Adapting to Climate Change in Squamish:

Backgrounder Report

November 2016

Prepared by:

Dr. Ian M. Picketts and Benjamin Hamilton

Acknowledgements

This report was created in close collaboration with Matt Gunn, and with significant direction from David Roulston and Jonas Velaniskis from the District of Squamish. Thanks to District of Squamish staff members for their participation in the 'Climate Change Adaptation in Squamish BC' workshop. Special thanks to our volunteer expert reviewers: Stewart Cohen (Environment and Climate Change Canada); Frank DeGagne (BC Ministry of Forests Lands and Natural Resource Operations); Erica Crawford (Independent Consultant); Arelia Schoeneberg and Trevor Murdock (Pacific Climate Impacts Consortium); and Steve Litke, Jim Vanderwal and Eliana Chia (Fraser Basin Council). Your assistance in helping communities adapt to climate change is very much appreciated!

About the authors

Ian Picketts is a Tutor and the Physical Sciences Coordinator at Quest University Canada. His research focus is on community adaptation to climate change. Benjamin Hamilton is a senior student at Quest.

Purpose of report

Communities around the world are being impacted by climate change. Squamish – with its extensive resources related to information, technology, public support and strong social networks – is uniquely well positioned to proactively adapt to climate change. By doing so, Squamish can minimize negative impacts, take advantage of any positive impacts, and become resilient to both expected and unexpected shifts and events. It is imperative to proactively plan, and not wait until unexpected events or a disaster forces us to react to the realities of climate change. The purpose of this document is to outline why and how climate change adaptation should be incorporated into the District of Squamish's Official Community Plan (OCP), and to highlight opportunities for ongoing action.

Introduction to climate change and adaptation

Climate change, also often called global warming, refers to long term changes in weather patterns, including both changes in averages and extremes. Climate change is different than climate variability and weather, which relate to changes over shorter time scales. Scientifically speaking, human-caused climate change is a fact. What this means is that we know that humans are having a significant effect on earth's climate system, primarily due to the release of greenhouse gases into the atmosphere. Greenhouse gases absorb and quickly re-radiate heat in the atmosphere, causing warming and other changes.

Often people think that climate change is a future problem. In fact, we are already seeing changes across the world and these changes are impacting both human and natural systems. For example, in March 2016 NASA declared February 2016 to be the warmest month (i.e., the largest temperature anomaly) ever recorded globally, since records started being kept in the 1880s (Freedman, 2016). January 2016 was declared to be the next warmest month.

Climate change is a reality that individuals and communities must be aware of. Climate change has the potential to disrupt many systems (such as emergency response, agriculture and transportation) that we rely upon. However, with good planning, communities can prepare themselves for both positive and negative impacts, and also take a leadership role in lessening our future effects on the climate.

The two main ways that humans can respond to climate change are through mitigation (i.e., reducing GHG concentrations) and adaptation (i.e., adjusting to impacts). These concepts are defined in more detail in the 'key terms' section. The purpose of this document is to help guide a discussion of how the District of Squamish can proactively prepare for and adjust to climate change, with a focus on impacts, vulnerabilities and adaptations. Adaptation is now a reality because changes in the climate will have significant further impacts on natural and socio-economic systems in the area in the next 35 years. These changes are going to happen regardless of mitigation efforts, due to GHGs already in earth's atmosphere. Mitigation is discussed as a separate part of the OCP process.

A detailed overview of the science of climate change is not within the scope of this report. There are a great number of informative resources freely available to people who would like to learn more. A couple of noteworthy resources are:

- The Intergovernmental Panel on Climate Change (IPCC) is a United Nations body that assesses and synthesizes climate science. The latest IPCC Assessment and Summary reports are available here: http://www.ipcc.ch/
- The Pacific Institute for Climate Solutions is a BC based organization focused on effective responses to climate change. They have created a series of interactive lessons regarding climate change here: http://pics.uvic.ca/education/climate-insights-101

A brief overview of a few key terms is included below. These terms should provide some common background that relates to the scope and objectives of this document.

