Future of Stephen Avenue Climate Resilience Assessment

Final Report

May 17, 2022

Prepared for:

The City of Calgary

Prepared by:

Stantec Consulting Ltd.

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Increased trends in the magnitude and frequency of climate related events have prompted the City of Calgary to develop a Public Infrastructure Climate Risk Assessment process that aligns with the Public Infrastructure Engineering Vulnerability Committee (PIEVC) and Infrastructure Canada climate lens requirements. An expanded version of this process was applied to the planned redevelopment of Arts and Culture Character area (referred to as The Commons) along Stephen Avenue. The physical project boundary extends from the east end of Stephen Avenue at the Public Library and Calgary City Hall to 11st St. SW and includes the entire right of way along the avenue and between buildings. The process involved engaging with City staff and members of the design team in virtual workshops to:

1. Complete a hazard impacts assessment
2. Score consequences
3. Review priority risks and identify adaptation measures

The results of the risk assessment show that the biggest shift in risks (from low/medium to high) between the baseline (1980-2010) and the future periods (2050's, 2080's) are related to an increased frequency and severity of extreme heat events and severe storms. The assets likely to be at greatest risk in the future include street trees, humans, gardens/flower beds, and asphalt if no adaptation responses are incorporated into the project design. Hazards that pose lower risk to assets include drought, heavy snowfall, and wildfire. The low ratings are related to existing resilience in that many of the assets along Stephen Ave are resilient to drought events; there is a projected decline in heavy snowfall events; and Stephen Ave is an urban environment with no wildland-urban interface meaning that there is a low fire risk. While there is a low fire risk, smoke, smog and other pollutants in the air shed may increase in concentration during high heat or fire events and result in increased human health risks.

As part of the adaption planning process, 29 proposed adaptation measures were identified and prioritized based on defined evaluation criteria and in consideration of commentary from City staff and the design team. The highest rated adaptation measures are as follows:

- Extensive planting of trees and other vegetation to increase shade.
- Create and maintain an emergency operation budget that can immediately be used for emergency response purposes
- Plant trees with large canopy covers in areas with high solar radiation
- Identify design flood levels and ensure assets meet current flood predictions (pluvial and riverine). Update where necessary
- Retrofit green spaces such as grassed center medians of roads with bioretention systems, street planters or tree-box filters
- Develop heat/air-quality action plans (e.g., cooling centers, water fountains / features)
- Use permeable paving and a sub-surface drainage system
- Plant trees and other vegetation around roadways to lower the water table

- Develop a management program to check drains, etc.
- Create gradients/borders of open areas and shading elements where sun and shade alternate
- Create diversities of microclimates combined with park furniture
- Development of management plans - updating operation and maintenance (O&M) procedures to check trees and plants after events
- Reduce asphalt/hardscape spaces

The next steps of the project will be to incorporate the recommended adaptation measures into the next design phase of the project. As these recommendations are considered and quantified, a climate cost benefit analysis can be completed where the avoided costs of damage or loss to assets can be compared to the cost of the adaptive measures.

1.0 INTRODUCTION

The City of Calgary (the City) engaged Stantec Consulting Ltd. (Stantec) to complete a climate vulnerability and risk assessment (CVRA) of the planned redevelopment of Arts and Culture Character area (referred to as The Commons) along Stephen Avenue. The physical project boundary extends from the east end of Stephen Avenue at the Public Library and Calgary City Hall to 11st St. SW and includes the entire right of way along the avenue and between buildings.

1.1 SCOPE OF WORK

With the Future of Stephen Avenue Project entering into Phase 2A: Schematic Design, the purpose of the project was to complete a CVRA based on the Stephen Avenue Phase 1A: Public Realm Study and identify a series of recommendations that could be integrated into the Phase 2A Schematic design stage to reduce the climate risks to infrastructure and users. The project involved deploying an expanded version of the City's Public Infrastructure Climate Risk Assessment process and engaging with City staff and members of the Stantec Stephen Avenue design team in three virtual workshops to:

1. Complete a hazard impacts assessment
2. Score consequences
3. Review priority risks and identify adaptation measures

This report summarizes the methodologies used in undertaking this assessment and provides a summary of the priority adaptation measures that should be considered as part of the Phase 2A Schematic Design process of the Stephen Avenue development process.

1.2 CLIMATE RISK FRAMEWORK

Risk management is a systematic approach to identifying, assessing, communicating, and acting on potential problems before they occur. In the context of adapting to climate change, climate change risk assessment protocols (e.g., the City's Public Infrastructure Climate Risk Assessment, Public Infrastructure Engineering Vulnerability Committee (PIEVC), etc.) and management standards (e.g., ISO14090-92) provide a framework to identify and evaluate the risks that climate-related hazards may have on assets, processes, and services, and to identify resilience measures to reduce the risk. As risks evolve and change over time, assessing climate-related risks and adaptation planning is an iterative process that involves (Figure 1):

