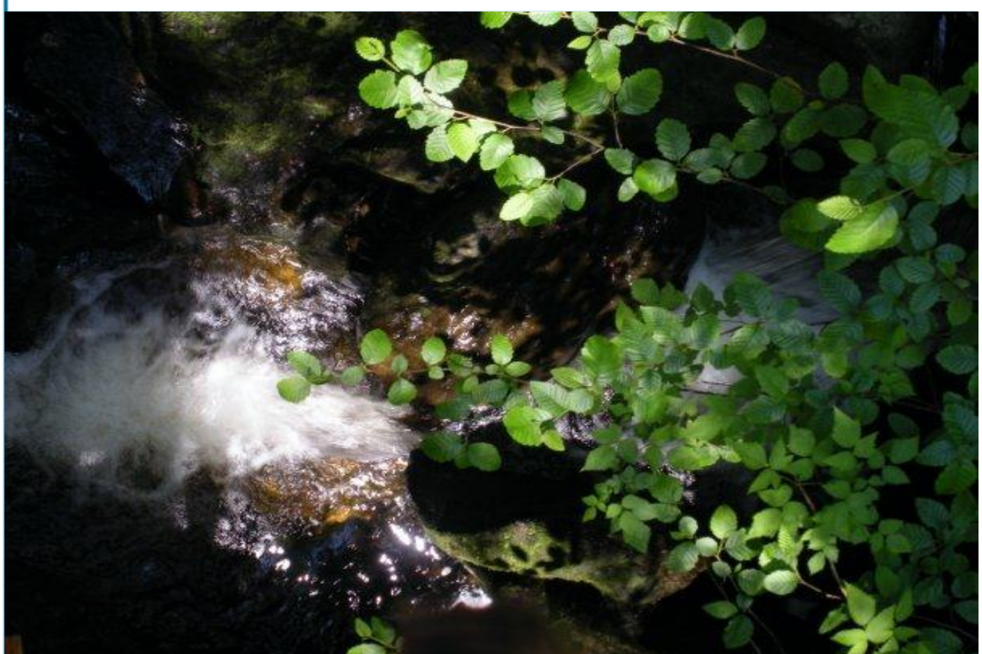
Climate Changes and Impacts for the City of North Vancouver

Summary Report for ICLEI Adaptation Milestone 2



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1 Introduction

The City is currently completing the ICLEI Canada five milestone framework for planning and adapting to the impacts of climate change. The initiative involves a network of leading municipalities across Canada and focuses on assessing local vulnerability to climate change, implementing adaptation strategies, and integrating adaptation planning with other key planning processes. The process consists of five milestones: initiating the plan, researching impacts on City infrastructure and service areas, creating the plan, implementing the plan, and monitoring its success over time.

The City completed the first of the program's five milestones in December 2012, identifying adaptation team members and internal and external stakeholders, completing an initial list of climate change impacts, reviewing existing plans, policies, and actions, and committing to the process through Council's endorsement.

This report summarizes the final results of Milestone 2, to research the climatic changes and impacts expected for the City, and to prioritize these impacts based on risk and vulnerability assessments. Section 2 reviews the historic and projected climatic changes for the Lower Mainland, and how the climate of the North Shore differs from the regional averages. This is followed in Section 3 by an overview of the impact identification and assessment process, and a summary of the highest priority impacts and how they related to the City's policy areas and operations. The detailed results of the vulnerability and risk assessments area also included in the appendices.

Figure 1 ICLEI Canada five milestone framework for climate change adaptation

2 Historical and Projected Climate Change for the City of North Vancouver

2.1 Regional Analysis

The effects of climate change are already evident in the City of North Vancouver, with measurable changes in temperature, precipitation, and extreme events in recent decades. If these trends continue the City's climate will hardly be recognizable by the end of the century, and without adequate planning and adaptation these changes will have extensive impacts on the liveability of the City.

Regional climate projections and local historic trends

Within Metro Vancouver the historical rates at which temperature, precipitation, and extreme events are changing vary by location and elevation, but *future* climate projections are only available for the region as a whole. To put future projections into context for more specific locations, local historical trends must also be used. YVR Airport has the most complete climate record in the region, which makes it critical for analyzing regional trends, but it is often not representative of the North Shore. By comparing the trends at YVR with the Vancouver Harbour and Grouse Mountain climate stations, which are the best representatives of the City and the higher elevation regions that affect its water resources, the regional climate models can be customized to gain a better understanding of the potential impacts.

