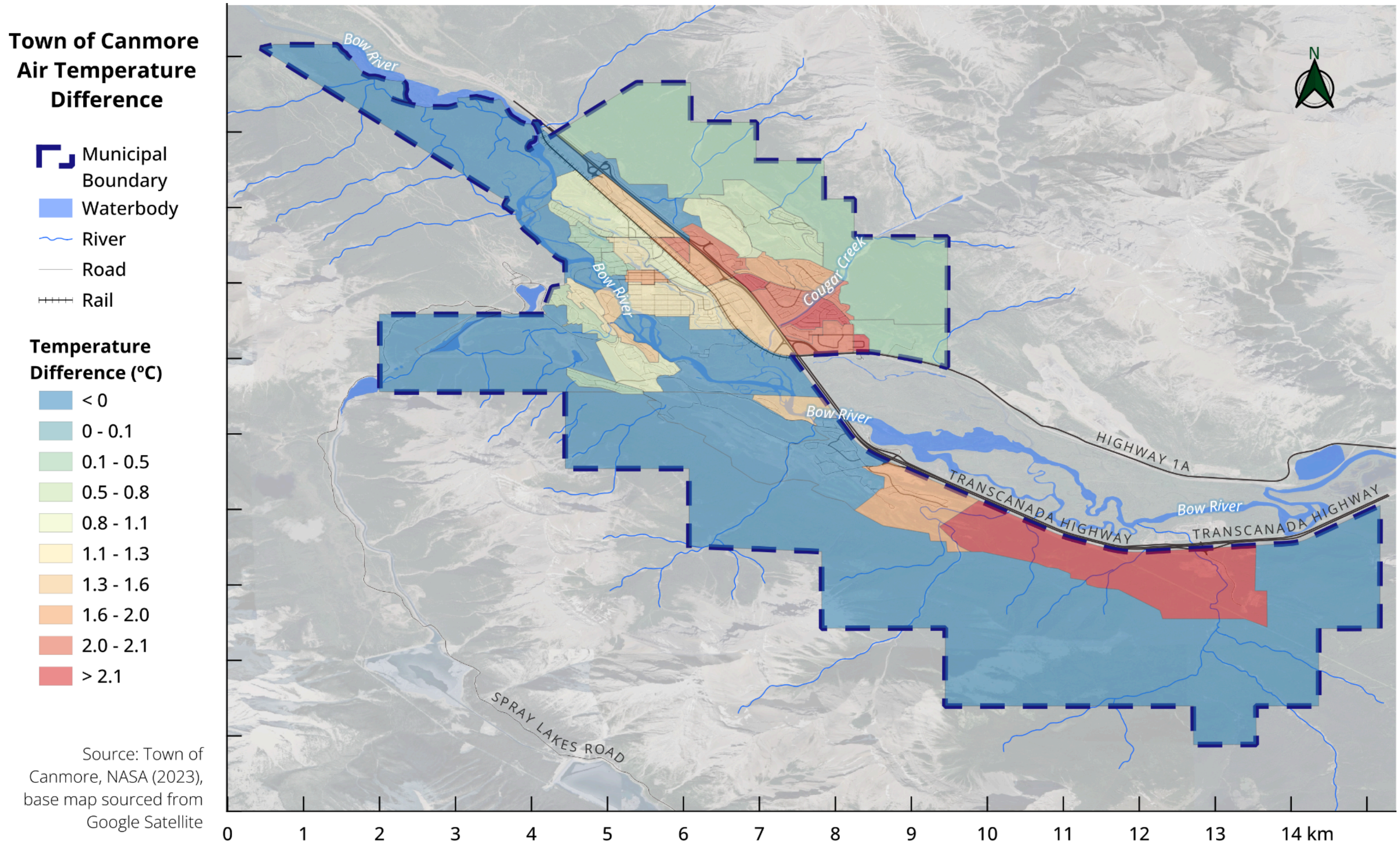


Figure 8. Temperature variation across Canmore relative to the baseline temperature of the Banff weather station, based on temperatures recorded on August 7, 2022.[37]

[37] Modified from: NASA, 2021. ASTER surface temperature data. EarthData Open Access for Open Science. Accessed July 2023.

A comparison between the present day (Figure 9) and the 2070 (Figure 10) temperatures during a 1-in-10 year heat event highlights the increase in temperatures across the town, with almost the whole town experiencing nighttime temperatures exceeding the 14°C heat warning threshold in the 2070 scenario, with the highest temperatures found in the most densely developed areas of the town.

This analysis examines nighttime land surface temperatures,[38] as daytime surface temperatures show more variability while nighttime temperatures more closely mimic air temperatures. Additionally, elevated nighttime temperatures where people lack the ability to cool off overnight are strongly linked with negative health impacts including death, hospital admissions, cardiovascular issues, and other health conditions.[39]

[38] NASA, 2023. Land surface temperature is how hot the “surface” of the Earth would feel to the touch in a particular location.

[39] Murage P, Hajat S, Kovats RS. Effect of night-time temperatures on cause and age-specific mortality in London. Environ Epidemiol. 2017 Dec;1(2):e005. doi: 10.1097/EE9.0000000000000005. Epub 2017 Dec 13. PMID: 33195962; PMCID: PMC7608908.

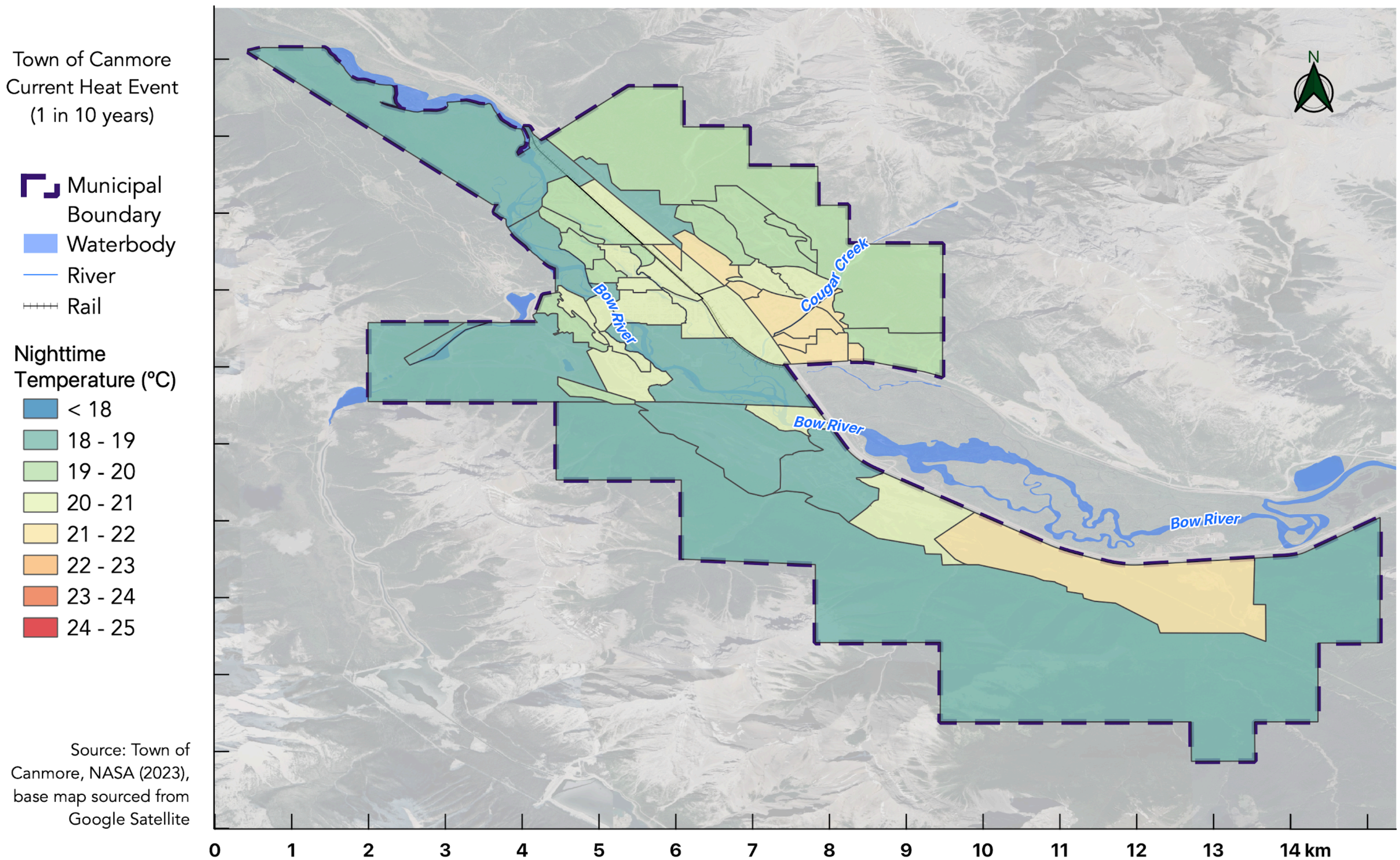


Figure 9. Estimated minimum nighttime temperatures across Canmore during a 10-year heat event in the present day.[40]

[40] A 10-year heat event has a 1-in-10 chance of happening in any given year.

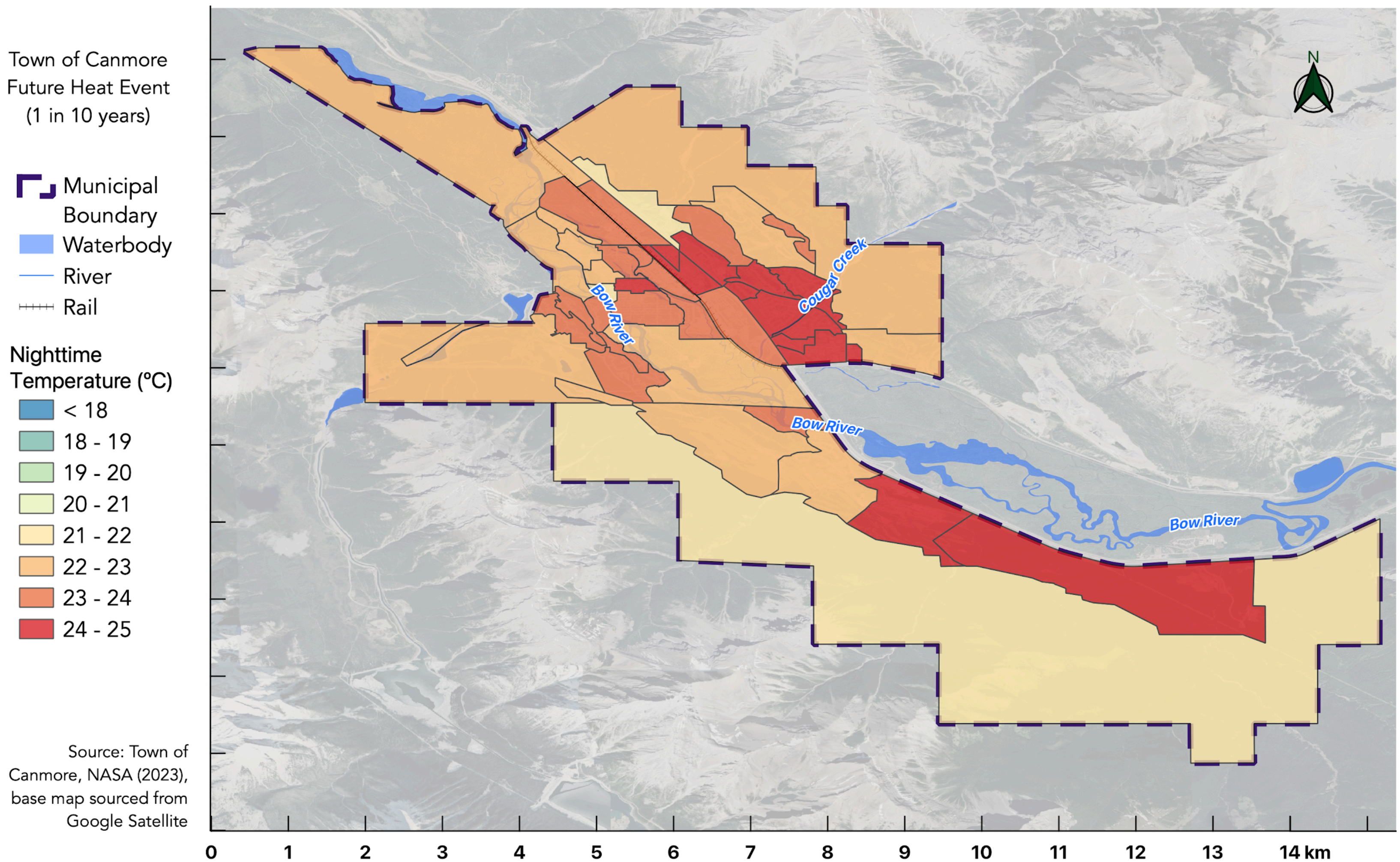


Figure 10. Minimum nighttime temperatures across Canmore during a 10-year heat event in 2070, with the combined impacts of climate change and development.