- Assessing the risks
- Managing the risks
- Reporting on outcomes

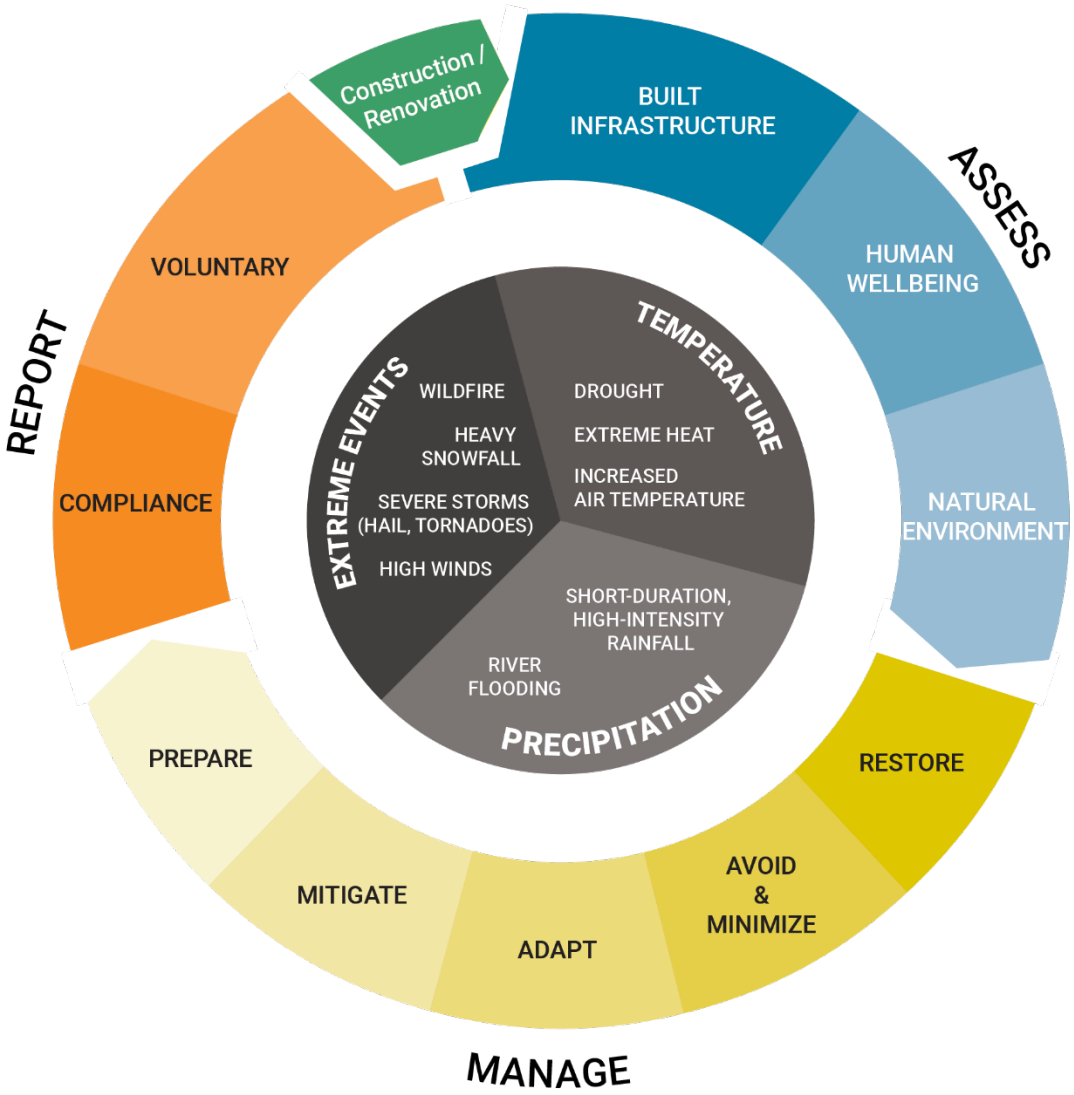

Figure 1. Climate Risk Framework

1.2.1 Assess

The process of assessing climate risks is about understanding how various climate hazards (such as excessive heat, increased precipitation, etc.) might impact:

- Built Infrastructure, e.g. surface infrastructure, underground utilities, buildings and facilities.
- Natural Environment, e.g. vegetation, species, water supply, air quality
- Human Wellbeing, e.g. vulnerable or at risk populations, equity, accessibility.

A climate change risk process enables users to categorize varying climate hazards across a risk spectrum ranging between extreme to low risk. Climate risk is a function of probability / likelihood of the threat occurring multiplied by the impact / consequence.

The assessment process typically considers the overall vulnerability, adaptive capacity and exposure of an asset, program, policy or system to climate change hazards, evaluates the probability of a hazard's occurring and the resulting consequences, and recommends resilience measures to decrease the consequence of the highest risks. In determining the probability of a hazard's occurrence, the annual frequency of a climate hazard is compared to the historical climate trends and a threshold relevant to the asset, process or program being considered.

The City's Public Infrastructure Climate Risk Assessment process, which is based on PIEVC, sits within the assessment realm of the climate risk framework.

1.2.2 Manage

Once climate risks are evaluated and prioritized, adaptive strategies can be identified, assessed and implemented to manage the priority risks. Adaptive strategies are often categorized in the following manner:

- **Restore** – Land use decisions can eliminate or interrupt natural systems, leading to permanent loss of ecosystem goods and services that the City or community relies on. For example, the burying of streams increases downstream flows and impacts and limits the ability of natural systems to reduce flooding. The restoration of natural systems provides one of the more promising options to both mitigate and adapt to the effects of climate change.

- **Avoid & Minimize** – In terms of land use planning, avoid and minimize actions typically involve planning development in areas with minimum climate change risk (e.g., not in the floodplain). Where there are residual risks, they are minimized through planning controls and requirements (e.g., requiring that buildings with piled construction be raised above future flood levels).

- **Adapt** – Adapting to climate change typically involves some form of intervention to increase the resilience of an existing asset, system of process. For example, raising roadways and/or modifying the construction of roadways to minimize the damage of flooding.

- **Control** – Risk mitigation controls refers to acceptance of residual risk and implementation of administrative controls to manage the risk. For example, increasing insurance, asset maintenance inspection frequencies, operational adjustments, reserve funds for early asset replacement, etc.

- **Prepare** – Preparing for climate change typically means that actions that can be deployed have been and that residual risk and the associated loss is accepted by the City. It recognized that even despite all the best efforts, assets and people are still at risk and emergency preparedness and response planning are put in place in anticipation of the risk event. This often involves the use of the "pathways approach" to adaptation planning which is focused on avoiding actions that "lock" a City into actions that may not be the best solutions for longer-term hazards.

1.2.3 Report

Reporting is the process of sharing and tracking implementation of climate risks and adaptive strategies. This also helps to inform the risk reassessment process through reflection and evaluation of the effectiveness and impact on strategies to reduce priority risks.

2.0 RESILIENCE ASSESSMENT PROCESS

The methodology applied in this project built upon the City's Public Infrastructure Climate Risk Assessment process and expanded it to include adaptation planning and reporting to align with the climate risk framework. This consisted of four procedural steps:

1. Impacts assessment
2. Consequence scoring
3. Risk assessment
4. Adaptation identification and prioritization

Steps 1-3 aligned with the City's Public Infrastructure Climate Risk Assessment.

Details pertaining to each of these steps are presented in the following subsections.

2.1 IMPACTS ASSESSMENT

The impacts assessment step evaluates how current and future climate-related hazards could materialize as impacts to assets, operations or users along Stephen Avenue. By assessing the range of possible impacts, consequences can be assessed, priority risks identified, and appropriate adaptive responses established to reduce risks.

To support the completion of this step, the project team first reviewed project related materials provided by the City to develop a list of assets along Stephen Avenue. These assets were organized using the City's asset system categories (built infrastructure, human wellbeing, natural environment) and asset class (Table 1).

Table 1. Infrastructure Systems, Asset Classes and Assets

System	Asset Class	Asset(s)
Built Infrastructure	Asphalt	Parking spaces
		Roads
	Electrical	Transformer boxes
	Fire Hydrants	Fire hydrants
	Other Hardscape	Sidewalks
	Signage and Lights	Commercial, construction, traffic signage
		Traffic lights
		Streetlights
	Stormwater system	Stormwater system
	Street Furnishings	Heaters, fences, scaffolding, planters
		Shaded bus stops, pop up tents, food trucks

System	Asset Class	Asset(s)
Human Wellbeing	Humans	Users
		City personnel, contractors
Natural Environment	Natural Infrastructure	Animals, pollinators
		Gardens, planting
	Trees	Street trees

The next step of the process involved identifying which climate-related hazards would pose risks to the Stephen Avenue assets, users, and related City operations. After reviewing the City's Public Infrastructure Climate Risk and Resilience Assessment guidance document, nine (9) climate hazards were identified for use in the CVRA (Table 2). These climate hazards were selected based on the potential to interact and disrupt or damage Stephen Avenue assets, users, and related City operations.

To validate the work completed so far, and to collect input on other possible impacts and past climate related events that have impacted Stephen Avenue, a virtual climate impact workshop was conducted on February 7, 2022, with City staff. Workshop participants were presented with the work completed so far and invited to vote on which climate-related hazards would interact and impact each asset. The outcome of this workshop is presented in Table 2. The table shows that street trees and humans are most likely to be impacted by the greatest number of hazards. It also shows that SDHI rainfall and river floods[1] were thought to be the hazards that impact the greatest number of assets.