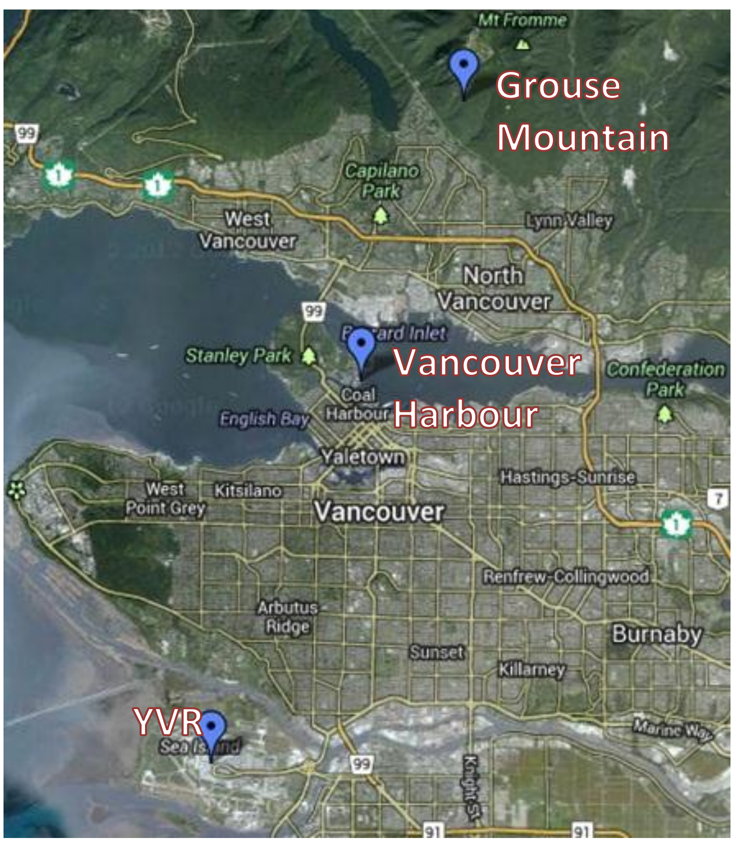

Figure 2: Locations of the Grouse Mountain, Vancouver Harbour, and YVR Environment Canada Climate Stations.

2.2 Temperature

Average temperature

Between 1951 and 2000, average temperatures increased by 1.0°C at YVR Airport (0.2°C/decade), with further increases of 1.7°C and 2.7°C projected for the region by 2050 and 2080, respectively. However, at Grouse Mountain the average temperature is increasing at twice that rate, +0.4°C/decade, summer high temperatures at +0.7°C/decade, and January low temperatures at +0.8°C/decade (Table 1). At Vancouver Harbour the average and summer high temperatures are increasing at a rate similar to or slightly faster than at YVR, but the January low temperatures are increasing much faster, at 0.7°C/decade. These historical rates of change are already outpacing the climate model projections, particularly at Grouse Mountain where continuing at the historical trend would see temperatures near or above the warmest model scenarios (Figure 2).

Frost free periods

Related to the rapid warming of January low temperatures at Grouse Mountain and Vancouver Harbour, the frost free period each year is decreasing by 9.5 days/decade at Grouse Mountain, much faster than at either YVR or Vancouver Harbour (Table 1). If this more rapid winter warming continues, the hydrologic impacts to the City could be much larger than projected by the regional climate models.

Summer temperatures

Projected increases in average summer temperatures would result in a summer climate warmer than present-day Seattle by the 2050s, and warmer than San Diego by the 2080s.

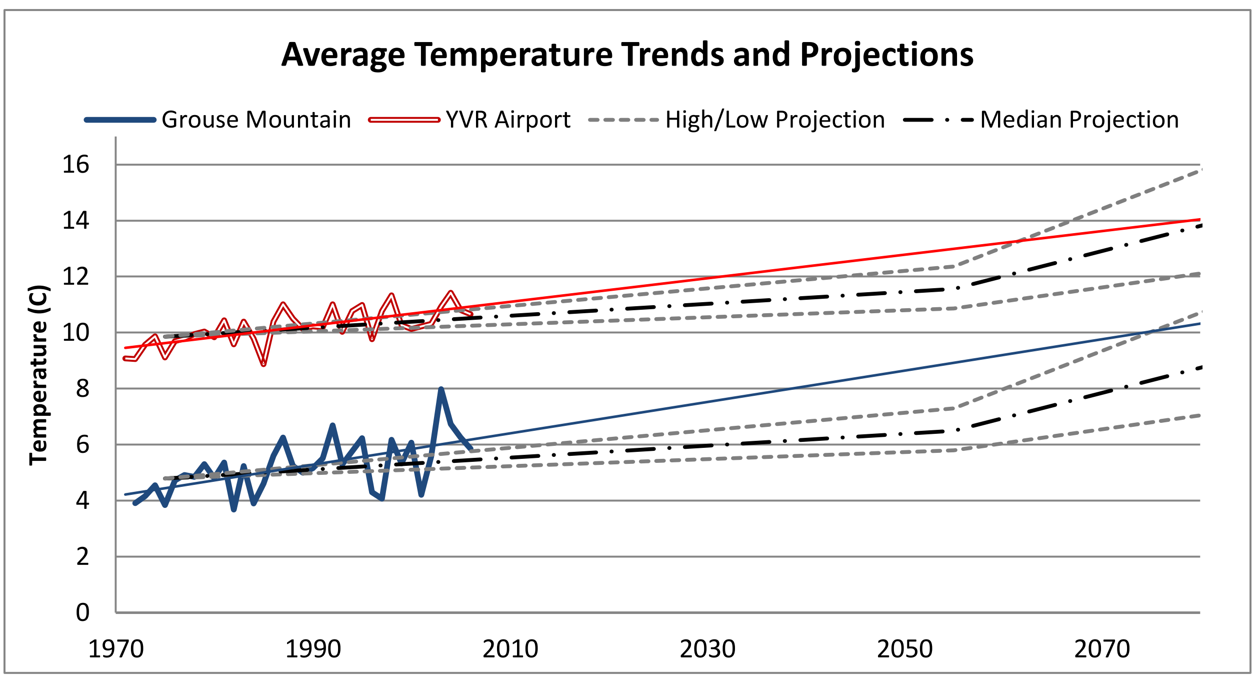

Figure 3: Historical trends in annual mean temperature at YVR Airport and Grouse Mountain. The solid red and blue lines show extrapolations of historical linear trends. The black and grey dotted lines show low, median, and high climate projections to the 2050s an and 2080s, compared to local 1961-1990 climate baselines. Projections are based on the 30 member PCIC Plan2Adapt ensemble. Historical data obtained from Environment Canada's National Climate Data and Information Archive.

Figure 4: Historical temperature and related trends for the Environment Canada climate stations at Grouse Mountain, Vancouver Harbour, and YVR Airport. Heating degree days (HDDs) and cooling degree days (CDDs) are measurements that are used to estimate annual energy demand for heating and cooling. HDDs measure how many degrees the daily average temperature is below 18°C, summed over the year. Similarly, CDDs measure how many degrees the daily average temperature is above 18°C, summed over the year.