Human Health and Safety Impacts

Vulnerability to heat is influenced by a number of physical and social factors. For example, people over age 65 and those with lower incomes are more at risk of serious consequences or death during heat events, as they are physically more vulnerable and/or have reduced access to space cooling. Climate change is increasing the frequency of heat waves that put people at risk, including high daytime temperatures and warm nights.

Identifying highly vulnerable neighbourhoods is essential when developing preventative programs and responding to emergency events. Figure 11 shows Canmore's highly vulnerable populations (older than 65 years and lower income[41]) for a present day 10-year heat event: approximately 210 individuals are at risk presently. Figure 12 shows the impacts of increasing heat on the number of highly vulnerable people in 2070 for a 10-year heat event, assuming that the distribution of socioeconomic factors stays consistent across neighbourhoods in Canmore over time. The number of highly vulnerable people jumps to 580 by 2070, due to a combination of development patterns and population growth.

A minimum nighttime temp of 14°C is Environment Canada's threshold for issuing a heat warning for most of Alberta.[42] Extended periods of high heat (above 29°C), particularly when paired with nighttime temperatures above 14°C, lead to a higher risk of health impacts and death.[43] Those without the ability to escape the heat through the use of air conditioning or improved building quality are more likely to feel the negative effects of high temperatures.

[41] Individuals are classified as being in low income if their income falls below 50% of the median adjusted household income.

[42] Environment and Climate Change Canada, 2020. MSC Heat Warning Criteria. Issued when two or more consecutive days of daytime maximum temperatures are expected to reach 29°C or warmer and nighttime minimum temperatures are expected to fall to 14°C or warmer.

[43] Environment and Climate Change Canada, 2020. MSC Heat Warning Criteria.

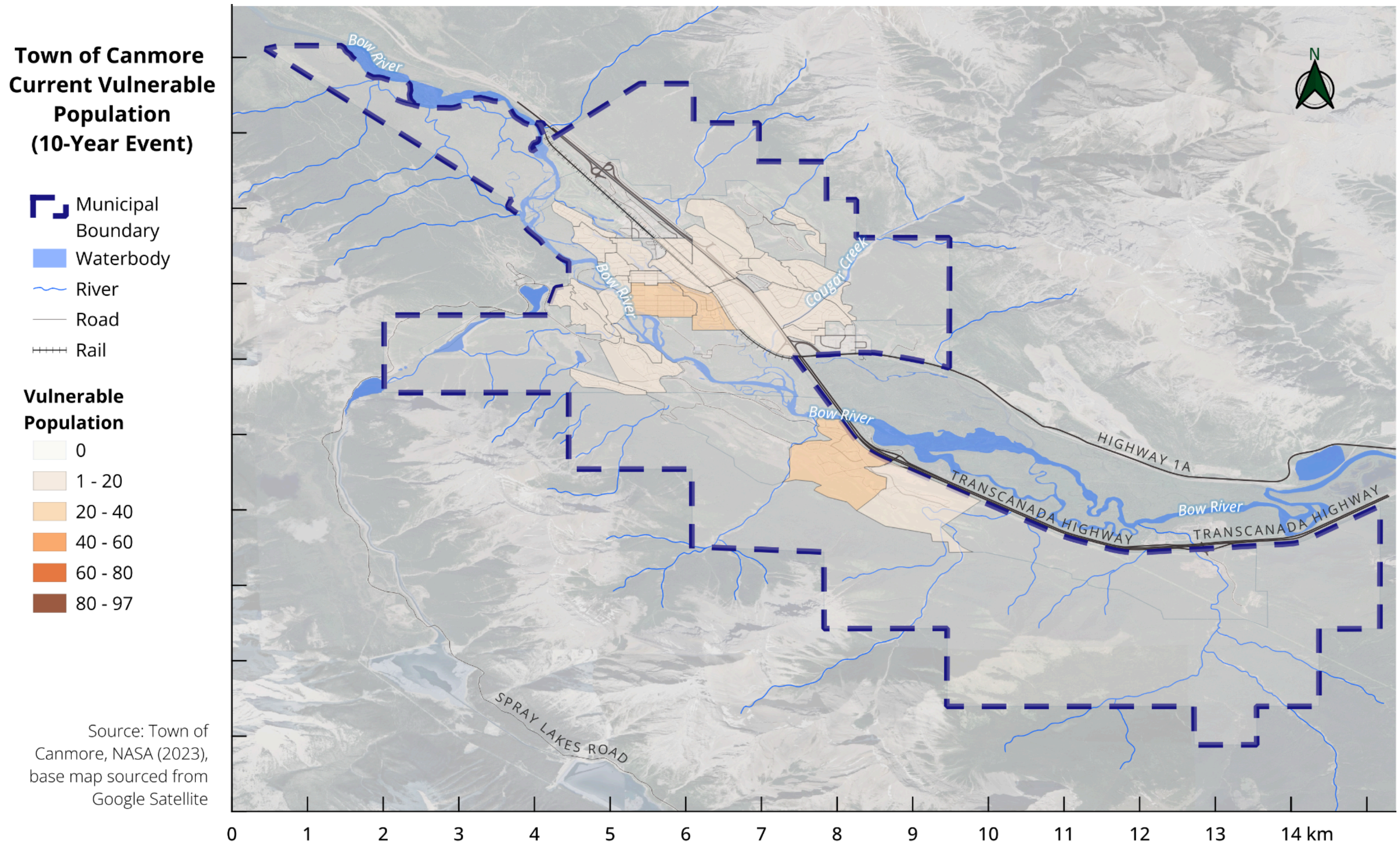


Figure 11. Present day segments of the population with low income and aged over 65 who are vulnerable to a heat wave (10-year heat event).

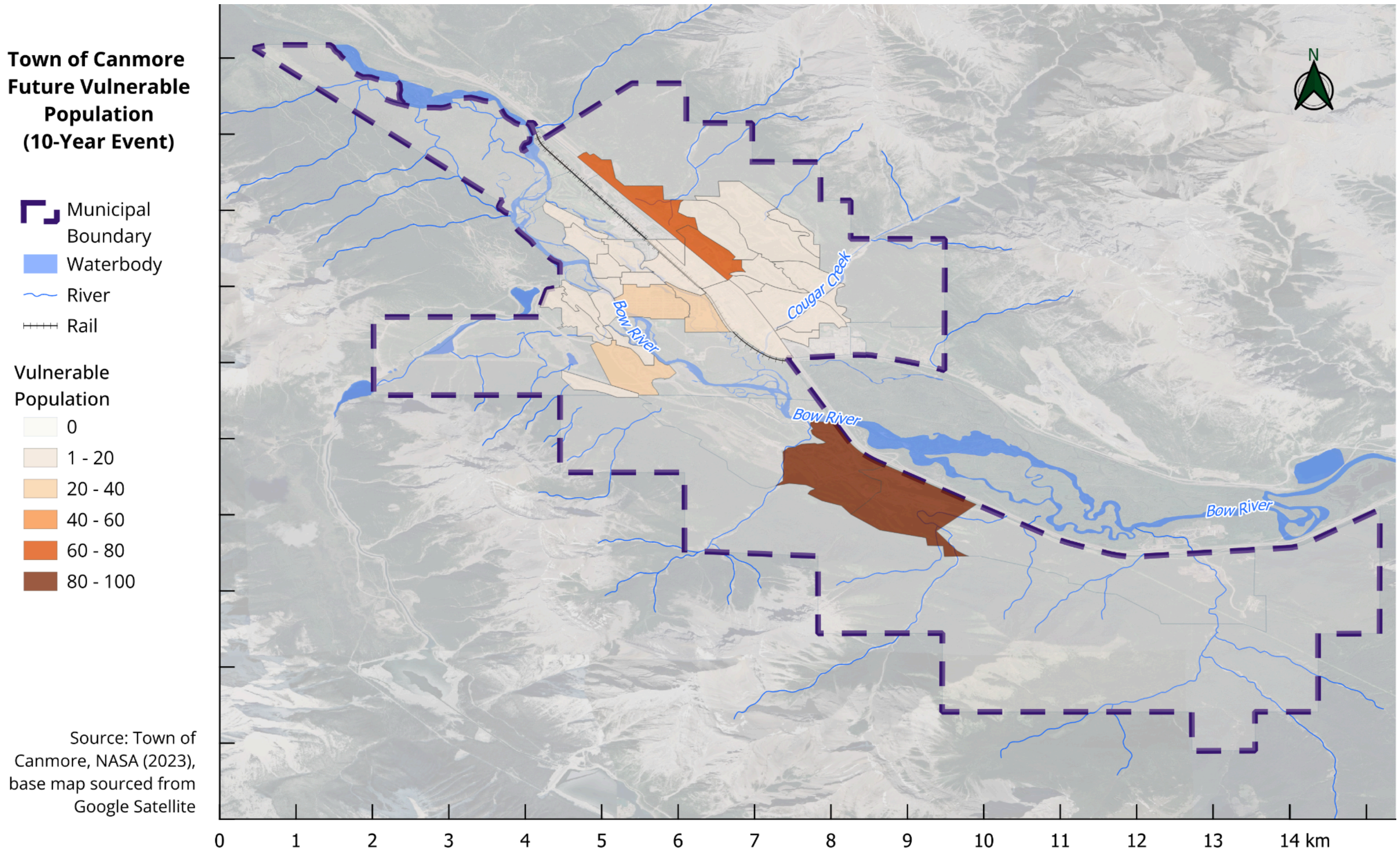


Figure 12. Future segments of the population with low income and aged over 65 who are vulnerable to a heat wave (10-year heat event).

Figures 11 and 12 reflect the location of people where they live, as nighttime temperatures present the highest risk for mortality and serious health consequences for most people. High nighttime temperatures mean that people lose the ability to cool off overnight, exacerbating heat-related illnesses and serious consequences. Because of this, the identification of vulnerable people is focused on dwelling location and the condition of their home. Elderly people living in assisted living centres likely have access to space cooling, and are less exposed to temperature extremes than those living in their own homes, especially if they do not have access to air conditioning or cannot afford adequate space cooling.

The 2023 report *Adapting to the Risks of Extreme Heat and Wildfire Smoke in Canmore* identifies additional locations with larger numbers of workers in vulnerable sectors that should be prioritized for protective measures. This report also identifies locations for potential cooling centres, supportive infrastructure like water fountains and temporary drinking water sources, and shade structures. Canmore's Emergency Response Plan outlines communication and management protocols for the Town before, during, and after a heat event.[44]

Socio-economic factors and densification influence heat vulnerability, making risk uneven across Canmore. Remedial actions to protect people during heat events should focus on neighbourhoods currently characterized by a higher proportion of low-income households or neighbourhoods likely to experience the most densification in the future. These neighbourhoods include Three Sisters, Stewart Creek, Palliser, South Canmore, Homesteads, and Spring Creek Mountain Village.

Other Impacts

Critical Infrastructure

Cooled indoor spaces will play a key role in providing protection against extreme heat events in the future. The difference in temperature between air conditioned homes and commercial buildings will increase as the years pass for all climate scenarios. As reliable space cooling depends on a reliable supply of electricity, electrical grid stability will play a critical role in mitigating heat risk in the future. Prolonged blackouts will be potentially fatal. Furthermore, electricity demand will follow outdoor temperature patterns and peak during

[44] AllOneSky Foundation, Associated Engineering, and The Resilience Institute, 2023. Adapting to the Risks of Extreme Heat and Wildfire Smoke in Canmore. Final Report.

the most extreme heat events, causing the most strain on the grid during times when its stability will be paramount.