Table 2. Impacts Workshop Results

Asset Class	n	SDHI Rainfall	River Floods	Extreme Heat	Heavy Snowfall	Severe Storms	High Winds	Higher Average Temps	Wildfire	Drought
Trees	9	7	7	9	8	8	9	8	6	9
Humans	10	8	8	10	9	8	10	7	9	2
Sidewalks	9	9	7	8	8	4	8	7	2	1
Natural Infrastructure	7	7	4	7	4	3	2	6	2	4
Street Furnishings	9	6	4	6	7	8	6	6	2	0
Asphalt Structures	9	6	6	8	7	5	3	4	0	0
Stormwater System	9	9	8	1	5	6	2	1	0	1
Signage and Lights	8	3	2	2	6	5	7	0	1	0
Fire Hydrants	9	1	6	4	2	0	0	3	3	5

[1] Stephen Ave was not significantly impacted by the floods in 2013 and only minor flooding is expected to occur along Stephen Avenue during high precipitation events. The assigned consequence scores for this hazard are therefore lower than what would be suggested by the survey results.

Asset Class	n	SDHI Rainfall	River Floods	Extreme Heat	Heavy Snowfall	Severe Storms	High Winds	Higher Average Temps	Wildfire	Drought
Electrical Transformers	9	6	7	3	1	2	0	1	0	1

Notes to Table: The number of votes for each asset-hazard combination was considered by Stantec in determining whether there is a likely interaction between them for the risk assessment. The asset rows and hazard columns are ordered by the total number of votes received by each.

Workshop participants were also invited to comment on past or potential future impacts to assets along Stephen Ave or from similar environments. The information collected during the workshop was used to update the impact tables (Table 2 and Table 4). The impact tables support the next stage of the process where the consequences of the impacts are rated, probability assigned and risk ratings derived.

Table 3. Temperature-Related Impacts

Asset Class	Impacts
Fire Hydrants	• More likely to be used during drought and extreme heat events for both fire prevention and as a cooling resource for vulnerable populations
Hardscape	• Freeze-thaw cycles produce potholes and deteriorate the hardscape surface (i.e., asphalt) • Extreme heat events can be amplified, generating a greater heat-island effect • Extreme heat events can cause buckling • Roads/parking spaces see increased use during extreme heat events
Street furnishings	• Extremely high temperatures increase heat load and degradation of asset – liability concerns (e.g., hot slides on playgrounds) • Increased demand for shaded spaces to protect humans • Food trucks may not be able to operate during heat waves
Signage and Lights	• Wildfire smoke could impact visuals for traffic and pedestrians • Wildfire smoke could result in increased streetlight usage
Electrical	• Extreme heat events could result in transformer damage or failure, as the components do not cool down overnight
Humans	• Extreme heat events impact both users and workers, especially due to heat-island effect, preventing users from moving around in the space and preventing workers from doing their jobs • Equity issues related to extreme heat events as vulnerable populations require increased emergency response capabilities • Wildfire smoke impacts the respiratory system and can be damaging to human health, inhibiting exercise and work capabilities
Street Trees	• Warmer temperatures result in increased evapotranspiration • Freeze-thaw events can 'trick' trees into preparing for spring • Extreme heat events can dry out or otherwise stress trees • Increased air temperatures can increase the spread of invasive species • Wildfire smoke can reduce productivity
Natural Infrastructure	• Extreme heat events can damage plants/flowers in gardens

Asset Class	Impacts
	• Increased air temperatures can change the flora-fauna species mix, and increase the spread of invasives • Extreme heat events reduce animal activity, inhibiting their ability to (e.g.) pollinate or find food • Wildfire smoke can impact animal respiratory systems, and reduce plant productivity

Table 4. Precipitation- And Wind-Related Impacts

Asset Class	Impacts
Fire Hydrants	• Droughts could result in limitations to water availability for hydrants • Heavy snowfall events can obscure hydrants, and snow clearing equipment has been known to damage them
Stormwater System	• Drought can result in stagnation and degradation of water quality in stormwater ponds • Lack of stormwater collection can stress drinking water systems, since recycled stormwater is used for irrigation • SDHI rainfall events, hail and debris from extreme wind events can overwhelm the stormwater system – resulting in localized flooding • Rivers can back up storm drains where pipes are routed directly into the river. Sedimentation can occur at storm drains • Ice and snow can clog storm drains, resulting in localized flooding
Hardscape	• Localized flooding during SDHI rainfall events and severe storms increases the degradation of hardscapes and limits their use • High wind events can bring down street trees, signs etc. thereby blocking road or parking space access and damaging the hardscape • Riverine flooding can scour/erode hardscape surfaces • Snow clearing equipment and salt use can damage hardscapes after heavy snowfall events
Street furnishings	• SDHI rainfall events could knock over or damage temporary furnishings • Shelters may be insufficient for pedestrians with SDHI rainfall events • Hail during severe storms can shatter bus shelters and damage other street furnishings • High wind events can knock furnishings around, such as construction materials • River floods could cause water damage to some furnishings and possibly pick up/move temporary fixtures • Snow removal equipment and increased salt use can damage furnishings
Signage and Lights	• Signs and lights can be difficult to see during SDHI rainfall, severe storms • River floods can damage signs • High wind events can pick up signs or push them over
Electrical	• Localized flooding during SDHI rainfall events could impact inner workings • Lightning strikes during severe storms can knock out transformers • Are designed to withstand river floods to a particular standard (100-year event?) but sustained inundation could cause damage
Humans	• People are less likely to use the space during SDHI rainfall events • Hail and lightning during severe storms can injure users or personnel • High wind events can blow over debris, street furnishings or signs • High winds make it difficult to move around along the avenue due to wind tunnels • Windchills from high winds and winter storms prevent workers from completing their duties in winter

Asset Class	Impacts
	• River flooding limits access to the site for personnel
Street Trees	• Hail, SDHI rainfall, and wind can damage young/vulnerable trees • Off-season snowfall events can cause tree branches to come down ('Snowtember') • River floods can impact trees if they are inundated for too long
Natural Infrastructure	• Drought could impact plants, though watering is conducted manually • SDHI rainfall or riverine flooding could inundate gardens/planters, damaging plants • Hail flattens plants • Sustained high winds can kill/damage plants and challenges for animals (birds and insects) • Flooding of urban environments can increase non-point source pollution, affecting fish

2.2 PROBABILITY AND CONSEQUENCE SCORING

This next step of the analysis involved qualitatively assessing the probability and possible consequences that could result from the climate hazard. Probability refers to the likelihood of a climate-related hazard materializing as an impact, and consequence refers to the known or estimated outcomes of a particular climate related impact. The probability ratings were taken from the City's Public Infrastructure Climate Risk and Resilience Assessment guidance document which used climate science/climate models to determine the likelihood a certain climate hazard will exceed the threshold assigned (i.e. 50 mm of rain in one hour) as compared to the baseline (Table 5). The probability ratings are based on a 5-point scale where 1 is 'rare' and 5 is 'almost certain' the event will occur.