Key terms:

Greenhouse gases (GHGs):

Atmospheric gases that absorb and emit solar radiation, and affect the temperatures of earth. The greenhouse effect is natural (and is why earth is a habitable planet), but additional GHGs in the atmosphere enhance the greenhouse effect. The primary GHGs are water vapour, carbon dioxide, methane, nitrous oxide and ozone.

Weather:

Look outside! Weather is the state of the atmosphere at a particular time and place, and refers to a time period of minutes to weeks.

Climate variability:

Changes in temperature and precipitation regimes, and/or the number of and severity of events, over periods of weeks to years.

Climate change (aka global warming):
Long term changes (generally over at least 30 years) in temperature and precipitation regimes, and/or the number of and severity of events.

Climate normals:
Measured averages in weather parameters (such as temperature or precipitation) over a long time period, usually 30 years. This information represents a baseline from which future changes can be compared.

Climate impacts:
The consequences of climate change. It is worth noting that impacts can be both positive and negative.

(Climate change) adaptation:
Responding to the impacts (both positive and negative) of climate change. Adaptations can be made by natural systems, individuals, communities, businesses, other organizations and/or higher orders of government.

(Climate change) mitigation:
Actions that limit human influences on the climate by reducing the concentration of GHGs in the atmosphere. This is done by reducing the amount of GHGs emitted, or by enhancing the earth's ability to naturally sequester GHGs (e.g., by planting trees or preserving forests).

Global climate models (GCMs):
Mathematical representations of the climate system, which are based on the physical and chemical principles of the climate system. These computer-based models provide quantitative estimations of future climates, and climate change.

Climate projections:
Projections are the outputs of GCMs, and are a description of the future that accounts for the development of certain conditions (such as increases in GHG emissions). Therefore, projections are expectations that are conditional on certain things happening. Long term projections vary considerably based on what GHG emissions scenario is used: which is to say that the amount of climate change we can expect is dependent on how many GHGs we emit into the atmosphere.

Vulnerability:
The extent to which a community may be adversely affected by climate change. Vulnerability depends on how sensitive a community is to changes, and also its ability to cope with or adapt to new conditions (see adaptive capacity).

Adaptive capacity:
Ability to effectively adapt to climate change. The adaptive capacity of a community depends on many factors, including: available information; available monetary resources; available human resources; local leadership; and the public's willingness to support action.

Squamish's climate

Squamish is known for its moderate coastal climate, including mild and wet winters, and warm and dry summers. The mean annual temperature for Squamish is approximately 10°C, and mean annual precipitation is approximately 2200mm.

According to historical climate data from the Squamish airport (2016), the coldest month of the year in Squamish is December, when the average daily temperature is -0.1°C (average nighttime low -2.4°C; average daytime high 2.2°C). The warmest month is August, when the average daily temperature is 17.8°C (average nighttime low 11.2°C; average daytime high 24.5°C). The wettest month of the year is November, which sees an average of 380mm of precipitation, and the driest is August, which receives approximately 60mm of precipitation. Due to the moderate climate, snow accumulation at low elevations rarely occurs, and snow rarely falls outside of the months of December and January. That being said, there is significant snow accumulation in the higher altitude areas surrounding Squamish in the winter, and glaciers are visible from town.

The climate in BC's southern coastal area can be unpredictable and hard to model due to many factors. One factor is the complex terrain. Because of the steep topography there are a large number of small watersheds in the region, and precipitation rates are high and highly variable. The mountainous areas around Squamish can also block large weather systems, such as cold arctic fronts.