Other infrastructure implications from increased summer temperatures will be faster degradation of transportation infrastructure, including roads and highways.[45] This will not only increase transportation infrastructure maintenance and investment expenses, but will also require more labour to assess and repair the increased deterioration. Additionally, projected summer temperatures will lead to more frequent periods of unsafe outdoor working conditions for infrastructure workers, shrinking their window of opportunity to repair these assets.

Services

Increased demand for electricity will not only put additional strain on the grid, but it will also put financial strain on households, who will need to cool their homes for longer periods of time. In addition, households will require more energy to keep their homes at a comfortable temperature as outside temperatures rise. For Canmore's higher-income households, this will pose an inconvenient increase in household expenditures, while lower-income households may be forced to make difficult decisions of whether to prioritize health or financial security. Lower-income households with air conditioning may be forced to make decisions to delay and minimize their use of space cooling. Households without space cooling will face increasingly difficult living conditions in the summer; as the years pass, they will not be able to safely shelter from rapidly increasing summer temperatures and extreme heat events, and will have to rely more heavily on public cooled spaces. Additionally, health services will see a marked increase in heat-related illnesses,[46] which will add significant pressure to the healthcare system in summer months.

Environment

Higher summer temperatures and an increase in frequency and intensity of heat waves will lead to poorer air quality. During periods of high temperatures, the amount of ground-level ozone pollution and particulate pollution increases. This can lead to increased health risks

---

[45] Barrow, Elaine, et al. "Pavement and Extreme Temperatures in the City of Toronto." *Canadian Centre for Climate Services*, https://climatedata.ca/case-study/pavement-and-extreme-temperatures-in-the-city-of-toronto.

[46] Healthlink BC. *Heat-Related Illness*. https://www.healthlinkbc.ca/healthlinkbc-files/heat-related-illness.

related to poor air quality, mainly impacting respiratory and cardiovascular systems,[47] which may lead to an increase in heart attacks and asthma attacks and further stress the capacity of the town's health services.

Trees, which provide valuable cooling and shelter during extreme heat events, will also experience increased periods and frequency of heat stress. Trees can withstand short periods of extreme heat, but prolonged periods of high heat can lead to significant tree damage and loss, especially when coupled with extended periods of drought.

Increased temperatures can result in higher water temperatures, particularly in lakes and smaller water bodies. Hotter and drier summers result in warmer, stagnant water in these water bodies—favourable conditions for the growth of blue-green algae, or cyanobacteria, which can release cyanotoxins into the water that affect the health of humans, pets, and aquatic life. This can be exacerbated by increased runoff during heavy storm events delivering nutrient-rich water to ponds and lakes. Blue-green algae is a concern for recreational uses of water bodies, such as swimming or splashing in shallow waters where algal blooms have been observed. Additionally, many fish species rely on cool waters to provide them with oxygen, and warmer waters can stress or kill these animals.

Economy

Increased temperatures, particularly heat waves, increase space cooling costs for households, businesses, and institutions. Prolonged periods of high heat place additional pressures on emergency services and health care services, and increase the demand for emergency supports like cooling centres.

Canmore's primary industry is the tourism industry, which brings in about $500 million annually.[48] Most of this tourism is driven by the natural beauty and mountains surrounding the town. Snow sports, as well as hiking, camping, and summer activities, are a critical contributor to the Canmore economy. Any changes to the environmental health resulting from elevated temperatures and heat waves, including degradation of forest health and instability of snowpack and glaciers, threaten the security of this industry.

[47] Government of British Columbia. "Air Quality Health Index." *Air Quality Data*, https://www2.gov.bc.ca/gov/content/environment/air-land-water/air/air-quality/aqhi.

[48] Tourism Canmore Kananaskis, 2023. https://www.explorecanmore.ca/

Riverine Flooding

Summary of Impacts

Category	Impact
Changes to hazard due to climate change	● Increased total precipitation annually and seasonally in spring and fall ● Higher average temperatures in winter and spring affect peak flows during spring freshet.
Infrastructure/ Critical infrastructure	● The wastewater treatment plant and pumping stations for drinking water are located within the Bow River floodplain. ● Other critical infrastructure buildings and operations centres are located outside of floodplains. ● Emergency service demand will be elevated during flooding because of the number of private homes and businesses located within the floodplains.
Services	● Municipal buildings, and other essential services are located outside of floodplains.
People	● Currently, over 3,100 people are at risk of being impacted by a very rare flood event (200–500 year event). ● By 2070, over 4,200 people are at risk of being impacted by a very rare flood event. ● Most of the buildings located within floodplains are residential or private businesses.
Environment	● River-adjacent lands could experience soil erosion. ● Flood events may cause the release of chemical contaminants such as paint solvents, fertilizer, and hydrocarbons as well as physical debris into the environment.
Economy	● Financial impact of potential structure damage, content damage, and business disruption during a rare flood event (50–100-year event) is estimated to be $225 million currently and $463 million in 2070

Context

Riverine flooding refers to flooding that happens when rivers, streams, and other water bodies overflow, spilling out onto the surrounding area. This type of flooding often occurs during the spring freshet, or during periods of prolonged, intense precipitation. In the future, total precipitation, as well as volume of precipitation over short periods, are expected to rise, in turn increasing the potential for riverine flooding.

Climate change is resulting in larger storms and reducing our ability to predict their severity as well as resultant flooding. Buildings, homes, roads, and other infrastructure located within flood zones are at risk of damage during floods. Access to essential services is also at risk during floods and during recovery periods. Flooding in Canmore often coincides with the spring freshet, with the melting of the snowpack, but can also occur from rainfall-driven storm events.

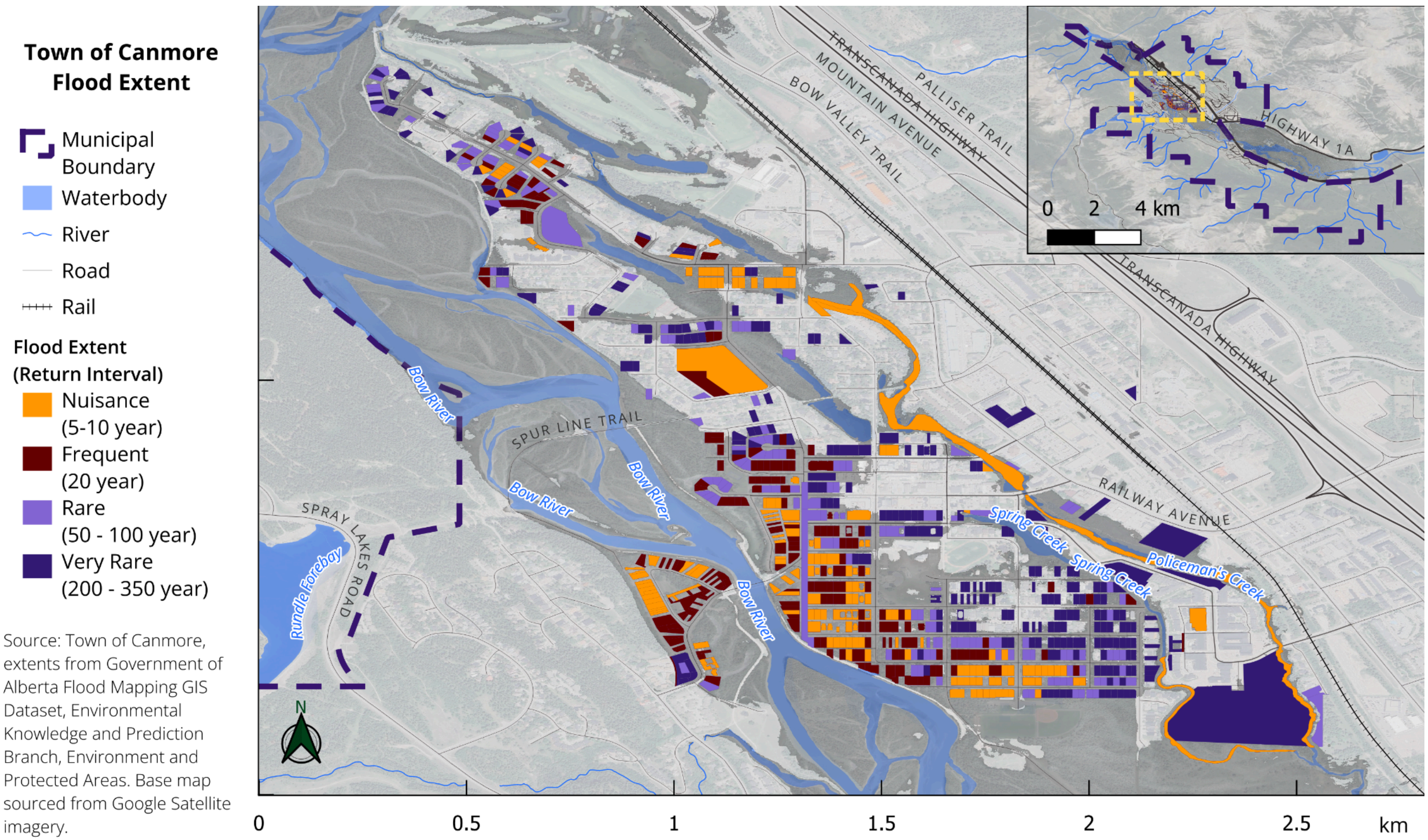
Floods are categorized by return periods, which refer to the statistical probability that a flood of a given severity will occur each year. A 1-in-100 year (or 100-year) return period flood has a 1/100 (or 1%) chance of occurring in any given year. A 1-in-10 year return period flood has a 10% chance of occurring in any given year, and a 1-in-500 year event has a 0.5% chance of occurring in a given year.

Flooding data in Canmore covers a range of return periods, from 2 to 1,500 years, with data availability varying by water body. To compare flood risk across Canmore, return periods are grouped into four categories. These categories are defined based on how often a person with a lifespan of 85 years can expect to experience a flood event of a specific magnitude.

Table 11. Flood categories and associated return periods

Category	Description	Return Periods
Nuisance	Events that occur often in a lifetime	5-year, 10-year
Frequent	Events that may occur several times in a lifetime	20-year
Rare	Events that may occur once or twice in a lifetime	50-year, 100-year
Very Rare	Events that may occur once, if at all, in a lifetime	200-year, 350-year

Climate change impacts on flooding extent was incorporated into the provincial flooding data for the Bow River used for this project. Figure 13 shows the extent of flooding in Canmore for all of the grouped return period categories. Note that areas that flood during a less-severe flood will also be flooded during more severe floods. For instance, an area that floods during a “Rare” flooding event will also be flooded in a “Very Rare” event; an area flooded in a “Nuisance” event will also be flooded in “Frequent,” “Rare,” and “Very Rare” events.



Source: Town of Canmore, extents from Government of Alberta Flood Mapping GIS Dataset, Environmental Knowledge and Prediction Branch, Environment and Protected Areas. Base map sourced from Google Satellite imagery.

Figure 13. Flooding extent in Canmore for all return periods. Inset map shows geographic extent of riverine flooding damages in Canmore.

Flood Damages

Figure 14 illustrates the geographic extent of flood-damaged areas for the present day, summed by neighbourhood. The map shows all flood return periods, with lighter yellow indicating less severe flood damages, and darker blue reflecting more severe damages. Areas that experience damages in a less severe flood will also experience damages in the more severe floods. For example, a home close to a frequently flooded area will experience damages during Nuisance, Frequent, Rare, and Very Rare floods, but a home further away from the flood-prone area may only experience damages during rare and very rare floods.