Table 5. Climate Hazard Probability Rating

Climate Hazard	Projected Trend	Baseline	2050s	2080s
Extreme Heat	↑	2	5	5
Increased Air Temperature	↑	4	5	5
Wildfire	↑	2	4	5
Drought	Likely ↑	3	4	5
SDHI Rainfall	↑	3	4	5
Severe Storms	Likely ↑	3	4	5
High Winds	Likely Stable	3	3	3
River Flooding	Likely ↑	2	3	3
Heavy Snowfall	↓	3	2	2

The consequences of the climate-related impacts were assessed using a five-point rating system ranging from "very low" (1) to "extreme" (5). The consequence scoring criteria was divided amongst three different consequence types - health and safety, structural integrity, and functionality – as required by the City's Public Infrastructure Climate Risk and Resilience Assessment guidance document (Table 6).

Table 6. Consequence Scoring System

Rating	Consequence Classification	Consequence Types		
		Health & Safety (H&S)	Structural Integrity (SI)	Functionality (F)
1	Very Low	First aid injury	No permanent damage	No/minimal service disruption
2	Low	Medical treatment for a minor injury	Minor asset or system damage. Minor repairs or restoration	Minor service disruption may occur
3	Medium	Bodily injury/illness with work restrictions	Moderate damage to asset or system. Minor repairs and some equipment replacement or restoration	Brief service disruption may occur
4	High	Permanent disabling injury or multiple people injured	May result in significant damage, loss, or require complete replacement	Lengthy service disruptions may occur
5	Extreme	Fatality or significant irreversible disability	Will result in significant damage, loss, or require complete replacement	Lengthy service disruptions may occur, alternate service delivery may be required

Consequence scores were derived based on the project team's experience in rating similar assets and through a consequence workshop with City staff that has held on March 2, 2022. The purpose of the workshop was to review the consequences of select hazard/asset combinations that were flagged by the project team worthy of the group's discussion. Seventeen climate hazard and asset combinations (Table 7) were evaluated in the workshop, while the remaining combinations were evaluated independently by the project team. The consequence scores were reviewed for outliers, adjusted based on the project teams experience (as necessary), averaged and rounded to the nearest whole number. The consequence scores for each climate hazard and asset combination are presented in Table 7.

Table 7. Mean Consequence Scores Assigned

Asset/Asset Class	Hazard	Health & Safety (H&S)	Structural Integrity (SI)	Functionality (F)
Street Furnishings	River Flooding	2	4	4
Street Furnishings	High Winds	3	3	3
Signs	High Winds	3	3	3
City Personnel, Contractors	River Flooding	3	3	4
Street Trees	Heavy Snowfall	2	4	3
Sidewalks	Increased Air Temps	2	3	3
Fire Hydrants	Heavy Snowfall	2	3	3
Asphalt	Extreme Heat	2	3	2
Street Trees	Increased Air Temps	1	3	3

Asset/Asset Class	Hazard	Health & Safety (H&S)	Structural Integrity (SI)	Functionality (F)
Users	Extreme Heat	3	2	2
Gardens, Flower Beds	Severe Storms	1	3	3
Animals, Pollinators	Drought	1	3	3
Fire hydrants	River Flooding	2	2	2
Signage and Lights	Wildfire	2	1	2
Animals, Pollinators	SDHI Rainfall	1	2	2
Stormwater System	Drought	2	2	2
Personnel	Extreme Heat	3	1	1

2.3 RISK ASSESSMENT

The risk assessment process helps to qualitatively make decisions about which climate risks should become priorities. Climate risk refers to the possibility that an asset would be adversely affected if it had a severe or prolonged interaction with a climate-related hazard. As such, risk can be expressed as a function of **Probability x Consequence.**

The risk to each asset was assessed under baseline climate period (1980-2010) and three future climate periods (2050s, 2080s). To streamline the risk assessment process, it is assumed that the City continues to maintain the condition of the assets to retain a similar level of resilience to future climate events. The risk rating evaluation matrix and recommended treatment (based on risk level) were obtained from the City's Public Infrastructure Climate Risk and Resilience Assessment guidance document. These are presented in Figure 2 and Table 8.

Figure 2. Risk Rating Evaluation Matrix and Classification

Risk Scoring Matrix							
Probability Score	Almost Certain	5	5	10	15	20	25
	Likely	4	4	8	12	16	20
	Possible	3	3	6	9	12	15
	Unlikely	2	2	4	6	8	10
	Rare	1	1	2	3	4	5
			1	2	3	4	5
			Very Low	Low	Medium	High	Extreme
			Consequence Score				

Table 8. Risk Classification And Treatment Table

Risk Classification	Rating	Recommended Risk Treatment
Very Low	1-2	Tolerable: risks do not require further consideration
Low	3, 4 and 6	Monitor: controls or coping strategies recommended
Medium	5, 7-9	Requires some attention: some controls required to reduce risk levels. Monitor risk for changes over time.
High	10-16	Requires much attention: high priority control measures required.
Extreme	20-25	Not acceptable: significant controls required.

2.4 ADAPTATION IDENTIFICATION AND PRIORITIZATION

The last stage of the climate risk assessment process involves identifying possible adaptation measures that could be applied to reduce the highest risks. Adaptation options were identified through desktop research, using a variety of resources which included published literature, various guidelines and reports, and measures used in other Stantec climate resilience and adaptation projects. Candidate adaptation measures were shortlisted based on their applicability and viability to reduce the risks related to the asset / climate hazard combinations with the highest risk scores.

The candidate adaptation measures were presented to City staff during a virtual workshop on April 6, 2022 to review, assess, and provide feedback. Workshop participants were asked to rate the measures using a virtual voting platform (Mentimeter) against a set of evaluation criteria approved for use by the City (Table 9). City staff were asked to only rate the adaptation measure on their practicality, equity, and synergy criteria on a scale of 1 (Low – adaptation disagrees with evaluation criterion) to 3 (High – adaptation strongly agrees with evaluation criterion). This was done to take advantage of the workshop time available for discussion, and because the remaining evaluation criteria are difficult to score without detailed knowledge of the resiliency context. The scores assigned by participants were reviewed and (in some cases) modified by Stantec prior to finalization of the evaluation scores.

Table 9. Adaptation Evaluation Criteria

Evaluation Criteria	Criteria Description	Information Source
Practicality	The feasibility of the measure. (e.g., moving a community to avoid flooding is not practical).	Obtained through City of Calgary Staff during adaptation workshop
Equity	The equitable nature of the measure (e.g., vulnerable / at-risk populations benefit).	
Synergy	The synergy / coherence with other strategic objectives (e.g., reducing GHG emissions).	
Urgency	Urgency of the risk relative to the implementation of the measure.	Determined by Stantec Consulting Ltd., based on available information and professional judgement.
Effectiveness	The level of risk reduced by the measure.	

Evaluation Criteria	Criteria Description	Information Source
Cost Efficiency	The cost benefit of the measure (i.e., the return on investment).	
Robustness	The measure is flexible and applicable to a range of plausible risk scenarios.	
Potential for External Funding	Availability of implementation tools and possible funding sources (e.g., grants, using mitigation revenues to fund adaptation programs, etc.).	
Foundational Importance of Action	The action lays the foundation for other efforts/ actions at the City though by itself may not increase the resilience of the asset group measurably.	

3.0 RESULTS

3.1 RISK ASSESSMENT RESULTS

A summary of the risk assessment outcomes by asset, hazard and time period (2080's) as presented in Table 10. The results show that the biggest shift in risks (from low/medium to high) between the baseline and the future periods occurs because of increased frequency and severity of extreme heat events and severe storms. The assets likely to be at greatest risk in the future include street trees, humans, gardens/flower beds, and asphalt. The complete risk assessment table, outlining risk based on consequence category and all future time periods is included in Appendix A.