Another major factor that affects the climate is the influence of the Pacific Ocean. The Pacific Ocean is a massive heat sink (because water has a very high heat capacity) and serves to moderate temperatures. Also, winds blow moisture from the Pacific Ocean over land, and when the wind encounters the mountains it tends to release the moisture as precipitation. The Pacific Ocean is a major reason why both winters and summer are mild in coastal areas like Vancouver and Squamish, and why winters are very wet. Due to these factors – as well as the influences of long term patterns of climate variability (most notably the *El Niňo Southern Oscillation* [ENSO] and *Pacific Decadal Oscillation* [PDO]) - the climate is highly spatially and temporally variable in the south-coastal region (Mantua and Hare, 2000).

Past climate change in Squamish

Since 1900, temperatures in Southwestern British Columbia (BC) have increased by approximately 1.2°C, and overall precipitation has increased by approximately 5%. Figure 1 and Figure 2 show the historical trends in winter and summer temperature and winter and summer precipitation.

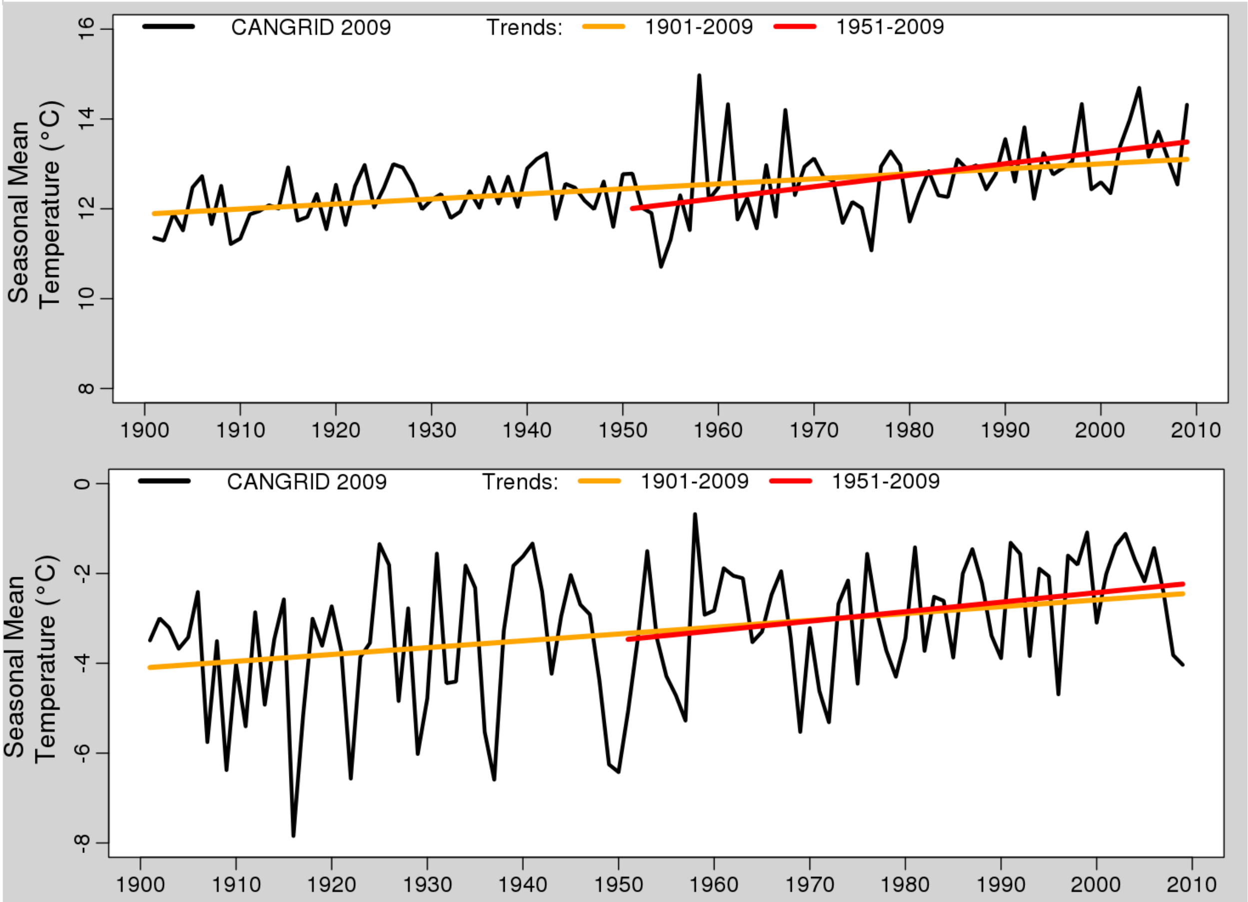

Figure 1 Historical summer (A) and winter (B) temperature time series for the South Coast region of BC, which includes Squamish. Note that temperature has increased in summer and winter since 1900, with winter temperatures increasing faster than summer temperatures. Temperatures have increased at a greater rate since 1950 in winter and summer. (Adapted with permission from PCIC, 2013).