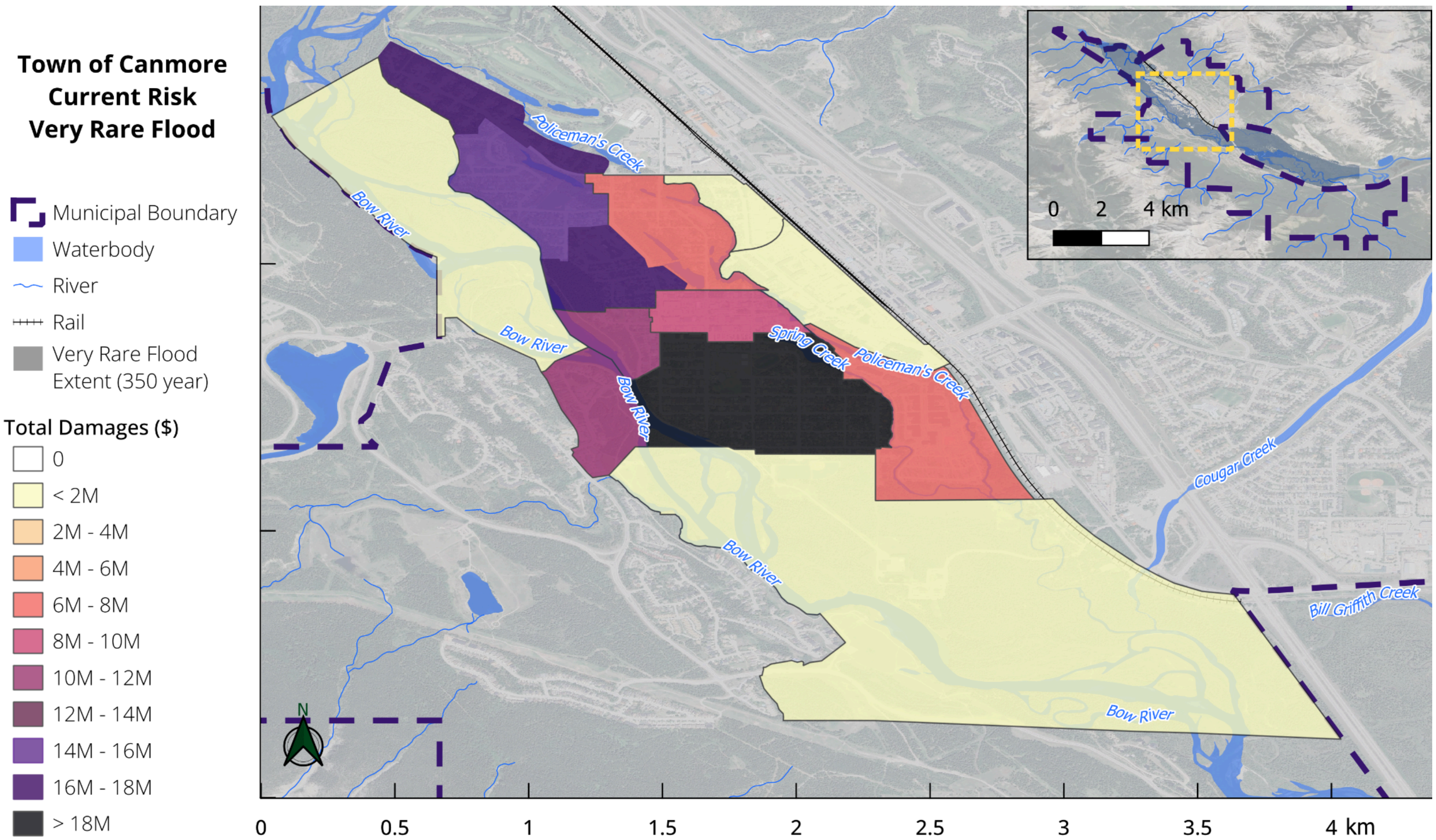
Because this map shows the presence of damages to buildings or their contents, or of disruptions in business operations, this analysis does not identify areas that may experience flooding but do not have buildings. Such areas, like parks or natural areas, may experience damage from flooding because of downed trees, erosion, changes in water quality, or other ecosystem alterations, but this analysis does not capture the economic damages to these natural systems.

The increase in potential damages from flooding between the present day and 2070 is a result of both the impacts of climate change and development across Canmore (Figure 15).

Where development intersects with flooding, damages to buildings, and their structures and contents, have been calculated.

Buildings and infrastructure that experience flood damages from riverine flooding, both now and in the future, have one thing in common: proximity to floodplains. River flooding is worsening as a result of climate change, in terms of the frequency and severity of floods. What counts as a 100-year flood today will become more frequent in 2070, potentially becoming a 50-year flood. This does not necessarily mean the previous 100-year flood is less severe, simply that it will become more frequent in the future.

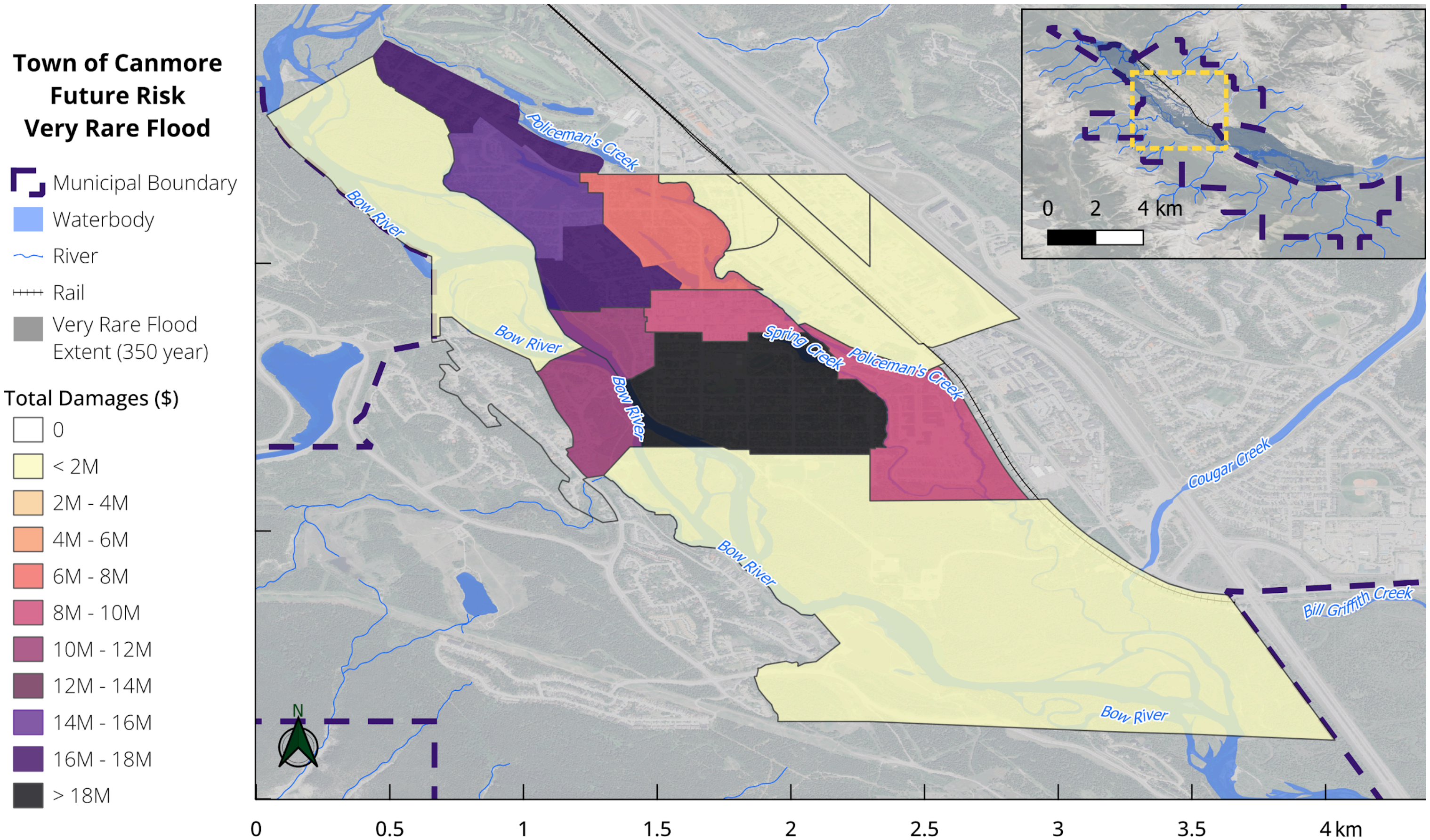
Protecting buildings, infrastructure, and people from riverine flooding can involve retreating from the highest-risk locations, modifying development planning to avoid these high-risk areas, and installing measures to flood-proof buildings and assets in flood-prone areas.



Source: Town of Canmore, extents from Government of Alberta Flood Mapping GIS Dataset, from Environmental Knowledge and Prediction Branch, Environment and Protected Areas. Base map sourced from Google Satellite imagery.

Disclaimer: Flood events are described by the "return interval," the probability of a flood event of a particular threshold to occur. Flood frequencies are grouped by the likelihood of an event to occur during a lifetime (average lifespan of 85 years). A "nuisance flood" describes flood events that occur many times in a lifetime. "Frequent flood" events occur several times a lifetime. "Rare flood" events may occur once or twice a lifetime. "Very rare flood" events may occur in a lifetime.

Figure 14. Flood damages from a Very Rare (200-year+) flood in the present day.



Source: Town of Canmore, extents from Government of Alberta Flood Mapping GIS Dataset, from Environmental Knowledge and Prediction Branch, Environment and Protected Areas. Base map sourced from Google Satellite imagery.

Disclaimer: Flood events are described by the "return interval," the probability of a flood event of a particular threshold to occur. Flood frequencies are grouped by the likelihood of an event to occur during a lifetime (average lifespan of 85 years). A "nuisance flood" describes flood events that occur many times in a lifetime. "Frequent flood" events occur several times a lifetime. "Rare flood" events may occur once or twice a lifetime. "Very rare flood" events may occur in a lifetime.

Figure 15. Flood damages from a Very Rare flood in 2070.

Financial Impacts

Financial damages from flooding depend on the severity of the flooding event, as well as the structures and infrastructure located within the floodplains. For this study, three types of damage were considered: direct, indirect, and intangible. Direct damages are damages that are quantifiable in terms of replacement value or repair cost; subtypes of direct damage included in the analysis are structure damage and content damage (e.g., furniture, electronics,). Indirect damages refer to road and utility infrastructure damage. Intangible damages represent financial burdens that occur because of displacement (e.g., hotels, meals) as well as business disruption (lost productivity).

Direct and intangible damages were calculated using damage functions from the Federal Flood Damage Estimation Guidelines for Buildings and Infrastructure.[49] These functions derive damages based on flood depth and the type of building impacted. Indirect damages are calculated as a percentage of direct damages based on the type of infrastructure (also from the Federal Flood Damage Guidelines). Appendix 1 provides further details on the damage functions used for this analysis.

Figure 16 shows the potential annual direct damages from flooding today across all four return periods in the present day, and in 2070. Figure 17 shows the same data categorized by damage to structure, contents, or disruption. The differences between the damages are a result of increased development as the population grows, as well as increasing severity of flooding caused by climate change.

[49] NRCAN. (2021). Federal Flood Damage Estimation Guidelines for Buildings and Infrastructure.