Severe storm frequency is estimated based on the number of days with convective events, lightning, and hail. The likelihood score based on these indicators is projected to increase from a 3 (possible) over the baseline period to 4 (likely) in the 2050s and 5 (almost certain) in the 2080s. Based on workshop discussion and the project team's judgement, many of the assets considered are projected to be at high risk due to severe storms in the 2080s. Humans are at high risk due to the increasing likelihood of injury from lightning and hail, whereas assets in the built environment (e.g., street furnishings, electrical transformer boxes and hardscape) are at risk of damage to their structural integrity, which could also impact their functionality. Those most at risk are vulnerable populations. In the context of the Stephen Avenue project, these may include, but are not limited to older adults, persons with disabilities, homeless persons, persons with addictions, low-income or socioeconomic persons, youth, and those dependent on walking, or transit. Street trees and gardens/flower beds are also projected to be at high risk, as hail events could flatten planting and lightning/high winds associated with thunderstorms could damage the structural integrity of trees.

Similar to severe storms, short-duration, high-intensity (SDHI) rainfall events are also projected to increase in the future (3 in the baseline to 5 in the 2080s). These heavy rainfall events have wide-ranging impacts due to localized flooding in the urban environment. Assets from the built environment could be damaged or at least lose functionality for short periods of time as they are overwhelmed. While these events pose a relatively low risk for humans, they could impact the structural integrity of street trees, other planting, and animals/pollinators.

Extreme heat events are projected to rapidly increase over the next 30 years, from a likelihood score of 2 (unlikely) in the baseline to 5 (almost certain) in the 2050s and 2080s. This increase drives the high risk scores observed for asphalt/hardscape, electrical transformers, humans, and the natural environment (trees, plants, animals). Asphalt roads, parking spaces and existing buildings are likely to exacerbate the heat effect due to the heat-island effect and increase the risk of heat related illnesses to humans and animals (e.g., dogs). Asphalt based surfaces are susceptible to buckling during extreme heat events which can reduce their life expectancy by up to half. Electrical transformers can overheat during extreme heat events which can result in localized power outages and fires. Such power outages can result in cascading impacts to humans as they will not be able to maintain air conditions spaces.

Hazards that pose lower risk to assets include drought, heavy snowfall, and wildfire. As Calgary is a relatively dry city, many of the assets along Stephen Ave are already resilient to drought events (low or no consequence), and therefore the increasing likelihood of drought does not result in significant change to the risk profile. Heavy snowfall events are projected to decrease in the future, and therefore current practices should be sufficient to manage these events. Since Stephen Ave is an urban environment with no wildland-urban interface, the direct impacts of wildfire are not projected to impact assets; however, the increasing likelihood of wildfire smoke exposure does constitute an appreciable risk for users and personnel.

Table 10. Climate Risk Assessment Results

Asset Class	Asset(s)	Extreme Heat			Higher Temps			Wildfire			Drought			Heavy Rainfall			Severe Storms			High Winds			River Floods			Heavy Snowfall		
		1980-2010	2050's	2080's	1980-2010	2050's	2080's	1980-2010	2050's	2080's	1980-2010	2050's	2080's	1980-2010	2050's	2080's	1980-2010	2050's	2080's	1980-2010	2050's	2080's	1980-2010	2050's	2080's	1980-2010	2050's	2080's
Fire Hydrants	Fire Hydrants										3	4	5													9	9	9
Stormwater System	Stormwater system										9	12	15	9	12	15	9	12	15	9	9	9	6	9	9	9	9	9
Asphalt	Parking spaces	6	15	15	8	10	10							9	12	15	9	12	15	9	9	9	6	9	9	9	9	9
	Pavement (roads)	6	15	15	8	10	10							9	12	15	9	12	15	9	9	9	6	9	9	9	9	9
Other Hardscape	Sidewalks	4	10	10	4	5	5							9	12	15	9	12	15	9	9	9	6	9	9	9	9	9
Street Furnishings	Heaters, fences, scaffolding, planters	2	5	5	4	5	5							6	8	10	6	8	10	12	12	12	6	9	9	9	9	9
	Shaded bus stops, pop-up tents, food trucks	4	10	10	4	5	5							6	8	10	12	16	20	12	12	12	6	9	9	9	9	9
Signage and Lights	Commercial, construction, traffic signage							4	8	10				6	8	10	6	8	10	9	9	9	6	9	9			
	Traffic lights							4	8	10				6	8	10	6	8	10	3	3	3						
	Streetlights							4	8	10				6	8	10	6	8	10									
Electrical	Transformer box	6	15	15										9	12	15	9	12	15				6	9	9			
Humans	City personnel, contractors	8	20	20	8		5	6	12	15				6	8	10	12	16	20	9	9	9	8	12	12	6	6	6
	Users	6	15	15	8		10	6	12	15				3	4	5	12	16	20	9	9	9						
Street Trees	Street trees	6	15	15	12		15	4	8	10	9		15	6	8	10	9	12	15	9	9	9	6	9	9	9	9	9
Natural Infrastructure	Animals, pollinators	4	10	10	8		10	4	8	10	6		10	6	8	10							6	9	9			
	Gardens, flower beds	6	15	15	12		15	4	8	10	6		10	6	8	10	9	12	15	9	9	9	4	5	6			

3.2 LIMITATIONS OF RISK ASSESSMENT

While the section above provides a summary of the climate risks identified in this study, there are several limitations to the results presented, as discussed below. These limitations should be considered in evaluating next steps and the recommended adaptation measures to reduce climate-related risk in the design of Stephen Ave. Key limitations of the risk assessment include:

- **Asset Inclusion/Classification:** Since this assessment could not possibly include all assets that currently exist on Stephen Ave, or might exist after the redevelopment, this study was conducted with a subset of assets, which were reviewed and approved by the City at the beginning of the project. These assets were classified according to their similarity as it relates to the impacts of climate-related hazards. It is possible that some assets not considered in this study could be subject to significant climate-related risk, which would not have been captured.
- **Climate Projections:** The most important limitation of this study stems from uncertainty in climate projections and hazard trends. Uncertainty in climate projections come from a variety of sources including global climate model (GCM) ensemble members, scenario selection, and internal model variability/bias. The climate hazard likelihood scores applied in this study were provided by the City, as part of the Public Infrastructure Climate Risk and Resilience Assessment guidance document.
- **Consequence Scoring:** While the consequence scores assigned were based on the results from workshop discussions/voting, and expert judgement they are nevertheless highly subjective. No quantitative data were used in the consequence scoring.

3.3 PRIORITY ADAPTATION MEASURES

This study produced 29 proposed adaptation measures, which were rated based on the adaptation measure evaluation criteria. The evaluation process helps identify which of the proposed adaptation recommendations should be considered in the next phase of the project. The highest scored recommendations (with exception to measures that are already being implemented) are presented below in Table 11. The full list of prioritized adaptation measures and their associated scores are presented in Appendix B.