Historical Trends	Grouse Mountain	Vancouver Harbour	YVR Airport
Average Temperature (°C/decade)	0.4	0.3	0.2
Summer High Temp. (°C/decade)	0.7	0.2	0.2
January Low Temp. (°C/decade)	0.8	0.7	0.3
Heating Degree Days (HDDs/decade)	-298.4	22.1	-62.2
Cooling Degree Days (CDDs/decade)	6.7	116	7.3
Annual Frost Free Days (Days/decade)	9.5	6.2	3.3

All trends reported in change per decade (Murdock et al., 2012)

2.3 Precipitation

Historical trends at local stations

The high natural variation in precipitation makes it more difficult to determine long term trends, especially for climate stations with shorter records. Most of the region experienced little change in annual precipitation, with small increases in the west, including at YVR (~10mm/decade), and decreases in the east. The major outlier was Grouse Mountain which experienced a large decrease of -147mm/decade (Figure 4). However, this rapid change is unlikely to continue and appears to represent an increase in the severity of dry years, rather than an overall, continuing decline. Despite warmer winter temperatures the percent of precipitation as snow showed no long term trend.

Projected changes in precipitation

The most likely model projections show a 7% increase in total precipitation for the region by the 2050s, and 8% by the 2080s. However, the range of projections is much larger than for temperature, with results from -2% to +11% for the 2050s, and +1% to 18% for the 2080s. Given Grouse Mountain's past declines it would therefore be prudent to plan for both an increase and decrease in total precipitation.

Predicted changes in precipitation timing and snowfall contribution

A change in the seasonal timing is also expected, with less precipitation in spring and summer, large increases in the fall, and smaller increases in winter. Along with these changes in precipitation totals, the amount that falls as snow is projected to decline substantially, particularly in the spring (Table 2). Although Grouse Mountain has shown no decline in the percentage of snowfall to date, this change may just be delayed due to the lower starting temperatures at higher elevations. The combination of historically declining precipitation and projections of a smaller contribution from snowfall and increasing precipitation for the region make it very difficult to predict the future impacts to the City's hydrology.

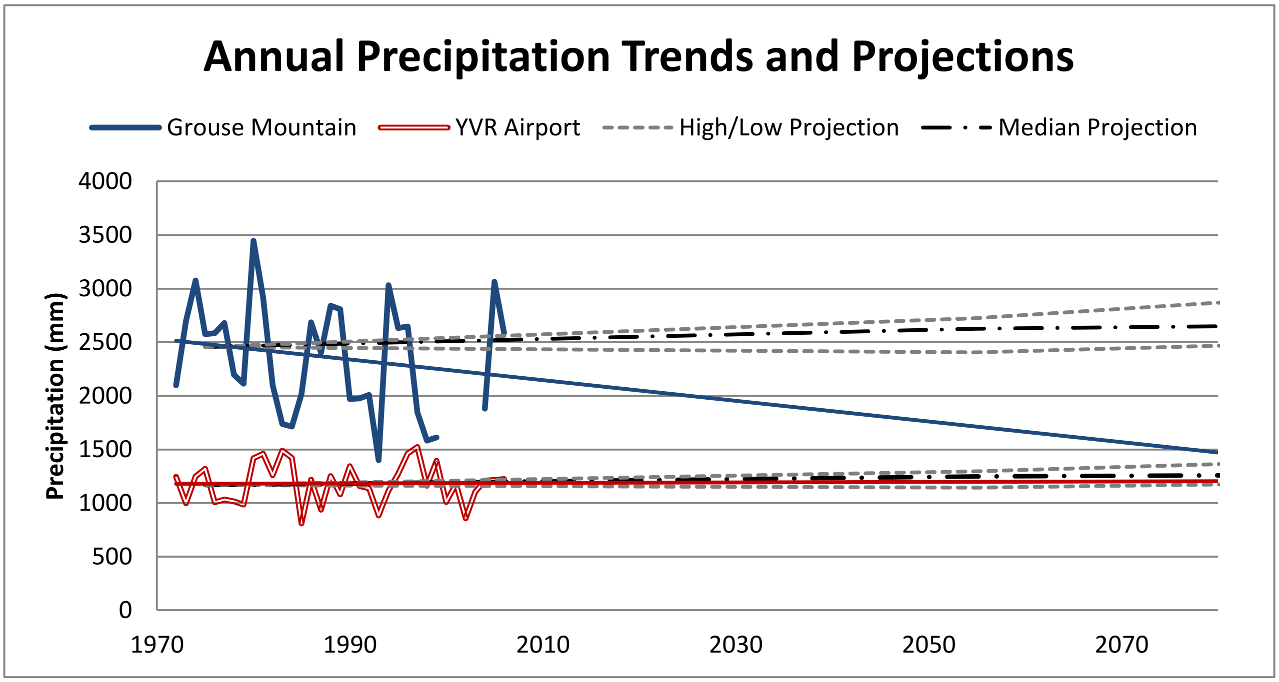

Figure 5: Historical trends in annual precipitation at YVR Airport and Grouse Mountain. Solid red and blue lines show extrapolations of past trends. Black and grey dotted lines show low, median, and high climate projections to the 2050s and 2080s, compared to local 1961-1990 baselines. Projections are based on the PCIC Plan2Adapt ensemble. Historical data obtained from Environment CanadaNational Climate Data and Information Archive.