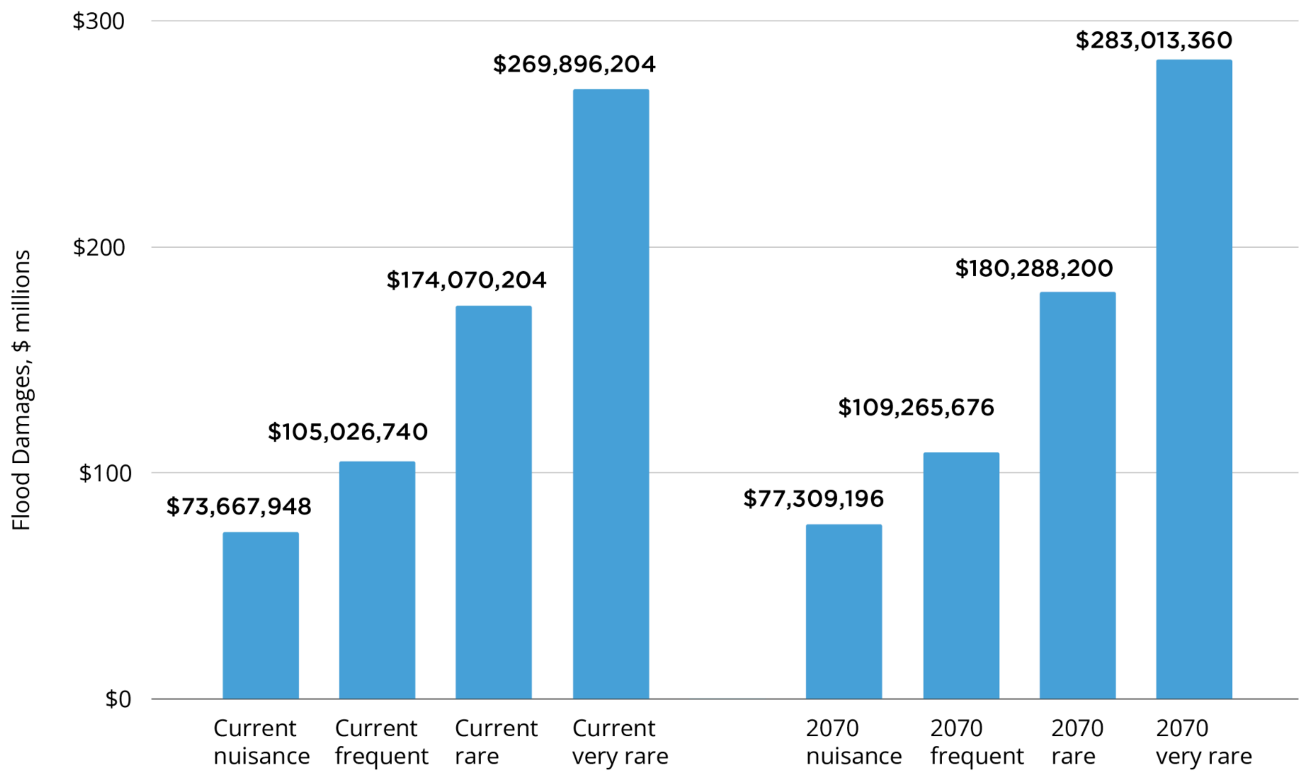


Figure 16. Total annual damages from flooding by return period for the present day ($ millions) and 2070 summed across the entirety of Canmore.

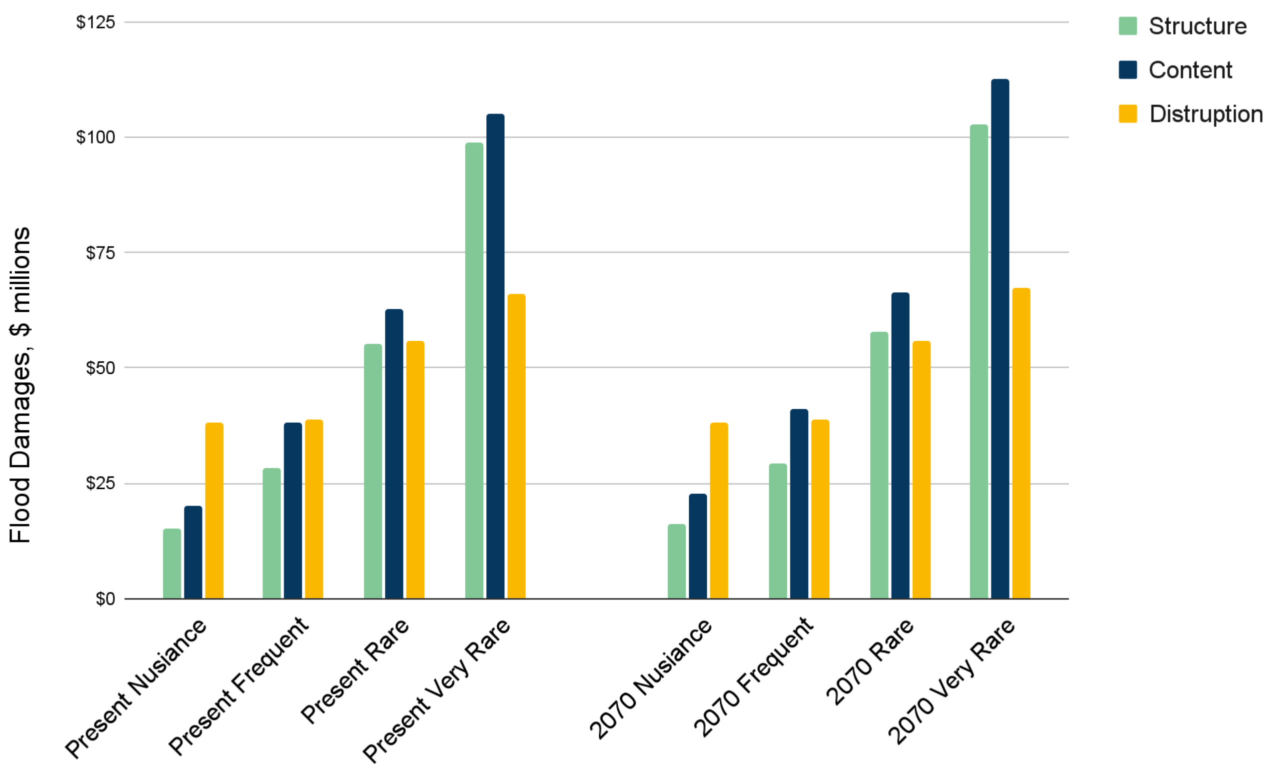


Figure 17. Potential total annual damages from flooding to structures, their contents, and disruptions to business and activities for the present day (left) and 2070 (right) across the entirety of Canmore.

A frequent flood in the present day causes $105 million in damages and a flood with the same return period in 2070 will cause $109 million in damages. While damages are slightly increased in the future, the lack of new development in the riverine floodplains limits the increase in damages in the future. New development in these areas, including infill development to increase density, would increase the potential damages from all levels of flooding along the river.

It is important to note that any development included in this analysis is built to current building and planning standards, and does not include any additional flood management measures either at the landscape or building level. An analysis of both the cost to implement flood management measures, and the potential avoided damages from these measures, will be included in the Adapted Scenario Report and the CEAP.

Human Health and Safety

Riverine flooding directly and indirectly impacts the health and safety of community members. Flooding to homes and businesses can negatively impact the health of people who live and work in these buildings, both from flood damages and the mental and physical health impacts of evacuation and disruption. Indirect impacts can include the loss of access to business and services because of flooding, or challenges in navigating the town because of road flooding or other blockages.

Figure 18 compares the total number of people at risk of flooding today and in 2070. In 2020, 18% (3,100 people) of Canmore was at risk of flooding during a very rare flood. By 2070, this will increase to 4,500 people as a result of population growth and infill development in flood-prone areas.

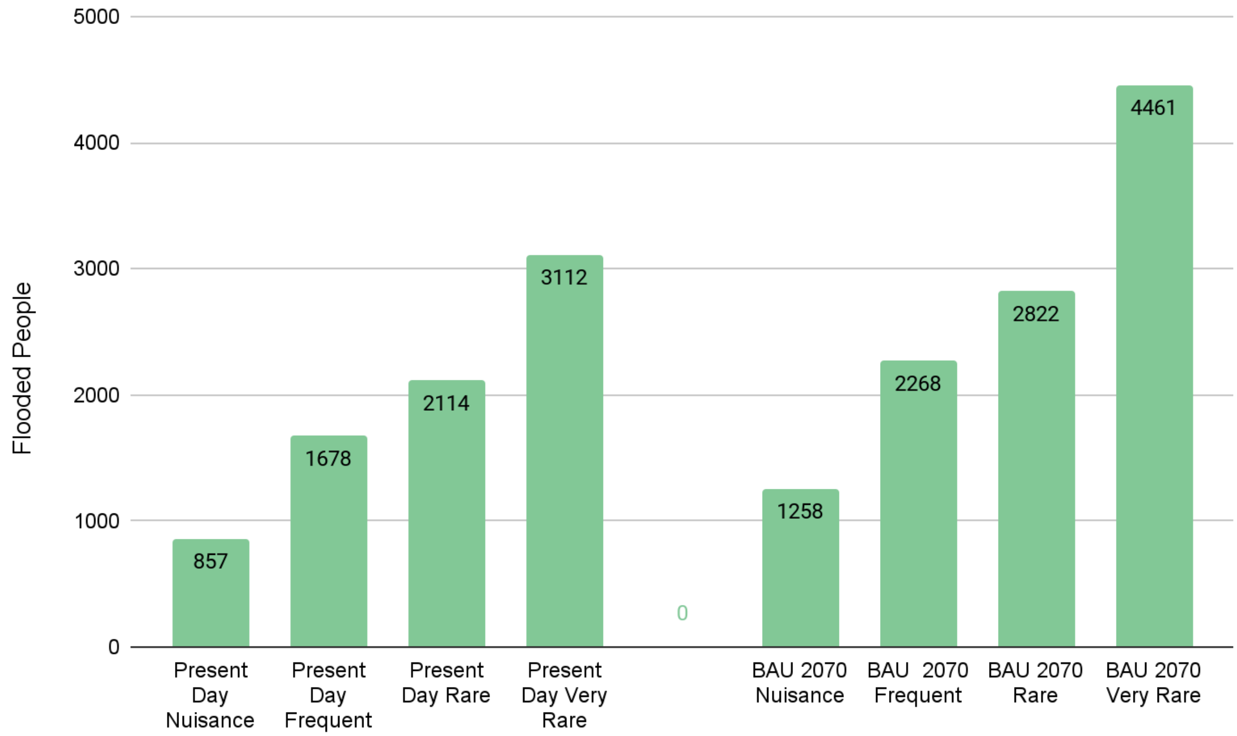


Figure 18. Total number of people in Canmore affected by flooding for each return period in the present day (left) and in 2070 (right).[50]

Flooding poses a physical risk to people who live in or near flooded areas, or who require access to services that are located in areas that are flooded or blocked by floods. In addition, flooding can have less tangible impacts on people, for example, through mental health issues like anxiety, depression, and trauma. Evacuations, particularly for extended periods of time, can exacerbate the mental toll natural disasters take on community members.

Insurance providers are increasingly limiting the types of coverage available to homeowners in high-risk locations. Supplemental coverage for flooding is sometimes available but requires residents to seek this coverage from their insurance provider.[51]

[50] People affected by flooding are those who experience flooding in the parcel of land on which they live. This includes all dwelling types, but does not include commercial or business properties unless they also have residential uses.

[51] Insurance Bureau of Canada, 2023. Water Damage and Flood Protection. Accessed: https://www.ibc.ca/stay-protected/severe-weather-safety/flood-and-water

The federal government completed a review of flood insurance options across the country and identified the need for standardized insurance options, as well as the need for property owners to participate in flood insurance programs to protect themselves and their assets.[52]

A person's increased vulnerability to flooding impacts is influenced by their physical abilities and socioeconomic factors. Those who experience more than one factor are increasingly vulnerable.

Older people (over age 65) are more at risk of negative impacts and death from flooding because of physical disabilities, reduced mobility, lack of access to medicine and medical equipment, and lack of housing that allows accessibility (e.g., single-floor buildings). Additionally, studies have found that older people are less likely to respond to evacuation or public safety orders, and may have physical difficulties with preparing their homes to protect against damages from flooding.[53] After a flood, many people experience trauma or struggle with the aftermath of damages. Older people, especially those who are socially isolated, may experience stress due to the disruption, lost property, or the challenges associated with insurance claims and repairs.[54]

Socioeconomic factors influence vulnerability to flooding in a number of ways. For the 2021 census, Statistics Canada provides different definitions of low income. For this analysis, a low-income household is considered to be a household whose total income is below the after-tax, low-income measure thresholds based on household size.[55] Persons living in these households may have a reduced ability to prepare for and evacuate during emergencies, relying heavily on emergency services where available, as they may lack the financial resources for preparedness measures and/or access to vehicles and funding to

[52] Government of Canada, 2022. Adapting to Rising Flood Risk. An Analysis of Insurance Solutions for Canada. Canada's Task Force on Flood Insurance and Relocation.

[53] Fielding, J., Burningham, K., Thrush, D. and Catt, R. (2007) Public response to flood warning. R&D Technical Report SC020116. Environment Agency, Bristol.

[54] Whittle, et al. (2010) 'After the rain: Learning the lessons from flood recovery in Hull', final project report for Flood, Vulnerability and Urban Resilience: A real-time study of local recovery following the floods of June 2007 in Hull. Lancaster University.