Table 11. Prioritized Adaptation Measures

Adaptation Measure	Hazard(s)	Asset(s)
Extensive planting of trees and other vegetation to increase shade.	Extreme Heat	Humans, Gardens, Planting
Create and maintain an emergency operation budget that can immediately be used for emergency response purposes	All	Humans
Plant trees with large canopy covers in areas with high solar radiation	Extreme Heat, Higher Temperatures	Humans
Identify design flood levels and ensure assets meet current flood predictions (pluvial and riverine). Update where necessary	SDHI Rainfall, River Floods	Transformer Boxes, Street Furnishings

Adaptation Measure	Hazard(s)	Asset(s)
Retrofit green spaces such as grassed center medians of roads with bioretention systems, street planters or tree-box filters	SDHI Rainfall	Asphalt, Other Hardscape, Stormwater system
Develop heat/air-quality action plans (e.g., cooling centers, water fountains / features)	Extreme Heat	Humans
Use permeable paving and a sub-surface drainage system	SDHI Rainfall, Severe Storms	Asphalt, Other Hardscape, Stormwater system
Plant trees and other vegetation around roadways to lower the water table	SDHI Rainfall, River Floods	Asphalt, Other Hardscape, Stormwater system
Develop a management program to check drains, etc.	SDHI Rainfall, Severe Storms, High Winds, Heavy Snowfall	Stormwater system
Create gradients/borders of open areas and shading elements where sun and shade alternate	Extreme Heat	Humans
Create diversities of microclimates combined with park furniture	Extreme Heat	Humans
Development of management plans - updating O&M procedures to check trees and plants after events	Severe Storms, High Winds, SDHI Rainfall, Heavy Snowfall	Trees, Gardens, Planting
Reduce asphalt/hardscape spaces	Extreme Heat, SDHI Rainfall	Asphalt, Humans

3.4 NEXT STEPS

The next steps of the project will be to incorporate the recommended adaptation measures into the next design phase of the project. As these recommendations are considered and quantified, a climate cost benefit analysis can be completed where the avoided costs of damage or loss to assets can be compared to the cost of the adaptive measures.

APPENDICES

Appendix A COMPLETE RISK ASSESSMENT RESULTS

The complete risk assessment results are presented in the table below.

Appendix A Complete Risk Assessment Results

System		Project asset / component		Extreme Heat							Increased Air Temperature							Wildfire						
				C			L	R			C			L	R			C			L	R		
				H&S	SI	F	L	H&S	SI	F	H&S	SI	F	L	H&S	SI	F	H&S	SI	F	L	H&S	SI	F
Built Infrastructure	Fire Hydrants	Fire hydrants	Present				2	0	0	0				4	0	0	0				2	0	0	0
			2050s				5	0	0	0				5	0	0	0				4	0	0	0
			2080s				5	0	0	0				5	0	0	0				5	0	0	0
	Stormwater	Stormwater system	Present				2	0	0	0				4	0	0	0				2	0	0	0
			2050s				5	0	0	0				5	0	0	0				4	0	0	0
			2080s				5	0	0	0				5	0	0	0				5	0	0	0
	Asphalt	Parking spaces	Present				2	2	6	4				4	4	8	4				2	0	0	0
			2050s				5	5	15	10				5	5	10	5				4	0	0	0
			2080s	1	3	2	5	5	15	10	1	2	1	5	5	10	5				5	0	0	0
		Pavement	Present				2	2	6	4				4	4	8	4				2	0	0	0
			2050s				5	5	15	10				5	5	10	5				4	0	0	0
			2080s	1	3	2	5	5	15	10	1	2	1	5	5	10	5				5	0	0	0
	Other Hardscape	Sidewalks	Present				2	2	4	4				4	4	4	4				2	0	0	0
			2050s				5	5	10	10				5	5	5	5				4	0	0	0
			2080s	1	2	2	5	5	10	10	1	1	1	5	5	5	5				5	0	0	0
	Street Furnishings	Heaters, fences, scaffolding, planters	Present				2	0	2	0				4	0	4	0				2	0	0	0
			2050s				5	0	5	0				5	0	5	0				4	0	0	0
			2080s		1		5	0	5	0		1		5	0	5	0				5	0	0	0
		Shaded bus stops, pop up tents, food trucks	Present				2	0	0	4				4	4	0	4				2	0	0	0
			2050s				5	0	0	10				5	5	0	5				4	0	0	0
			2080s			2	5	0	0	10	1		1	5	5	0	5				5	0	0	0
	Signage and Lights	Commerical, construction, traffic signage	Present				2	0	0	0				4	0	0	0				2	4	0	4
			2050s				5	0	0	0				5	0	0	0				4	8	0	8
			2080s				5	0	0	0				5	0	0	0	2		2	5	10	0	10
		Traffic lights	Present				2	0	0	0				4	0	0	0				2	4	0	4
			2050s				5	0	0	0				5	0	0	0				4	8	0	8
			2080s				5	0	0	0				5	0	0	0	2		2	5	10	0	10
		Street lights	Present				2	0	0	0				4	0	0	0				2	0	2	4
			2050s				5	0	0	0				5	0	0	0				4	0	4	8
			2080s				5	0	0	0				5	0	0	0		1	2	5	0	5	10
	Electrical	Transformer box	Present				2	0	4	6				4	0	0	0				2	0	0	0
			2050s				5	0	10	15				5	0	0	0				4	0	0	0
			2080s		2	3	5	0	10	15				5	0	0	0				5	0	0	0
Human wellbeing	Humans	City personnel, Contractors	Present				2	6	0	8				4	8	0	4				2	6	0	6
			2050s				5	15	0	20				5	10	0	5				4	12	0	12
			2080s	3		4	5	15	0	20	2		1	5	10	0	5	3		3	5	15	0	15
		Users	Present				2	6	0	0				4	8	0	0				2	6	0	0
			2050s				5	15	0	0				5	10	0	0				4	12	0	0
			2080s	3			5	15	0	0	2			5	10	0	0	3			5	15	0	0
Natural Environment	Trees	Street Trees	Present				2	0	6	2				4	0	12	12				2	0	4	0
			2050s				5	0	15	5				5	0	15	15				4	0	8	0
			2080s		3	1	5	0	15	5		3	3	5	0	15	15		2		5	0	10	0
	Plants and Animals	Animals, Pollinators	Present				2	0	0	4				4	0	0	8				2	0	4	2
			2050s				5	0	0	10				5	0	0	10				4	0	8	4
			2080s			2	5	0	0	10			2	5	0	0	10		2	1	5	0	10	5
		Gardens, Flower Beds	Present				2	0	6	2				4	4	12	4				2	0	4	2
			2050s				5	0	15	5				5	5	15	5				4	0	8	4
			2080s		3	1	5	0	15	5	1	3	1	5	5	15	5		2	1	5	0	10	5