Figure 6 Projected future climate change for the Metro Vancouver region, compared to a 1961-1990 baseline. The median and range values are based on 30 projections from the PCIC Plant2Adapt ensemble, which include the A2 and B1 IPCC emission scenarios. The range represents the 10th to 90th percentiles of the projections

Variable	Future Period	Median	Range
Annual Temperature	2050s	+1.7°C	+1.0°C to +2.6°C
	2080s	+2.7°C	+1.5°C to +4.2°C
Summer Temperature	2050s	+2.1°C	+1.4°C to +2.8°C
	2080s	+3.2°C	+2.0°C to +5.0°C
Winter Temperature	2050s	+1.6°C	+0.8°C to +2.7°C
	2080s	+2.3°C	+1.2°C to +4.1°C
Annual Precipitation	2050s	7%	-2% to +11%
	2080s	8%	1% to +18%
Summer Precipitation	2050s	-15%	-25% to +5%
	2080s	-14%	-38% to -2%
Winter Precipitation	2050s	+6%	-5% to +16%
	2080s	+7%	+1% to +24%
Spring Snowfall	2050s	-36%	-19% to -56%
	2080s	-52%	-26% to -74%
Winter Snowfall	2050s	-56%	-17% to -73%
	2080s	-75%	-21% to -88%

Murdock et al. (2012)

2.4 Extreme Events

Increased frequency of high temperature events

In the future extreme temperature and precipitation events are expected to be much more common. High temperature events are projected to be 2.4 to 3.2 times more frequent by the 2050s. This means that temperatures that are currently expected only once every 10 or 25 years would instead occur every 3.6 or 7.8 years, respectively. (Murdock et al., 2012).

Increased frequency of heavy precipitation events

Extreme precipitation days are also projected to be 1.6 to 2.5 times more frequent, resulting in events that are now expected to occur once every 25 years instead occurring every 10 years by 2050. The increase in the most intense 3 hour precipitation events is projected to be even greater, becoming 2.5 to 5.5 times more frequent by the 2050s. (Murdock et al., 2012).

Challenges in predicting extreme wind events

Historical analyses of extreme wind speeds suggest that they follow a regular cycle, with peaks approximately every 9 years, but with no overall trend towards either stronger or weaker winds (Griffin et al., 2010). When projected to 2050, the spread of results is too broad to provide any clear picture. The projections of extreme wind frequencies range from 3 times as high as today down to essentially zero, while median scenarios are very similar to today's climate (Murdock et al., 2012)

Figure 7: **Projected changes in the return periods of extreme weather events by the 2050s, compared to a 1971-2000 climate baseline. The projections represent the new frequency at which currently rare temperature and precipitation levels will be exceeded in the future. Accompanying increases in rarer and more extreme events are also expected.**

	High Temperature		**24 Hour Precipitation**	
Current Return Period	2050s Return Period	Return Level Temperature (°C)	2050s Return Period	Return Level 24hr Precipitation (mm) (Grouse / Vancouver Harbour)
5 Year	2.1	31.5	3.1	142 / 95
10 Year	3.6	32.1	5.3	153 / 121
25 Year	7.8	32.4	10	159 / 145

Murdock et al. (2012)

2.5 Sea Level Rise

Historical and projected sea level rise

During the 20th century global mean sea level rose at approximately 1.7 mm/year (17 cm/century), however this rate has increased to around 3 mm/year since 1993. The IPCC estimates a further increase of 18 to 59 cm by the end of the 21st century, while other models show the potential for more than 1m of sea level rise. Given the uncertainty in model projections, and the rapid increase observed in the past decades, the BC Ministry of the Environment released draft guidelines to be used for evaluating long-term land use planning of 0.5m of global mean sea level rise by 2050, 1.0m by 2100, and 2.0m by 2200 (Table 4). (BC Ministry of Environment, 2012)

Local response to sea level rise

As a complicating factor, for a given rise in global mean sea level the relative local response can be very different from one location to another. Local sea level rise is determined by regional ocean temperatures and circulation, atmospheric pressure and wind speeds, and the rate at which the continent is rising or subsiding in response to geological processes, such as rebounding from being depressed during the last glacial period. A study of regional sea level rise in BC projected that the Vancouver area would experience 89 cm of local sea level rise (with a range of 58cm to 119cm) for a 1.0m rise in global mean sea level (Thomson et al., 2008).

Figure 8: BC Ministry of Environment sea level rise guidelines for evaluating long-term land use planning. The regional response for the Vancouver region is expected to be similar to the global increase in mean sea level.

Timeframe	Global Sea Level Rise
2050	0.5m
2100	1.0m
2200	2.0m

BC Ministry of Environment (2008)

2.6 Summary of Historical and Projected Climate Changes

	Summary	Measure	Regional Projections[1] (Compared to 1961-1990 Baseline) 2050s	2080s	Historical Trends and Local Notes
Temperature	↑ Temperatures Year-Round Much warmer Summer highs and Winter lows	Average	+1.7°C (+1.0°C to +2.6°C)	+2.7°C (+1.5°C to +4.2°C)	High Elevation[2]: Average temperatures rising 2x faster Summer highs and winter lows rising 3.5-4x faster
		Extreme Summer High[6]	Frequency of warm days (+24°C) to more than double, and rare extreme days (+32.4°C) to more than triple by the 2050s		
Precipitation	↑ Annual Total Average Precipitation Drier Summers and Falls Wetter Winters and Springs Lower proportion as snow	Average	+7% (-2% to +11%)	+8% (+1% to +18%)	High Elevation[2]: ↓ Annual precipitation No change in proportion as snow Low Elevation[2]: No change or small increases Follows long term climate trends instead (ENSO/PDO)
		Summer	-15% (-25% to +5%)	-14% (-38% to -2%)	
		Snowfall (Winter / Spring)	-36% / -52%	-56% / -75%	
		Intensity[6] (Top 5% / 1% wettest days)	+20% / +28% precipitation on the wettest days by the 2050s		
		Extreme Event Frequency (1971-2000 baseline)	Wettest 24-hour events to more than 2x more frequent (+121mm/day at sea level, +153mm/day at high elevation) Wettest 3-hour events up to 5.5x more frequent		
Wind Speed	Results Unclear Very wide range Increases and decreases	Extreme Events (1971-2000 baseline)	Frequencies range from increasing to 3 times as high as today down to essentially zero. Median scenarios are very similar to today's climate		No overall trend[2] Approximately 9 year cycle following climate oscillations (e.g. ENSO, PDO)[3]
Sea Level Rise	+0.5m by 2050[4] +1.0m by 2100 +2.0m by 2200	BC Ministry of Environment Global SLR Guidelines	+0.5m[4]	+1.0m[4]	Global[4]: 1.7mm/year 20th C average 3mm/year since 1993 Local Response[5]: 89cm (58cm to 119cm) for 1.0m in global sea level rise