[55] Statistics Canada. (2021) Dictionary, Census of Population, Table 2.4.

evacuate.[56] Those living in low-income households are also more likely to be renters or homeowners who are “house poor” (i.e., living in a home with an unaffordable mortgage).[57] People living in these situations may have reduced abilities to protect their homes from flood impacts (e.g., by installing physical structures to protect their home, by purchasing flood or disaster insurance), and difficulty recovering from the financial hardships associated with flooding events.

Based on the residential location of vulnerable people, 49 people meet both the criteria for vulnerability and live within the Bow River floodplain for a present-day Very Rare flood; this is projected to increase to 80 people by 2070. Figure 19 highlights specific neighbourhoods with higher concentrations of vulnerable people due to age and socioeconomic condition. This information can be used to help target programs for reducing risk to those most in need of support. While vulnerability is distributed across Canmore more broadly, programs and supports to protect those vulnerable to flooding in particular can start in these neighbourhoods.

[56] Substance Abuse and Mental Health Services Administration, 2017. Greater Impact: How Disasters Affect People of Low Socioeconomic Status. Disaster Technical Assistance Center Supplemental Research Bulletin.

[57] Statistics Canada. (2022) Housing Experiences in Canada: People in poverty. Accessed: https://www150.statcan.gc.ca/n1/pub/46-28-0001/2021001/article/00017-eng.htm

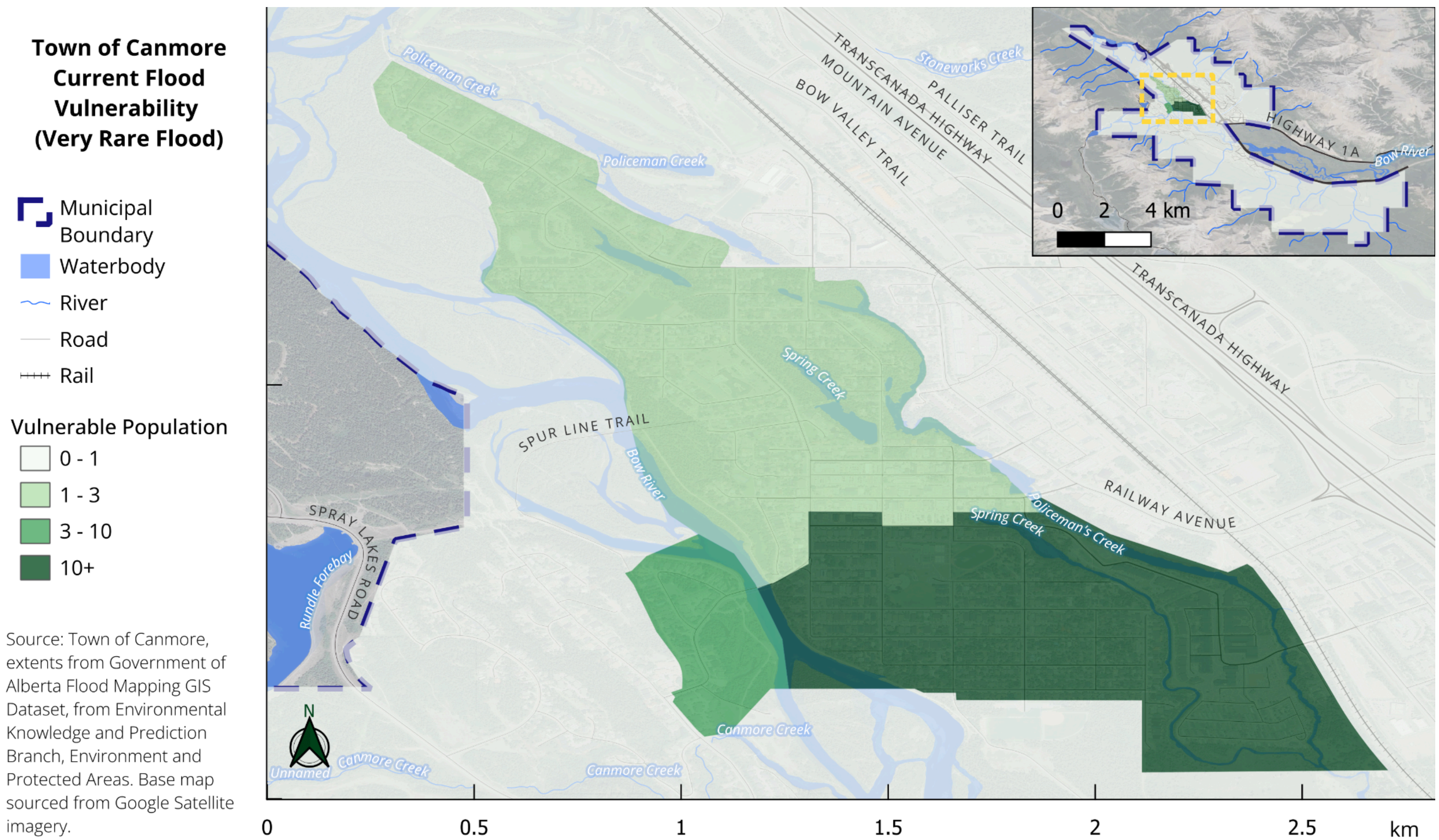


Figure 19. Number of ***highly vulnerable people*** *(defined by* ***age and socioeconomic condition)*** *affected by flooding in each neighbourhood during Rare or Very Rare flood events in the present day.*[58]

[58] Statistics Canada. 2023. (table). Census Profile. 2021 Census of Population. Statistics Canada Catalogue no. 98-316-X2021001. Ottawa. Released March 29, 2023.

Other Impacts

Critical Infrastructure

The wastewater treatment plant (WWTP) for Canmore is located near Bow River shoreline, within the existing 1-in-100 year floodplain. The WWTP, access roads, and supporting infrastructure are at risk of inundation during floods, and previous floods have rendered the WWTP an island within the river. The WWTP services the entire community of Canmore, and should the plant be damaged to the extent that it became inoperable, the town would have to be evacuated. Repairs could take many months and cost tens to hundreds of millions of dollars, resulting in severe disruptions to the community and economy of the area. Less severe flooding to the WWTP could still result in contamination of the Bow River, requiring the evacuation of downstream neighbourhoods.

Most of the buildings located in flood-prone areas within Canmore are private homes and businesses. Flooding will also affect roads and transportation as well as emergency services. Flooding on roads blocks vehicle travel, posing additional challenges for emergency access during flood events. Disruptions to travel within the community can affect community members outside of floodplains.

Infrastructure like bridges and culverts can experience additional stresses during high-flow events. These should be monitored to ensure they remain in safe operating condition, and are sized appropriately to withstand the increasing flood severity anticipated with the changing climate.

Services

Emergency services are essential for the community's safety and comfort during any emergency event, including flooding. Prolonged or frequent events can tax the human, physical, and financial resources of emergency services, and considerations must be taken to ensure all employees and volunteers are safe and supported so they can respond appropriately during emergencies.

Environment

Historically, Canmore has faced challenges with erosion along the riverbank during flood events. This erosion causes damage to homes, businesses, and other infrastructure, as well as reduced water quality in the Bow River and associated waterways. Climate change impacts and proximity of floods to the built environment may present changes in sediments which can alter the organic composition, chemical composition, and turbidity of water. The organic and chemical composition can affect the overall quality of water systems used for source water. If flood water becomes contaminated with agricultural waste, raw sewage (direct discharge due to overwhelmed stormwater systems), or metals, this may present biohazards.[59] Changes in the turbidity of water can negatively impact fish populations.[60]

Flooding overland could result in water pooling in areas not typically covered with water and debris. Stagnant pools of water in warmer seasons are a potential site for mosquito breeding, which can act as vectors for diseases.

Economy

Flooding can impact the economy through damages to homes, businesses, and infrastructure, as well as through lost work and productivity from business closures. Supply chain disruption can occur if flooding interrupts transportation, and agricultural crops and livestock can be lost in floods.

The financial impacts of structure damage, content damage, and business disruption during a very rare flood is estimated to be $370 million currently and $730 million in 2070.

The tourism industry, the primary industry in Canmore, is impacted by flooding due to the closure of roads and other transportation infrastructure; potential closures of accommodations, restaurants, and other services; and closures of tourism attractions like trails and outdoor activities within the town. Evacuation measures can be complicated for visitors, as visitors may not be prepared for emergency events, and tracking the location of

[59] Public Health Agency of Canada, 2021. Climate change, floods, and your health. Climate Change and Public Health Factsheets. Accessed: https://www.canada.ca/en/public-health/services/health-promotion/environmental-public-health-climate-change/climate-change-public-health-factsheets-floods.html

[60] McSheffrey, E, 2021. BC floods: Land, plants expected to recover, but concern for livestock remains, experts say. Global News, Nov 20, 2021. Updated Oct 7, 2022.

visitors is challenging. Long-term financial impacts may occur if closures of accommodations, businesses, and other attractions due to flood damages last for extended periods for repairs and reconstruction.

Water Security

Summary of Impacts

Category	Impacts
Changes to hazard due to climate change	• Higher average temperatures • Changes in freeze/thaw cycles • Changes in precipitation types and timing over the year
Infrastructure/ Critical infrastructure	• Changes in the supply of freshwater, and water storage needs. • Water treatment processes can require additional resources.
Services	• Disruption to emergency services due to shortages of water supply for catastrophic events (e.g., wildfire) during dry periods
People	• Drinking water supply can be affected, with a higher probability for disruption to residential water supply and enforcement of water restrictions during dry periods.
Environment	• Changes in soil during dry periods can reduce infiltration for groundwater sources. • Changes in snowpack upstream can negatively impact source water.
Economy	• Water use restrictions for visitors can be challenging to implement, and can impact the tourism industry. • Changes to water treatment processes can require additional costs.

Context

Increasing temperatures, as well as less predictable precipitation, pose a threat to water security for Canmore. Fresh water is supplied by upstream snow melt, glacial runoff, and precipitation. Changes in any of these elements affect both the quality and quantity of water available for municipal use, and in natural systems.

Increased precipitation, combined with more frequent severe precipitation events, leads to more dramatic fluctuations in water levels, with rapid influxes of surface runoff during rainfall events. These changes make it harder to use historic information to plan and manage freshwater resources into the future. Reduced high-elevation snowpack, or changes in the timing and types of precipitation, change the recharge of aquifers and the flow in surface water systems. Canmore relies on both groundwater and surface water for drinking water, and changes to the flow regimes in either of these systems will impact the availability of fresh water for the community.

Human Health and Safety

The sources that provide fresh water for Canmore, particularly the Rundle Forebay Reservoir, are susceptible to changes in upstream flow regime. Flooding can contaminate freshwater sources and require supplemental water treatment for safe human consumption. Historically, serious flooding events have necessitated boil-water orders. Additionally, droughts can reduce the volume of water available for freshwater uses, and result in water use restrictions to manage the quantity of water.

Recreational activities on the water can be impacted by contamination of rivers and lakes, including from runoff during flood or extreme precipitation, or as a result of higher temperatures and algal blooms.

Other Impacts

Critical Infrastructure

Drinking water in Canmore is supplied by both groundwater and surface water sources. All of these sources rely on upstream recharge from snowpack melt, glacial melting, and precipitation. Changes in the upstream water supply can affect the availability of freshwater in these aquifers and the Rundle Forebay Reservoir.

Changes in the quantity and condition of freshwater resources, particularly surface water sources, can impact how water must be treated for safe use. This can incur additional costs, in terms of chemical inputs, as well as energy demand for water treatment.

Services

Disruption to emergency services can occur due to shortages of water supply for catastrophic events (e.g., wildfire) during dry periods. Additionally, changes to water chemistry from flow regime alterations, such as changes in the volume and timing of precipitation events, can affect water treatment methods and potentially result in increased treatment costs or a potable water supply with undesirable odours or tastes.

Times of drought may necessitate water use restrictions, and in very severe or prolonged droughts, the community may require supplemental potable water.

Environment

Increasing temperatures, and longer periods of very high temperatures, will mean higher water temperatures in the summer months. Warmer water temperatures in lakes and rivers will mean lower dissolved oxygen levels, more harmful algae blooms, and stresses to cold-water species.