System		Project asset / component		Drought							SDHI Rainfall							Severe Storms						
				C			L	R			C			L	R			C			L	R		
				H&S	SI	F	L	H&S	SI	F	H&S	SI	F	L	H&S	SI	F	H&S	SI	F	L	H&S	SI	F
Built Infrastructure	Fire Hydrants	Fire hydrants	Present				3	0	0	3				3	0	0	0				3	0	0	0
			2050s				4	0	0	4				4	0	0	0				4	0	0	0
			2080s			1	5	0	0	5				5	0	0	0				5	0	0	0
	Stormwater	Stormwater system	Present				3	9	0	3				3	0	9	9				3	0	9	9
			2050s				4	12	0	4				4	0	12	12				4	0	12	12
			2080s	3		1	5	15	0	5		3	3	5	0	15	15		3	3	5	0	15	15
	Asphalt	Parking spaces	Present				3	0	0	0				3	0	9	9				3	0	9	9
			2050s				4	0	0	0				4	0	12	12				4	0	12	12
			2080s				5	0	0	0		3	3	5	0	15	15		3	3	5	0	15	15
		Pavement	Present				3	0	0	0				3	0	9	9				3	0	9	9
			2050s				4	0	0	0				4	0	12	12				4	0	12	12
			2080s				5	0	0	0		3	3	5	0	15	15		3	3	5	0	15	15
	Other Hardscape	Sidewalks	Present				3	0	0	0				3	0	9	9				3	0	9	9
			2050s				4	0	0	0				4	0	12	12				4	0	12	12
			2080s				5	0	0	0		3	3	5	0	15	15		3	3	5	0	15	15
	Street Furnishings	Heaters, fences, scaffolding, planters	Present				3	0	0	0				3	0	6	6				3	0	6	6
			2050s				4	0	0	0				4	0	8	8				4	0	8	8
			2080s				5	0	0	0		2	2	5	0	10	10		2	2	5	0	10	10
		Shaded bus stops, pop up tents, food trucks	Present				3	0	0	0				3	0	6	6				3	0	12	12
			2050s				4	0	0	0				4	0	8	8				4	0	16	16
			2080s				5	0	0	0		2	2	5	0	10	10		4	4	5	0	20	20
	Signage and Lights	Commerical, construction, traffic signage	Present				3	0	0	0				3	6	0	6				3	6	0	6
			2050s				4	0	0	0				4	8	0	8				4	8	0	8
			2080s				5	0	0	0	2		2	5	10	0	10	2		2	5	10	0	10
		Traffic lights	Present				3	0	0	0				3	6	0	6				3	6	6	6
			2050s				4	0	0	0				4	8	0	8				4	8	8	8
			2080s				5	0	0	0	2		2	5	10	0	10	2	2	2	5	10	10	10
		Street lights	Present				3	0	0	0				3	0	0	6				3	0	6	6
			2050s				4	0	0	0				4	0	0	8				4	0	8	8
			2080s				5	0	0	0			2	5	0	0	10		2	2	5	0	10	10
	Electrical	Transformer box	Present				3	0	0	0				3	0	9	9				3	0	9	9
			2050s				4	0	0	0				4	0	12	12				4	0	12	12
			2080s				5	0	0	0		3	3	5	0	15	15		3	3	5	0	15	15
Human wellbeing	Humans	City personnel, Contractors	Present				3	0	0	0				3	3	0	6				3	12	0	6
			2050s				4	0	0	0				4	4	0	8				4	16	0	8
			2080s				5	0	0	0	1		2	5	5	0	10	4		2	5	20	0	10
		Users	Present				3	0	0	0				3	3	0	0				3	12	0	0
			2050s				4	0	0	0				4	4	0	0				4	16	0	0
			2080s				5	0	0	0	1			5	5	0	0	4			5	20	0	0
Natural Environment	Trees	Street Trees	Present				3	0	9	3				3	0	6	0				3	0	9	0
			2050s				4	0	12	4				4	0	8	0				4	0	12	0
			2080s		3	1	5	0	15	5		2		5	0	10	0		3		5	0	15	0
	Plants and Animals	Animals, Pollinators	Present				3	0	6	6				3	0	6	6				3	0	0	0
			2050s				4	0	8	8				4	0	8	8				4	0	0	0
			2080s		2	2	5	0	10	10		2	2	5	0	10	10				5	0	0	0
		Gardens, Flower Beds	Present				3	0	6	0				3	0	6	0				3	0	9	9
			2050s				4	0	8	0				4	0	8	0				4	0	12	12
			2080s		2		5	0	10	0		2		5	0	10	0		3	3	5	0	15	15

System		Project asset / component		High Winds							River Flooding							Heavy Snowfall						
				C			L	R			C			L	R			C			L	R		
				H&S	SI	F	L	H&S	SI	F	H&S	SI	F	L	H&S	SI	F	H&S	SI	F	L	H&S	SI	F
Built Infrastructure	Fire Hydrants	Fire hydrants	Present				3	0	0	0				2	0	0	0				3	0	9	9
			2050s				3	0	0	0				3	0	0	0				2	0	6	6
			2080s				3	0	0	0				3	0	0	0		3	3	2	0	6	6
	Stormwater	Stormwater system	Present				3	0	9	9				2	0	6	6				3	0	0	9
			2050s				3	0	9	9				3	0	9	9				2	0	0	6
			2080s		3	3	3	0	9	9		3	3	3	0	9	9			3	2	0	0	6
	Asphalt	Parking spaces	Present				3	0	9	9				2	0	6	6				3	0	6	9
			2050s				3	0	9	9				3	0	9	9				2	0	4	6
			2080s		3	3	3	0	9	9		3	3	3	0	9	9		2	3	2	0	4	6
		Pavement	Present				3	0	9	9				2	0	6	6				3	0	6	9
			2050s				3	0	9	9				3	0	9	9				2	0	4	6
			2080s		3	3	3	0	9	9		3	3	3	0	9	9		2	3	2	0	4	6
	Other Hardscape	Sidewalks	Present				3	0	9	9				2	0	6	6				3	0	6	9
			2050s				3	0	9	9				3	0	9	9				2	0	4	6
			2080s		3	3	3	0	9	9		3	3	3	0	9	9		2	3	2	0	4	6
	Street Furnishings	Heaters, fences, scaffolding, planters	Present				3	6	12	12				2	0	6	6				3	0	0	9
			2050s				3	6	12	12				3	0	9	9				2	0	0	6
			2080s	2	4	4	3	6	12	12		3	3	3	0	9	9			3	2	0	0	6
		Shaded bus stops, pop up tents, food trucks	Present				3	6	12	12				2	0	6	6				3	0	0	9
			2050s				3	6	12	12				3	0	9	9				2	0	0	6
			2080s	2	4	4	3	6	12	12		3	3	3	0	9	9			3	2	0	0	6
	Signage and Lights	Commerical, construction, traffic signage	Present				3	6	9	9				2	0	6	6				3	0	0	0
			2050s				3	6	9	9				3	0	9	9				2	0	0	0
			2080s	2	3	3	3	6	9	9		3	3	3	0	9	9				2	0	0	0
		Traffic lights	Present				3	0	6	3				2	0	0	0				3	0	0	0
			2050s				3	0	6	3				3	0	0	0				2	0	0	0
			2080s		2	1	3	0	6	3				3	0	0	0				2	0	0	0
		Street lights	Present				3	0	0	0				2	0	0	0				3	0	0	0
			2050s				3	0	0	0				3	0	0	0				2	0	0	0
			2080s				3	0	0	0				3	0	0	0				2	0	0	0
	Electrical	Transformer box	Present				3	0	0	0				2	0	6	6				3	0	0	0
			2050s				3	0	0	0				3	0	9	9				2	0	0	0
			2080s				3	0	0	0		3	3	3	0	9	9				2	0	0	0
Human wellbeing	Humans	City personnel, Contractors	Present				3	9	0	6				2	4	0	8				3	0	0	6
			2050s				3	9	0	6				3	6	0	12				2	0	0	4
			2080s	3		2	3	9	0	6	2		4	3	6	0	12			2	2	0	0	4
		Users	Present				3	9	0	0				2	0	0	0				3	0	0	0
			2050s				3	9	0	0				3	0	0	0				2	0	0	0
			2080s	3			3	9	0	0				3	0	0	0				2	0	0	0
Natural Environment	Trees	Street Trees	Present				3	0	9	0				2	0	6	0				3	6	9	9
			2050s				3	0	9	0				3	0	9	0				2	4	6	6
			2080s		3		3	0	9	0		3		3	0	9	0	2	3	3	2	4	6	6
	Plants and Animals	Animals, Pollinators	Present				3	0	0	0				2	0	6	0				3	0	0	0
			2050s				3	0	0	0				3	0	9	0				2	0	0	0
			2080s				3	0	0	0		3		3	0	9	0				2	0	0	0
		Gardens, Flower Beds	Present				3	0	9	3				2	0	4	0				3	0	0	0
			2050s				3	0	9	3				3	0	6	0				2	0	0	0
			2080s		3	1	3	0	9	3		2		3	0	6	0				2	0	0	0