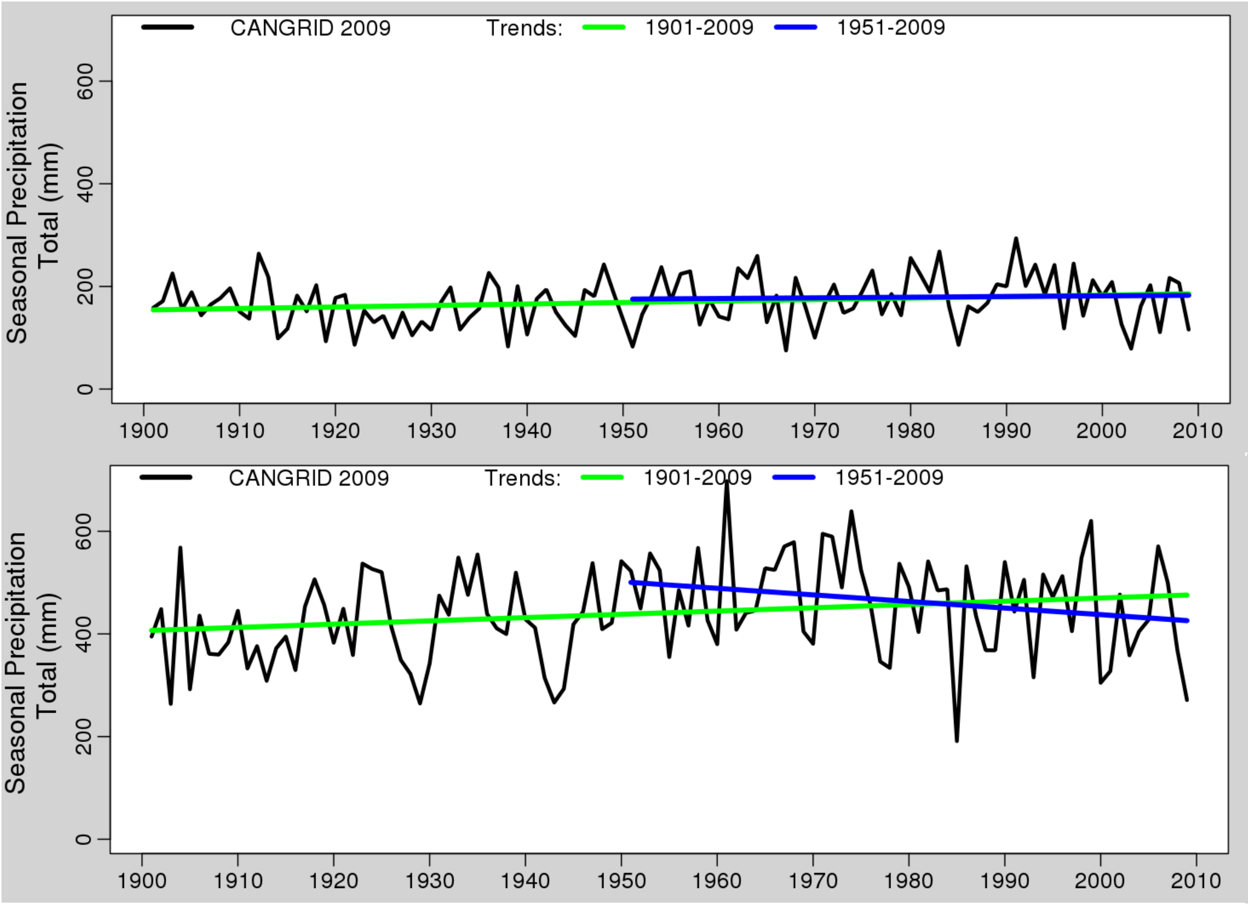

Figure 2 Historical summer (A) and winter (B) precipitation for the South Coast region of BC, which includes Squamish. Precipitation increased in winter and summer from 1900 to 2009, from 1950 to 2009 in summer, but declined from 1950 to 2009 in winter. Low confidence in observations for the early part of the record and the fact that precipitation amounts vary greatly from year to year, and decade to decade, make trends more difficult to discern than those for temperature. (Adapted with permission from PCIC, 2013).

Future climate change in Squamish

Climate projections give us insight into how the climate may continue to change in the Squamish region. Projected climate changes for the Squamish region were compiled by PCIC (2013) by analyzing the outputs of 30 GCMs. The **median,** or average, **value is reported first** (and the 10th to 90th percentile range of projected changes shown afterward in brackets).

- Future projections indicate that the region will warm by approximately **1.7°C** (From 1.1 to 2.5°C) in the 2050s, compared to the 1961-1990 baseline.
- Future projections indicate that the region will become **6%** wetter annually (2% drier to 11% wetter) in the 2050s, compared to the 1961-1990 baseline. Increases are projected for winter, while decreases are projected for summer. Not surprisingly, winter snowfall is projected to decrease substantially due to warmer temperatures.

When thinking about projected changes, it is important to consider and plan for a range of potential futures. This helps decision makers to be prepared for uncertainty, and also encourages people to build resilience into their systems.

What does climate change mean for Squamish?