1. Murdock et al. (2012)
2. Environment Canada National Climate Data and Information Archive
3. Griffin et al. (2010)
4. BC Ministry of the Environment (2012)
5. Thomson et al. (2008)
6. 1971-2000 baseline

3 Identifying and Assessing the Impacts of Climate Change

3.1 Introduction

Weather influences nearly all aspects of the City of North Vancouver's operations, design, and culture, and in some cases controls them entirely. From storm sewer and building design, to parks and environmental management, to festivals and recreation, the region's moderate oceanic climate plays a major role in shaping the City's structure and lifestyle. Because of these strong connections climate change will have a wide range of impacts, some of which will become major threats if we do not adapt to the changing conditions.

Through consultation with City staff and regional stakeholders, approximately 150 potential climate change impacts were identified, affecting the City's infrastructure, inhabitants, businesses, and environment. Next, vulnerability and risk assessments were used to rank the impacts, and to identify the highest risk impacts to be included in the City's adaptation strategy. This process included an interdepartmental team of City staff and external agencies, and consisted of direct consultations, a vulnerability survey, and a risk assessment workshop.

3.2 Assessment Process

Vulnerability Assessment

Vulnerability = Sensitivity x Adaptive Capacity

Vulnerability refers to the susceptibility to adverse effects of climate change (e.g. How susceptible is the drinking water supply to hotter and drier summers and more frequent droughts?), and is a combination of the sensitivity to climate change (e.g. How much will the water supply decrease during hotter and drier summers?) and the ability to respond or adapt, known as the adaptive capacity (e.g. How much effort and money would be required to maintain an adequate drinking water supply during drought conditions?).

↑ Sensitivity → ↑ Vulnerability
↑ Adaptive Capacity → ↓ Vulnerability

However, sensitivity and adaptive capacity have opposite relationships with vulnerability. Whereas vulnerability and sensitivity have a direct relationship, vulnerability and adaptive capacity are inversely related. For example, the City's water supply might be highly sensitive to drought (increasing the vulnerability), but we can adapt to this relatively easily through water use restrictions and conservation (reducing the vulnerability).

Risk Assessment

Risk = Likelihood x Consequence

Risk is a measure of the expected outcome of an uncertain event, which is estimated by multiplying its likelihood by the consequence. In the case of climate change there is still some uncertainty around the exact magnitude and variability in the projected changes, as well as the severity of the resulting impacts and our ability to adapt to them. Risk assessment helps to grapple with these uncertainties and allows for the creation of a prioritized list of impacts based on their threat to the City.

The risk assessment looked at the consequence of each impact to six sectors of City operations and quality of life based on the ICLEI Risk Assessment process: Health and Safety, Local Economy and Finance, Community and Lifestyle, Parks and the Environment, Infrastructure and Buildings, and Land Use.The geographic and socio-economic distributions of impacts were also considered, especially where the consequences are expected to fall disproportionately on vulnerable populations.

Timeline

It is important to use a consistent timeline throughout the impact assessment process to accurately frame the likelihood and magnitude of the expected climatic changes and to ensure that the impacts are being compared fairly. The 2050s was chosen as the City's timeframe because it is a common timeframe for climate change projections and is also within the lifespan of most new buildings and infrastructure, making it relevant for decisions being made today. The 2050s is also useful for visualization as it is distant enough for substantial climatic change, but close enough to have personal consequences.

3.3 Assessment Results and Priority Impacts

At each stage in the process lower priority impacts were combined, refined, or removed to create a list of the most pressing impacts the City will experience. All of these high priority impacts are summarized in Figure 8, organized by climatic change and the level of risk to the City. A comprehensive list of all impacts that were considered can be found in Appendix A, along with the full results of the vulnerability and risk assessments.

While all of the priority impacts require some form of adaptation, there are several that stand out as presenting the greatest risk to the City of North Vancouver:

1. **Flooding and inundation of coastal, creek, and low lying lands due to more intense precipitation and sea level rise**
2. **Buildings, infrastructure, and development patterns will not be well adapted to future climate within their lifespans (e.g. undersized stormwater sewers, excess heat gain and lack of cooling in buildings, roads and buildings built below adequate flood construction levels)**
3. **Emergency staff and equipment may be inadequate to deal with the higher frequency of emergencies and the increased likelihood of simultaneous emergencies**
4. **Direct health and safety effects, including heat and cold stress, UV radiation, air quality related respiratory illnesses, storm debris, downed power lines, flood, and land slide related health and injury risks**
5. **Increasing risk of major transportation disruptions due to flooding of transit hubs, roads, and bridges**
6. **Vulnerable populations will experience much greater impacts than the general population, which must be addressed to reduce inequality and prevent the most severe health and wellbeing consequences**