Appendix B ADAPTATION MEASURE ASSESSMENT RESULTS

The adaptation measures assessment results are presented in the table below. A 3-point scale was used in the assessment.

Appendix B Adaptation Measure Assessment Results

Adaptation Measure	Hazard(s)	Asset(s)	Practicality	Equity	Synergy	Urgency	Effectiveness	Cost-Efficiency	Robustness	Funding	Foundational Importance	Score
Extensive planting of trees and other vegetation to increase shade.	Extreme Heat	Humans, Gardens, Planting	3	3	3	2	3	3	3	2	2	2.6
Create and maintain an emergency operation budget that can immediately be used for emergency response purposes	All	Humans	3	3	3	3	3	3	2	1	3	2.6
Plant trees with large canopy covers in areas with high solar radiation	Extreme Heat, Higher Temperatures	Humans	2	3	3	2	3	3	3	2	2	2.6
Identify design flood levels and ensure assets meet current flood predictions (pluvial and riverine). Update where necessary	SDHI Rainfall, River Floods	Transformer Boxes, Street Furnishings	3	3	3	3	3	3	2	3	1	2.6
Retrofit green spaces such as grassed center medians of roads with bioretention systems, street planters or tree-box filters	SDHI Rainfall	Asphalt, Other Hardscape, Stormwater system	3	2	3	2	3	2	3	3	2	2.5
Develop heat/air-quality action plans (e.g., cooling centers, features)	Extreme Heat	Humans	2	3	2	3	3	3	2	1	3	2.5
Use permeable paving and a sub-surface drainage system	SDHI Rainfall, Severe Storm	Asphalt, Other Hardscape, Stormwater system	2	2	2	2	3	2	3	3	2	2.4
Plant trees and other vegetation around roadways to lower the water table	SDHI Rainfall, River Floods	Asphalt, Other Hardscape, Stormwater system	3	3	3	2	2	2	2	2	3	2.3
Develop a management program to check drains, etc.	SDHI Rainfall, Severe Storm, High Winds, Heavy Snowfall	Stormwater system	3	2	2	3	3	3	3	1	1	2.3
Create gradients/borders of open areas and shading elements where sun and shade alternate	Extreme Heat	Humans	2	3	3	2	2	2	3	2	2	2.3

FUTURE OF STEPHEN AVENUE CLIMATE RESILIENCE ASSESSMENT

Appendix B Adaptation Measure Assessment Results

Adaptation Measure	Hazard(s)	Asset(s)	Practicality	Equity	Synergy	Urgency	Effectiveness	Cost-Efficiency	Robustness	Funding	Foundational Importance	Score
Create diversities of microclimates combined with park furniture	Extreme Heat	Humans	2	3	2	2	2	2	3	2	2	2.3
Development of management plans - updating O&M procedures to check trees and plants after events	Severe Storms, High Winds, SDHI Rainfall, Heavy Snowfall	Trees, Gardens, Planting	3	2	2	2	2	3	3	1	3	2.3
Reduce asphalt/hardscape spaces	Extreme Heat, SDHI Rainfall	Asphalt, Humans	2	2	2	2	3	2	3	2	3	2.3
Install water foundations	Extreme Heat	Humans	2	3	3	3	1	2	2	1	2	2.1
Install pollinator boxes / flowers	Extreme Heat	Trees, Gardens, Planting	3	2	1	3	3	3	2	1	1	2.1
Confirm capability of current heat-resistant road materials and, if necessary, use more heat tolerant binders and materials	Extreme Heat	Asphalt	3	2	2	2	3	1	3	1	1	2.0
Move or relocate systems where there is better shade / cooler location	Extreme Heat	Transformer Boxes	2	2	3	2	2	2	3	1	1	2.0
Scheduling more frequent maintenance to improve the performance and durability of hard surfaces	Extreme Heat, Severe Storm, Freeze-Thaw	Asphalt, Other Hardscape	2	1	1	3	2	3	3	1	1	2.0
Ensure redundancy in control systems (transformers)	Extreme Heat	Transformer Boxes	2	2	1	3	3	2	2	1	1	1.9
Select tree/plant species to withstand warmer air temperatures, with more extreme heat and drought	Extreme Heat, Drought, Higher Temperatures	Trees, Gardens, Planting	2	3	3	1	2	2	2	1	1	1.9
Create spaces for sheltering from hail/lightning	Severe Storms	Humans	3	3	2	1	3	2	1	1	1	1.8
Use street fixtures that have a high reflectivity and are shaded (to avoid burns)	Extreme Heat	Humans	3	3	2	1	1	2	2	1	1	1.8

Appendix B Adaptation Measure Assessment Results

Adaptation Measure	Hazard(s)	Asset(s)	Practicality	Equity	Synergy	Urgency	Effectiveness	Cost-Efficiency	Robustness	Funding	Foundational Importance	Score
Require that furnishings are fixed to the ground	High Winds, Severe Storms, River Floods, SDHI Rainfall	Street Furnishings	2	2	1	2	3	2	2	1	1	1.8
Orient planting away from direct sun	Extreme Heat	Gardens, Planting	2	2	2	2	2	2	2	1	1	1.8
Reinforce bus shelters and other street furnishings to withstand hail	Severe Storms	Street Furnishings	2	2	2	2	3	1	2	1	1	1.7
Asphalt/concrete spray-on coating that has a higher reflectivity for near infrared rays and lower reflectivity for the visible rays	Extreme Heat	Asphalt, Humans	3	3	1	1	1	2	2	1	1	1.7
Increase temporary water storage of existing stormwater systems such as retention and detention basins	SDHI Rainfall	Stormwater system	2	2	1	1	2	1	3	2	1	1.7
Install cooling systems for substations and transformers	Extreme Heat	Transformer Boxes	2	2	1	1	3	1	2	1	1	1.5
Consider roof features above planting spaces	Severe Storms, SDHI Rainfall	Gardens, Planting	2	2	2	1	3	1	1	1	1	1.4
Increase capacity of stormwater drainage system	SDHI Rainfall	Stormwater system	1	1	1	2	3	1	1	1	1	1.4