There are many changes being experienced in the region. Some of these relate to changing average temperatures, altered river flow patterns, sea level rise, and shifting precipitation patterns. These changes have a number of impacts. For example, warming temperatures can result in reduced heating costs for residents, and can be beneficial for agriculture (due to more frost-free days and a longer growing season). Warming temperatures also can lead to a greater incidence of forest fires, and lead to more demands on water. Changes in precipitation can lead to many impacts as well, including impacts on building, storm-water and transportation infrastructure, and also agriculture.

In this section a number of climate impacts are highlighted that are considered to be highly relevant to Squamish. Each section begins with a brief overview of the impact, provides a summary of actions that Squamish is currently taking, summarizes some relevant actions that other organizations have taken and/or recent scientific updates, and ends with some recommendations for potential policy actions.

There are two categories of impacts:

1. Near-term Priorities: These impacts have been determined to be decidedly relevant to Squamish, and, if not properly planned for, can lead to considerable and undesirable (short term and long term) consequences for the District. These impacts are:
    a. Sea level rise
    b. Increased forest fires
    c. Extreme precipitation

2. Long-term Priorities: These impacts are relevant to Squamish, but may not have immediate and negative consequence on residents’ safety or quality of life. They are a priority for ongoing research and potentially for future action. These impacts are:
    a. Changing river flows
    b. Water supply vulnerability
    c. Economic development
    d. Health
    e. Food security

There are many other impacts which are relevant but not discussed in this document. These include impacts that relate to building infrastructure, transportation infrastructure, slope stability, and extreme heat.