Figure 9: High Priority Impacts of Climate Change

1. Hotter and Drier Summers and More Frequent Extreme Heat Events	
Increased maintenance and replacement costs for urban forests, green spaces and trees from temperature and precipitation extremes and wind storms	High Risk
Increased pressure from invasive species and stress on native species and habitat due to hydrologic changes and hotter, drier summers	High Risk
Increased risk of fire and a longer fire season due to decreased summer precipitation and increased temperatures, leading to increased fire prevention and suppression costs	High Risk
Increased summer energy use, decreased energy security, and stress on utility infrastructure due to higher temperatures and more demand for cooling	Moderate Risk
Increased risk of summer drought and water shortages due to decreased water supply and increased water use	Moderate Risk
Indirect health effects from the extension in the range of disease vectors and in the environmental survival of pathogens	Moderate Risk
2. Coastal Flooding and Inundation	
Flooding, inundation, and erosion of coastal property, parks, and habitat, and development impacts, due to more intense precipitation, sea level rise, and storm sewer overflow	Very High Risk
Disruption of sewerage and drainage systems and reduced gravity drainage of existing drainage systems, resulting in more frequent flooding	Moderate Risk
3. Increase in Precipitation and Heavy Rainfall	
Flooding of public and private property and development impacts for creek and low lying areas due to more intense precipitation and storm sewer overflow	Very High Risk
Increased risk of landslides and debris flows affecting property, infrastructure, public safety, and natural habitat	High Risk
Loss of recreational opportunities due to discomfort being outdoors and flooding	Moderate Risk
4. Increased Frequency and Intensity of Storms and Extreme Weather	
Increased need to consider natural disasters and emergency response during land use planning and the design of buildings and infrastructure	Very High Risk
Emergency staff and equipment may be inadequate to deal with higher frequency of emergencies and the increased likelihood of simultaneous emergencies	Very High Risk
Increased impact to utility, communications, and transportation infrastructure, including damage and loss of service due to increased extreme weather events	High Risk
Increased emergency response and clean-up costs, and liability when response is delayed or when hazards are left in place for later clean up due to prioritizing simultaneous or larger emergencies	High Risk
5. General and Indirect Impacts	
Direct health and safety effects, including heat and cold stress, UV radiation, air quality related respiratory illnesses, storm debris, downed power lines, flood, and land slide related health and injury risks	Very High Risk
Transportation disruptions due to flooding of transit hubs, roads, and bridges, and more frequent extreme wind and rain storms, and decreased use of transit and active transportation due to discomfort from increased temperatures and precipitation	Very High Risk
Decreased durability and lifecycle, and increased loss of service of civic infrastructure, property, and utilities, leading to increased maintenance and replacement costs	Very High Risk
Greater impacts to vulnerable populations and increasing health inequality due to less ability to	Very High

mitigate and adapt to climate change stresses	Risk
Increase in population and development pressure due to migration from regions less able to adapt to climate change	High Risk
Changing economic and demographic conditions in response to climate change in other regions will affect the local economy and culture	Moderate Risk
Food insecurity due to loss of local arable lands, loss of agricultural diversity, and disruption of the supply chain	Moderate Risk

3.4 Themes and Policy Areas

In addition to examining impacts based on expected climate changes, it is also useful to examine how these impacts will affect the City's operations and wider community goals. Looking for shared themes among the climate impacts makes it much easier to identify opportunities for adaptation and, where possible, how they can be integrated into existing policies and plans. The categories used below are based on the City's Official Community Plan.

Future Housing, Population & Employment

Coastal, creek, and low-lying areas will all be at higher risk of flooding due to more frequent intense precipitation, and to a lesser extent, sea level rise. Even for coastal lands the greatest risk comes from heavy rainfall combined with high tides. Sea level rise will worsen this type of flooding, increase coastal erosion, and eventually inundate low lying areas later the century, but will not lead to acute flooding within in the next several decades. The increasing flood risk, along with higher temperatures, more intense precipitation, and more frequent hazards, will lead to buildings, infrastructure, and land use patterns becoming maladapted to the City's climate. Without proper planning and adaptation this will lead to health and safety effects (e.g. inadequate cooling, flooding, landslides, and interface fires), decreased emergency response capabilities (e.g. flooded access roads, lack of evacuation routes, multiple simultaneous emergencies), loss of municipal services (e.g. improperly sized sewer systems, drinking water shortages), and wasted municipal and private investment (e.g. avoidable damage from flooding and severe storms, the need for retrofits or replacement).

The City may also experience increased population and development pressure due to migration from areas more severely impacted by climate change, or those less able to adapt. Concerted efforts will have to be made to balance this increasing development pressure with continued efforts to maintain the liveability and sustainability of the City.

Transportation, Mobility & Access

The City's position on the North Shore and limited east-west connectivity due to existing stream and ravine corridors make it particularly vulnerable to transportation disruptions, resulting in health and safety risks, economic harm, and a decreased quality of life. Significant vulnerabilities include this limited east-west connectivity, heavy reliance on the SeaBus, Lonsdale and Phibbs transit stations, and the Marine Drive, Lions Gate and Iron Workers Memorial bridges, all of which are at risk of flooding.

Active transportation and transit use may also be negatively impacted due to more frequent and severe inclement weather. Increasing summer temperatures and more intense precipitation during the winter and spring will make travelling or waiting outdoors more uncomfortable, possibly leading to more trips by car or a loss of mobility for vulnerable populations.

Natural Environment & Energy

Coastal erosion, hydrologic changes, more frequent landslides, and hotter, drier summers will all impact the natural ecosystems within the City, leading to habitat loss and degradation. Warmer and drier summers will also lead to increasing pressure from invasive species and stress on native species. Invasive species already present in the City are likely to become more abundant while the range of new species may expand to the north, allowing them to become established in the City.