Increased precipitation, combined with more frequent severe precipitation events, leads to more dramatic fluctuations in water levels, with rapid influxes of surface runoff during rainfall events. Surface runoff can carry contaminants, including pollution and hydrocarbons, and the fast-moving water can increase erosion in and around water bodies. Additionally, stresses for forests and vegetation on slopes can increase the risk of wildfires or landslides.

Economy

Water use restrictions resulting from droughts and water scarcity, can impact the tourism industry. Hotels and visitor accommodations use large volumes of water, and imposing use restrictions on guests can be challenging as there is no immediate feedback in the form of water utility bills, or measures restricting water use for domestic purposes.

Changes in the quantity, quality, and temperature of drinking water can require changes to the treatment systems in place. These changes may include increased use of chemicals, or increased industrial energy costs for water treatment, depending on the specific conditions of the source water.

Long-term changes to snowpack and glaciers in the mountains surrounding Canmore could impact the tourism industry, with reduced demand for snowsports and glacier tours in these natural spaces. Recreational activities on the Bow River can also be impacted by reduced water quantity or quality with upstream changes in flow.

Conclusion

As global atmospheric GHGs increase and the climate continues to change, the likelihood of all modelled hazards increase. Risk is elevated by continued population growth, which places greater numbers of people, buildings, and critical infrastructure in potentially vulnerable areas across Canmore.

Understanding the hazards posed by climate change, and the risks associated with those hazards, will allow Canmore to prioritize actions to improve resilience, prepare for emergencies, and avoid damages from future events. The Adapted Scenario will explore the impacts of adaptation actions. These actions will be modelled in the next phase of work—defining their costs, infrastructure and material damage reduction impacts, and how successful they will be at reducing the number of people at risk.

All of this information will be pulled together into a comprehensive Climate Emergency Action Plan for Canmore, addressing both adaptation and mitigation priorities, as well as strategies for implementing the plan across the entire community.

Appendix 1: Data, Methods, and Assumptions

23025 Town of Canmore CVRA DMA

Appendix 2: Historic Hazard Scan

Hazard Conditions		Historic Event Characteristics		
Hazard	**Key Climate Indicators**	**Event**	**Event Conditions**	**Impact**
Extreme Heat	• Summer temperature • Number of days over 30°C • Tropical nights over 20°C • Humidex over 30	Aug 3, 2021	• Consecutive extreme heat (6 days) • Temperature range: 32–38°C (+1°C to +7°C daily historic maximums)	The heatwave is described as roughly a 1-in-a-100-year event based on its magnitude and duration.
Extreme Cold/Cold Snaps	• Winter temperature • Wind speed	Jan 10, 2024	• Wind chill factor: −40°C to −50°C • Polar jetstream	Energy grid limits
Dry Weather Conditions/Drought	• Summer temperature • Summer precipitation • Number of consecutive dry days • Standardized Precipitation Evapotranspiration Index • Glacial melt	Jun 9, 2023	• Summer temperature	Levels in the reservoir that supplies the community with its drinking water have dropped to below 50%.
		Jun 26, 2023	• Drought monitor (abnormally dry)	Rockfall and crevasse risks are more common.
Snow Accumulation	• Winter temperature • Winter precipitation • Freeze/thaw cycle • Wind speed	Dec 20, 2020		Reduced visibility
		Dec 4, 2021	• Heavy snow • Winter precipitation • Freeze/thaw cycle • Wind speed	Avalanche triggered

Hazard Conditions		Historic Event Characteristics		
Hazard	**Key Climate Indicators**	**Event**	**Event Conditions**	**Impact**
Freezing Rain/Ice Accumulation	• Summer temperature • Summer precipitation • Freeze/thaw cycle	Jun 15, 2021	• Hail	
		Jul 24, 2018	• Hail • High winds	
		Aug 7, 2023	• Max. 1-day precipitation • Hail	Power outages
Flooding	• Summer temperature • Precipitation over 20 mm • Max. 1-day rainfall • Max. 5-day rainfall	Jun 20, 2013	• Max. 1-day precipitation: 250 mm (+200 mm above historical average) • Saturated subsurface (consecutive wet days 40 mm) • High winds • Convergence of 2 huge weather systems • Erosion and deposition of heavy load sediment (boulders)	• Cougar Creek flooded • High velocity water • Power outages • Evacuation • 130,000 sqm of the creek bed and banks eroded • 80,000 m^3 of eroded material flowed into the community. • 60,000 m^3 of eroded material flowed into the channel itself and redeposited.
High Winds	• Maximum wind speed	Dec 13, 2018	• Max. wind speed: 130 km/hr	• Large vehicles blown over
		Nov 14, 2021	• Max. wind speed: 100 km/hr	• Danger of high profile vehicle tipping

Hazard Conditions		Historic Event Characteristics		
Hazard	**Key Climate Indicators**	**Event**	**Event Conditions**	**Impact**
Wildfire	• Max. temperature • Number of consecutive dry days • High winds	Aug 14, 2021	• Max. wind speed: 40 km/hr • Max. temperature: 30°C	• Worst air quality in Canada[61]
		Jul 19, 2017		• Fire ban in effect
Landslides and Rockfall	• Summer temperature • Summer precipitation	Jun 9, 2021	• Snowmelt • Terrain instability • Earthquake	• Noise: "people in nearby Canmore, Alta., thought a bomb had gone off" • No one was injured

[61] According to IQAir,a Swiss company that ranks places by air quality index (AQI) and air pollution (PM2.5), the air at these locations is considered hazardous.

Appendix 3: Hazard Assessment

Most climate indicators are collected from climatedata.ca for RCP 8.5 (SSP5-8.5). Biodiversity data is collected from Adapt West.[62] Wind speed is collected from Natural Resources Canada databases.[63]

Timescale of Assessment

The historical time horizon is collected to benchmark the future climate scenarios. This period is defined by the years 1950–2010. The future scenarios analysis covers the time span from the present day to 2100 with results for three time horizons: near-term (2011–2040), mid-term (2041–2070), and long-term (2071–2100).

The 2100 end year is used to align with climate data projections which typically span projection periods with an end year between 2070 and 2100, with the largest weather changes typically projected to happen toward the end of this period. Although a time span ending in 2100 is longer than typical community planning guidelines, many decisions made in the near-term will continue to determine the level of risk the community will face further into the future. For example, decisions around future development locations and infrastructure investments have resilience implications that will endure to the end of the century.

Scope of Boundaries for Assessment

The climate assessment values relate to the ~10 km x 6 km grid cell that Canmore lies within, as available on climatedata.ca. The values for this grid cell do not necessarily reflect varying microclimates. The grid cell covers most of the built environment of the municipal boundary.

[62] Wang, Tongli, et al. "Locally Downscaled and Spatially Customizable Climate Data for Historical and Future Periods for North America." *PLOS ONE*, edited by Inés Álvarez, vol. 11, no. 6, June 2016, p. e0156720, https://adaptwest.databasin.org/app/ecoregion

[63] Environment and Climate Change Canada. "Projected Surface Wind Speed Change Based on CMIP5 Multi-Model Ensembles." *Open Government Licence - Canada*, https://dd.weather.gc.ca/climate/cmip5/netcdf/historical/annual/anomaly/.

This area is the primary investigation for adaptation planning and decision-making for this project.

Data Gaps

No data gaps are noted for the hazard assessment.

Hazard Assessment

The threat likelihood for each climate indicator (CI) is calculated as the difference between the future value and the historical value. For indicators related to temperature measurements, change is measured in degree Celsuis. Many indicators are measured in terms of time (specifically days); these values are converted to weeks to be measured by “timing” thresholds. Precipitation and other non-frequency indicators are calculated as the percentage of change between the future value and historical value.

$$\text{CI Threat Likelihood} = \text{future value} - \text{historic value}$$

$$\text{CI Threat Likelihood (\%)} = (\text{future value} - \text{historic value}) / \text{historic value}$$

The change in a climate indicator is given a score that can be described as “no change” (score: 0), “minimal change” (score: 1), “low change” (score: 2), “moderate change” (score: 3), “high change” (score: 4), or “very high change” (score: 5) based on the degree of change (negative or positive). Table A3.1 summarizes the scale to use by the type of climate indicator for the assessment.

Table A3.1. A qualitative analysis of threat probability based on the change of the climate indicator.[64]

Table A: Hazard Threat Likelihood Scoring Methodology

Score	Definition	Temperature Change (°C)	Precipitation and Other Non-Frequency Indicators	Flooding (elevation, m)	Timing (weeks)	SPEI[65]	Wind (km/hr)*
−5.0	Very High Decrease	−20	−200%	−2.0	−20.0	−2.0	−100
−4.0	High Decrease	−10	−100%	−1.0	−10.0	−1.0	−70**
−3.0	Moderate Decrease	−5	−50%	−0.5	−5.0	−0.5	−50
−2.0	Low Decrease	−2	−20%	−0.2	−2.0	−0.2	−20
−1.0	Minimal Decrease	−1	−10%	−0.1	−1.0	−0.1	−10
0.0	No Change	0	0%	0.0	0.0	0.0	0
1.0	Minimal Increase	1	10%	0.1	1.0	0.1	10
2.0	Low Increase	2	20%	0.2	2.0	0.2	20
3.0	Moderate Increase	5	50%	0.5	5.0	0.5	50
4.0	High Increase	10	100%	1.0	10.0	1.0	70**
5.0	Very High Increase	20	200%	2.0	20.0	2.0	100
*	*Absolute value of the wind speed (a vector); negative or positive values refer to the direction of the wind*						
**	*Defined by the Fujita Scale, also from Environment Canada Thresholds: "70 km/hr or more sustained wind; and/or gusts to 90 km/h or more."*						

[64] American National Standards. *AWWA J100-21 Risk and Resilience Management of Water and Wastewater Systems*. 2021, https://engage.awwa.org/PersonifyEbusiness/Bookstore/Product-Details/productId/88116441.

[65] Standardised Precipitation Evapotranspiration Index

To assess the hazard threat level, the combination of climate change indicators that promote the hazard threat are grouped. This step is not included explicitly in the J-100 method, but adds local context for how hazards form in the region. The hazard threat is given a final threat score based on the average of the threat likelihood score for the combined climate change indicators.

$$\textbf{Hazard Threat Likelihood} = (\text{CI Score}_1 + \text{CI Score}_2 + \ldots \text{CI Score}_n) / n$$

The scores are reviewed and adjusted with additional context provided by subject-matter experts.[66] This final list is ranked from highest to lowest threat level with the intent to help prioritize risk reduction measures.

Table A3.2 summarizes the climate hazard assessment for Canmore, and shows how the hazards change over the near-, mid-, and long-term.

[66] In the case where the climate indicator trends decrease the threat likelihood of a hazard, the inverse score of the climate indicator threat likelihood is used. For example, a warming winter average temperature may have a high likelihood score for rapid increasing changes in the temperature, but this indicator will negatively impact the hazard threat likelihood of snow accumulation once values significantly rise above 0°C. The inverse value will be applied to reflect a lower likelihood over time for snow accumulation.

Table A3.2. Climate hazards in Canmore, and the climate indicators.