As summer temperature rise, energy use for cooling will also increase. Without adaptation through modified building codes and land use planning this increase will put additional strain on the local and provincial electricity systems when they have the least flexibility, increase utility costs for City facilities and private buildings, and increase the environmental effects of energy generation.

Arts, Culture & Heritage

While there will certainly be global impacts of climate change, the local effects of these changes on the art, culture, and heritage of the City are very difficult to predict. The increasing population pressure the City may experience, changing economic conditions and uncertainty, and cultural shifts related to the changing climate could all influence the local community. Sense of place on the North Shore is also tied very tightly to the climate and environment and could be affected under extreme climate change.

Parks, Recreation & Open Space

Coastal, creek, and low lying parks and other green spaces will all experience increased flooding, inundation, leading to a loss of recreational opportunities and increased maintenance costs. More frequent inclement weather, including intense precipitation and extreme heat events, will also impact outdoor activity, park use, organized sports, and other events.

The City's parks, fields, and street trees will also require increased maintenance and replacement costs due to heavier rainfall, hotter and drier summers, and more frequent storms. Summer heat and droughts will increase watering requirements, flooded and inundated fields will require more maintenance or replacement with artificial turf, and more careful management will be needed to reduce health and safety risks from damage during more frequent severe storms.

Community Wellbeing

The effects of climate change are expected to have a range of direct acute and long-term health consequences for the City's inhabitants. More frequent extreme heat events and winter storms pose the greatest health risks, especially for vulnerable populations such as the elderly and homeless. Other long-term impacts could also arise from greater UV radiation exposure, decreased air and water quality, and new or increased disease vectors and environmental survival of pathogens. Increased disease pressure could coming the form of water-borne illnesses (e.g. Legionnaires disease, influenza), food-borne illnesses (e.g. salmonella), animal and plant vectors for disease (e.g. mosquitos and West Nile

Virus, ticks and Lyme disease), and new fungal pathogens. Food security may also become an important issue, particularly for lower income households, due to price volatility and crop losses from droughts, hail, and other unusual weather patterns. Healthier food will likely see a much greater increase in price compared to unhealthy and processed food, meaning that both nutrition and access to food will have to be addressed.

As with many negative societal effects, vulnerable populations will experience much greater impacts from climate change compared to the general population due to less ability to mitigate and adapt to changing conditions and stresses. Particularly vulnerable populations could include the homeless and those on the street, the poor, outdoor workers, shut-ins and those stuck indoors, elderly, children, and families. Issues of particular concern include the elderly's high vulnerability to extreme heat and the City's rapidly aging population, health and safety impacts to the homeless and lower income households from more frequent severe storms, extreme heat, and other natural hazards, decreased emergency response capabilities and health impacts to the sick and elderly during more frequent power outages, and health and safety risks for outdoor workers during more frequent extreme heat events and severe storms. Ensuring a more equitable distribution of impacts and protecting the most vulnerable from the catastrophic consequences of climate change will be a substantial challenge.

The frequency and severity of several climate related hazards are expected to rise dramatically in the coming decades, including extreme heat and storm events, flooding, and fires. With higher rates of occurrence emergency staff and equipment may be inadequate to deal with the higher frequency of emergencies and the increased likelihood of simultaneous emergencies, resulting in delayed response and potentially serious health and safety impacts. More frequent and severe climate related emergencies will also require greater clean-up and response costs, as well as posing increased liability issues. While the City of North Vancouver may not experience a significant increase the occurrence of some climate hazards, the sharing of emergency response resources through the North Shore Emergency Response Office means that emergencies in the Districts of North and West Vancouver, such as forest fires, will also impact response times and costs for the City as well. The City may also become exposed to increased liability when response is delayed or when hazards are left in place for later clean to attend to higher priority situations.

Economic Development

The largest economic impacts of climate change will likely arise from direct losses due to flooding, transportation disruptions, and other climate related damage and emergencies. Several major commercial and industrial areas are vulnerable to flooding, including the Harbourside business park and the industrial lands along the Seymour River. Transportation disruptions related to the flooding of transit hubs and bridges would have also major impacts on the economy of the region.

The local economy will also likely be affected by regional, national, and global economic change and uncertainty related to climate change. While the local effects of these impacts are difficult to predict, they could include changes in resource use and availability, supply chain disruptions, and increased uncertainty and volatility in the economy.

Municipal Services & Infrastructure

As with building design and land use planning, there will be an increasing need to consider natural disasters, emergency response, and future climatic conditions during the design, building, and retrofitting of City infrastructure. Ensuring that the storm and sanitary sewer systems are sized appropriately and have adequate drainage and pumping capacity will be vital to minimizing the flood risk. Higher temperatures, more intense precipitation, and more frequent extreme weather events will decrease the durability and lifecycle of the City's infrastructure. Freeze-thaw weathering of roads could also worsen with increased weather variability, but may decrease later in the century as temperatures continue to rise.

Despite large amounts of annual rainfall and projections of small increases in total precipitation, climate change will increase the risk of summer droughts and water shortages because of both reduced supply and increased usage. Currently, Metro Vancouver's potable water supply is limited by the capacity of its reservoirs rather than by total precipitation in its watersheds. This limitation makes the water supply vulnerable to changes in the timing of precipitation, the proportion that falls as snow, and when the snowmelt occurs each spring. Decreasing snowfall and earlier snowmelt will cause the reservoirs to fill and begin to be drawn down earlier in the year, while hotter and drier summers will increase water use, speed up reservoir drawdown, and decrease refill from summer precipitation. With summer water use restrictions already in place, these changes could greatly increase the risk of summer water shortages.