	Hazards	2020s (2011–2040) Threat	2050s (2041–2070) Threat	2080s (2071–2100) Threat	Average Threat Score	Threat Level	Key Climate Indicators	Trend	2020s (2011–2040) Score	2050s (2041–2070) Score	2080s (2071–2100) Score	Average Indicator Score
1	**Ecoregion Changes**	1.6	2.2	2.8	2.2	Low	Mean Annual Temperature	Increasing	2.0	2.0	3.0	2.3
							Mean Annual Precipitation	Increasing	0.0	1.0	2.0	1.0
							Frost-Free Days	Increasing	3.0	4.0	4.0	3.7
							Freeze/Thaw Cycles	Decreasing	0.0	0.0	0.0	0.0
							Annual Number of Growing Degree Days >5°C	Increasing	3.0	4.0	5.0	4.0
2	**Wildfire**	1.3	2.3	2.8	2.1	Low	Number of Consecutive Dry Days	Increasing	0.0	1.0	0.0	0.3
							Summer Temperature	Increasing	2.0	3.0	4.0	3.0
							Summer Precipitation	Increasing	1.0	2.0	3.0	2.0
							Maximum Temperature	Increasing	2.0	3.0	4.0	3.0
3	**Landslides**	0.8	1.5	2.3	1.5	Low	Number of Consecutive Dry Days	Increasing	0.0	1.0	0.0	0.3
							Maximum 1-Day Precipitation	Increasing	0.0	0.0	2.0	0.7
							Summer Temperature	Increasing	2.0	3.0	4.0	3.0
							Summer Precipitation	Increasing	1.0	2.0	3.0	2.0

	Hazards	2020s (2011–2040) Threat	2050s (2041–2070) Threat	2080s (2071–2100) Threat	Average Threat Score	Threat Level	Key Climate Indicators	Trend	2020s (2011–2040) Score	2050s (2041–2070) Score	2080s (2071–2100) Score	Average Indicator Score
4	**Severe Storm and Flooding**	0.3	0.8	1.5	1.1	Low	Maximum 5-Day Precipitation	Increasing	0.0	1.0	2.0	2
							Maximum 1-Day Precipitation	Increasing	0.0	0.0	2.0	0.7
							Precipitation Days >20 mm	Increasing	0.0	1.0	1.0	0.7
							Windspeed (Median)	Incremental	1.0	1.0	1.0	1.0
5	**Freezing Rain/Ice Accumulation**	1.0	0.6	1.1	0.9	Minimal	Frost Days	Decreasing	3.0	0.3	0.3	1.2
							Maximum 1-Day Precipitation	Increasing	0.0	0.0	2.0	0.7
							Summer Precipitation	Increasing	1.0	2.0	3.0	2.0
							Summer Temperature	Increasing	1.0	0.5	0.3	0.6
							Freeze/Thaw Cycles	Decreasing	0.0	0.0	0.0	0.0
6	**High Winds**	1.0	1.0	1.0	1.0	Minimal	Windspeed (Median)	Incremental	1.0	1.0	1.0	1.0

Hazards		2020s (2011–2040) Threat	2050s (2041–2070) Threat	2080s (2071–2100) Threat	Average Threat Score	Threat Level	Key Climate Indicators	Trend	2020s (2011–2040) Score	2050s (2041–2070) Score	2080s (2071–2100) Score	Average Indicator Score
7	**Extreme Heat**	0.5	1.3	2.3	1.3	Minimal	Maximum Temperature	Increasing	2.0	3.0	4.0	3.0
							Tropical Nights >20°C	Increasing	0.0	0.0	0.0	0.0
							Annual Number of Days with Max. Temp. >30°C	Increasing	0.0	2.0	3.0	1.7
							Days with Max. Humidex >30	Increasing	0.0	0.0	2.0	0.7
8	**Dry Weather Conditions/Drought**	0.4	1.1	0.8	0.8	Minimal	Number of Consecutive Dry Days	Increasing	0.0	1.0	0.0	0.3
							SPEI	Increasing	0.0	1.0	0.0	0.7
							Summer Precipitation	Increasing	1.0	2.0	3.0	2.0
							Summer Temperature	Increasing	0.5	0.3	0.3	0.4
9	**Snow Accumulation**	0.4	0.8	0.9	0.7	Minimal	Winter Temperature	Increasing	1.0	0.5	0.3	0.6

	Hazards	2020s (2011–2040) Threat	2050s (2041–2070) Threat	2080s (2071–2100) Threat	Average Threat Score	Threat Level	Key Climate Indicators	Trend	2020s (2011–2040) Score	2050s (2041–2070) Score	2080s (2071–2100) Score	Average Indicator Score
							Winter Precipitation	Increasing	0.0	1.0	2.0	1.0
							Ice Days	Decreasing	0.0	0.3	0.3	0.2
							Precipitation Days >10 mm	Increasing	0.0	1.0	1.0	0.7
							Windspeed (Median)	Incremental	1.0	1.0	1.0	1.0
10	**Extreme Cold/Cold Snaps**	0.6	0.8	0.8	0.8	Minimal	Minimum Temperature	Increasing	0.5	0.3	0.3	0.4
							Annual Number of Days with Min. Temp. <−15°C	Decreasing	1.0	2.0	2.0	1.7
							Freeze/Thaw Cycles	Decreasing	0.0	0.0	0.0	0.0
							Windspeed (Median)	Incremental	1.0	1.0	1.0	1.0

Appendix 4: Vulnerability Assessment

Vulnerability is conceptually a function of the **adaptive capacity**, **sensitivity**, and **susceptibility** of an area or sector. Adaptive capacity is a measure of the ability of built, natural, human, and social systems to **respond** to climate hazards. Sensitivity describes the extent to which the built environment and public resources are **prepared** to withstand impacts to the climate hazard. Susceptibility describes the **spatial vulnerability** to a climate risk (the proximity of known hazardous zones or where historical impacts have occurred). Scores are assigned to the three components of vulnerability per sector. In Table A4.1, each component of vulnerability is prompted by a key question that can be used in engagement activities to collect insights from key municipal departments.

Table A4.1. Thresholds for vulnerability scores.

Score		**Susceptibility** Is this area within direct impact if left unmitigated?	**Sensitivity** Is there adequate preparation to withstand hazard impacts?	**Adaptive Capacity** Is there adequate capacity to respond to this hazard?
1.0	Very High	• Very high likelihood the threat will translate to identified consequences • Within impact extent • History of impact	• Very high state of repair • Public resources overwhelmed	• Lack of capabilities to address hazard • Responses not implemented
0.8	High	• High likelihood the threat will translate to identified consequences. • Within/adjacent to impact extent • History of impact	• High state of repair • Public resources at capacity	• Low level capabilities to address hazard • Responses partially implemented or not achieving control objectives
0.6	Medium	• Medium likelihood the threat will translate to identified consequences • Adjacent to impact extent • History of impact	• No immediate repairs needed • Public resources at moderate capacity	• Medium level capabilities to address hazard • Responses implemented and mostly achieving control objectives

Score		Susceptibility Is this area within direct impact if left unmitigated?	Sensitivity Is there adequate preparation to withstand hazard impacts?	Adaptive Capacity Is there adequate capacity to respond to this hazard?
0.4	Low	• Low likelihood the threat will translate to identified consequences • Adjacent to impact extent	• Minimal repairs needed • Public resources available	• Medium to high level capabilities to address hazard • Responses implemented and achieving control objectives except in extreme conditions
0.2	Very Low	• Very low likelihood that the threat event (if occurs) will translate to identified consequences (adjacent to impact extent)	• System recently received adequate repairs/upgrades • Public resources readily available	• High level capabilities to address hazard • Responses implemented and regularly test for critical risks

Vulnerability Score	Very High (1.0–0.81)	High (0.80–0.61)	Moderate (0.60–0.41)	Low (0.40–0.21)	Very Low (0.20–0)

To assess Canmore's climate vulnerability to each of the nine hazards, a qualitative review of the town's adaptive capacity, sensitivity, and susceptibility was completed. This assessment was based on research, interviews with staff and community members, and reviews of current plans and policies.

Table A4.2 shows the assessed values for Canmore's adaptive capacity, sensitivity, and susceptibility to the climate hazards.

Table A4.2. Vulnerability assessment for Canmore.

Hazard Threat Level

Rank	Hazard	Threat Score	Rank	Key Features	Adaptive Capacity	Score	Sensitivity	Score	Susceptibility	Score	Sum	Average	Score
1	Ecoregion Changes	2.2	Low	Increases in temperature, the number of annual growing degree days, and the number of frost-free days will impact species composition and pest survival.	Moderate	0.6	Moderate	0.6	High	0.8	2	0.7	High
2	Wildfire	2.1	Low	Increasing overall and summer temperatures,, and less predictable summer precipitation	Low	0.8	High	0.8	Very High	1	2.6	0.9	Very High
3	Steep Creeks	1.5	Low	Summer precipitation increasing, and max. 1- and 5-day precipitation increasing by 30+% by 2080	Moderate	0.6	High	0.8	High	0.8	2.2	0.7	High
4	Extreme Heat	1.3	Low	Increasing max. temperature, annual number of days >30ºC, and days with humidex >30ºC	High	0.4	Low	0.4	Low	0.4	1.2	0.4	Low
5	Riverine Flooding	1.1	Low	Increasing max. 1-day and 5-day precipitation	Moderate	0.6	High	0.8	Moderate	0.6	2	0.7	High
6	High Winds	1.0	Minimal	Minimal changes	High	0.4	Low	0.4	Very Low	0.2	1	0.3	Low
7	Freezing Rain/Ice Accumulation	0.9	Minimal	Minimal changes	Very High	0.2	Very Low	0.2	Very Low	0.2	0.6	0.2	Very Low

Hazard Threat Level

Rank	Hazard	Threat Score	Rank	Key Features	Adaptive Capacity	Score	Sensitivity	Score	Susceptibility	Score	Sum	Average	Score
8	Dry Weather Conditions/ Drought	0.8	Minimal	Minimal changes	High	0.4	Low	0.4	Low	0.4	1.2	0.4	Low
9	Extreme Cold/Cold Snaps	0.8	Minimal	Minimal changes	Very High	0.2	Very Low	0.2	Low	0.4	0.8	0.3	Low
10	Snow Accumulation	0.7	Minimal	Minimal changes	Very High	0.2	Very Low	0.2	Very Low	0.2	0.6	0.2	Very Low

Appendix 5: Consequences Assessment

Consequence is measured qualitatively for direct impacts and indirect impacts. Direct impacts are costs related to financial, environmental and human health impacts. Indirect impacts are measured as delay and disruption to normal activity. Thresholds have been set for direct and indirect impacts based on historical impacts (see Table A5.1). Similar to vulnerability, all five sectors are attributed scores.

Table A5.1. Consequence Scoring Criteria.

Qualitative Analysis Thresholds

Score	Definition	Direct Impacts	Indirect Impacts
5.0	Severe	- Fatality - Catastrophic environmental impacts - Catastrophic financial impacts - Costs of >$10M	Loss of ability to meet business objectives based on severely impacted infrastructure or operations • months of delay (>1 year) • significant recovery
4.0	Major	- Long-term injuries and/or shock - Major environmental impacts - Major financial impacts - Costs of $1M–$10M	Reduced ability to meet business objectives based on major impacts to infrastructure or operations • weeks to months of delay • major recovery
3.0	Moderate	- Short-term injuries and/or shock - Moderate environmental impacts - Moderate financial impacts - Costs of $100K–$1M	Disruption to infrastructure or normal operations • days to weeks of delay • moderate recovery
2.0	Minor	- Minor injuries - Minor environmental impacts - Minor financial impacts - Costs of $10K–$100K	Minimal impacts to infrastructure or normal operations • hours to days of delays • minimal recovery
1.0	Insignificant	- Costs of <$10K	Insignificant impacts to infrastructure or normal operations • limited delays • limited recovery

Consequence	Severe (5.0–4.1)	Major (4.0–3.1)	Moderate (3.0–2.1)	Minor (2.0–1.1)	Insignificant (1.0–0)

Table A5.2 shows the direct and indirect impacts of the nine assessed climate hazards.

Table A5.2, Consequences assessment for Canmore.

Hazard		Consequence						
Rank	Hazard	Direct Impacts	Score	Indirect Impacts	Score	Sum	Average	Level
1	Ecoregion Changes	Moderate	3	Minor	2	5	2.5	Moderate
2	Wildfire	Severe	5	Major	4	9	4.5	Severe
3	Steep Creeks	Severe	5	Moderate	3	8	4.0	Major
4	Extreme Heat	Moderate	3	Insignificant	1	4	2.0	Minor
5	Riverine Flooding	Severe	5	Moderate	3	8	4.0	Major
6	High Winds	Minor	2	Insignificant	1	3	1.5	Minor
7	Freezing Rain/Ice Accumulation	Insignificant	1	Minor	2	3	1.5	Minor
8	Dry Weather Conditions/Drought	Minor	2	Insignificant	1	3	1.5	Minor
9	Extreme Cold/Cold Snaps	Insignificant	1	Insignificant	1	2	1.0	Insignificant
10	Snow Accumulation	Insignificant	1	Insignificant	1	2	1.0	Insignificant

Town of
CANMORE