3.5 Climate Change Benefits

The Lower Mainland is comparatively well situated with respect to climate change due to its ocean moderated climate which will mitigate many temperature related impacts and keep average temperatures relatively comfortable for several decades. This room for change prior to substantial negative consequences also provides opportunities for potential benefits of climate change. Food growing conditions may be improved, allowing for greater productivity and the introduction of new species and varietals. Safer road conditions and potentially reduced snow clearing requirements may occur in the long term due to reduced snowfall. Freeze-thaw weathering of roads and other infrastructure may decrease with increasing winter temperatures. There is a potential for increased tourism potential and recreational opportunities due to longer, drier summers.

However, the likelihood and magnitude of these benefits are generally much lower than for the negative impacts identified above. Warmer temperatures will almost certainly improve food growing conditions, but the drier summers will increase watering requirements, and could increase disease pressure as well. Total snowfall will decrease in the future, but it may fall in fewer, larger events which actually require more snow clearing resources. Similarly, the number of freeze-thaw events will likely decrease as temperatures rise, but increased climate variability could reduce this effect and actually lead to increased weathering due to more frequent large temperature swings which are much more damaging than several smaller freeze-thaw events. Finally, tourism and recreational opportunities in the summer will benefits from warmer temperatures and less rainfall, but this effect could be outweighed by the effects of increased rainfall during the rest of the year.

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Appendix A: Glossary

Adaptation

Adaptation making adjustments in our decisions, activities and thinking to reduce the negative impacts of observed or expected climate change, or to take advantage of any benefits. Adaptation can include changes to human behaviour, or the natural or built environments.

Adaptive Capacity

Adaptive capacity is the ability to adjust to climate change, including moderating damages, taking advantage of opportunities, and coping with the consequences.
(e.g. *Can the emergency response system adjust to more frequent hazards without major costs and disruption?)*

Climate

Climate is the pattern of variability in atmospheric conditions in a given region over a long period of time, typically decades or longer. In contrast to weather which describes current atmospheric conditions (e.g. temperature, air pressure, humidity, cloudiness, precipitation), climate describes the

Climate Change

Climate change refers to the statistically significant variation in the average or variability of atmospheric conditions (e.g. temperature, humidity, wind speeds, precipitation) that persist over long periods of time, typically decades or longer. This includes shifts in seasonality (e.g. drier summers and wetter winters), diurnal patterns (e.g. nighttime warming faster than daytime), interannual variability (e.g. wetter wet years interspersed with more frequent drought years), changes in extremes (e.g. fewer days with precipitation but heavier rainfall when it does occur), and geographic shifts (e.g. the northward movement of the Pacific storm tracks). Climate change can be caused by natural processes either on the Earth (e.g. volcanic eruptions, changes in the Earth's angle of rotation), or external to the planet (e.g. solar intensity), or by human activity (e.g. greenhouse gas emissions, land use change).

FCL

The minimum Flood Construction Level is height above mean sea level above which the flood risk considered low enough to allow construction. The calculation of the FCL should take into account the higher high water level tide (HHWLT) elevation, an allowance for future sea level rise to a particular time horizon, the estimated storm surge and wave effects associated with the selected design storm, and freeboard. In British Columbia the FCL is required to be calculated using a 1 in 200 year design storm.

ICLEI

The International Council for Local Environmental Initiations, also known as *ICLEI – Local Governments for Sustainability*, is an association of local governments that promotes environmental sustainability through local initiatives. See http://www.icleicanada.org for more information.

ISMP
An Integrated Stormwater Management Plan is an ecosystem based approach to stormwater management that balances land use planning, stormwater engineering, flood and erosion protection, and environmental protection. In contrast to traditional stormwater practices that focus solely on infrastructure, Integrated Stormwater Management attempts to imitate a natural watershed by increasing infiltration and reducing runoff through careful land use planning, protecting natural lands, and mimicking natural processes.

LEC
The Lonsdale Energy Corporation is a district energy system that provides heating to residential and commercial buildings in the Lonsdale area of the City of North Vancouver. See http://www.cnv.org/City-Services/Lonsdale-Energy for more information.

Mitigation
Mitigation is the attempt to prevent climate change, and by doing so to avoid or lessen its negative impacts. Mitigation typically includes measures to stabilize or reduce atmospheric greenhouse gas concentrations and the prevention or reversal of damaging land use changes.

OCP
The Official Community Plan outlines the City of North Vancouver's long term vision, and is one of the City's most important policy documents. The OCP includes objectives and policies to guide planning and land use decisions, and aims to balance the social, environmental, and economic needs of the community. See http://www.cnv.org/Your-Government/Official-Community-Plan for more information.

Resilience
Resilience is the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the same capacity for self-organization and the same capacity to adapt to stress and change. Increased resilience is the objective of adaptation actions.
(e.g. *Can we maintain a comfortable outdoor environment given changing demands, climate, and levels of development?)*

Risk
Risk is a measure of the expected outcome of an uncertain event, which is estimated by combining an event's likelihood by the expected consequence. The concept of risk helps to grapple with uncertainties and allows for the comparison of potential impacts.

Sensitivity
Sensitivity is the degree to which a system is affected by climatic conditions or a specific climate change impact.
(e.g. *How much will landslide risk increase because of higher intensity precipitation?)*

Sustainability
Sustainability is the management of our communities in a way that balances the social, economic and environmental implications of our activities in order to meet the needs of people today without compromising the ability of future generations to meet their own needs.

Vulnerability

Vulnerability refers to the susceptibility of a social or ecological system to adverse effects of climate change, and is a combination of sensitivity and adaptive capacity.
(*How susceptible is the drinking water supply to more frequent droughts?)*

Weather

Weather is the short term, day-to-day condition of the atmosphere, and can be described with respect to heat, moisture, air pressure, cloudiness, wind, sunshine, precipitation, etc.