In creating this section, an initial list of impacts and policy response directions was drafted in discussion with the author and advisors at the District of Squamish. After a brief internal review, a multi-stakeholder workshop was held on June 29, 2016 with nine senior staff members at the district. During the workshop, participants worked in plenary and small groups to refine the impacts, and to make sure that the policy response directions were appropriate for Squamish. Based on the workshop the report was updated.

After the workshop, an expert panel of scientists and policy-makers reviewed the document before finalization. These were experts in many fields of climate change impacts and adaptation. Advisors at the District of Squamish also reviewed the updated draft before finalization.

This is not meant to be an exhaustive list of impacts affecting Squamish, or of adaptation strategies that the District can pursue. These impacts will change over time, and may become more or less of a priority for Squamish as the community changes, the climate changes and technology changes. It does serve as a starting point for future discussion and action.

Category 1 – Near-Term Priorities

For the near-term priority impacts, the recommended policy directions are separated into:

1. **Operational policies**: these relate to explicit actions that should be taken (i.e., bylaws and policies) to help the community adapt to climate change.
2. **Aspirational policies:** these relate to longer-term actions, more general policies, and/or information needs to help the community adapt to climate change.
3. **Response policies:** these relate to strategies and actions that will help the District of Squamish to be ready to respond to both expected and unforeseen impacts and events.

General overarching response strategies include:

- Require all new development to identify the hazards that they are exposed to, and identify measures taken to mitigate these hazards. Part of this assessment should include the consideration of climate change, and its effect on hazard exposure and risk.
- Establish an ongoing multi-stakeholder working group to explore how the District (and surrounding region) can enhance its emergency response capabilities in light of climate change.

Impact: Sea level rise

Overview

Climate change leads to sea level rise (SLR) due to melting glaciers and ice sheets, and to thermal expansion (i.e., water increasing in volume as it warms). Climate change is projected to result in approximately one metre of SLR by 2100. A study by the BC Ministry of Forests, Lands and Natural Resource Operations (2012) estimated that it would cost on the order of $9.5 Billion to prepare 250km of shoreline and low-lying areas in Vancouver for one meter of SLR. It is not as simple as just planning for a certain amount of rise, as communities need to account for other factors such as storm surges and land uplift or subsidence.

Many areas focal to Squamish's economic, social, environmental and cultural heritage are susceptible to impacts from SLR. Most of downtown Squamish is highly vulnerable to coastal flooding and storm surge currently, and with future SLR these vulnerabilities are projected to increase.

Summary of actions that Squamish is taking

The District of Squamish commissioned the report, 'Coastal Flood Hazard Mitigation Strategy and Flood Protection Options' (Kerr Wood Leidal, 2015). The final draft report was completed in late 2015, and provides detailed modeling of how sea level rise will affect Squamish. The report follows the Provincial guidelines, and plans for a 1m rise in sea level by 2100 and a 2m rise by 2200. The report also outlines strategies to prepare for and adjust to SLR, which fall under the general categories of:

- Protect (e.g., build dikes)
- Accommodate (e.g., flood proof buildings)
- Retreat (e.g., relocate existing development away from vulnerable areas)
- Avoid (e.g., do not build infrastructure in vulnerable areas)

The final draft of the Integrated Flood Hazard Management Plan was completed in August 2016 (Kerr Wood Leidal, 2016).

Additional science, community action examples, adaptation information

- On March 30, 2016, a study was released in the journal 'Nature' asserting that previous SLR projections have discounted the contribution from Antarctica's ice sheet. The study authors contend that, if global GHG concentrations continue to increase, the loss in volume of ice in Antarctica could as much as double projected global SLR for 2100. Fortunately, if the global community is successful in drastically reducing our GHG emissions, there will be only a small contribution to global SLR from Antarctica (Dennis and Mooney, 2016; Rappler, 2016).
- In response to reports regarding the costs of Sea Level Rise in the lower mainland, a 'Lower Mainland Flood Management Strategy' initiative has started. This initiative proposes a strategy for communities in the lower mainland (from Hope to Richmond, and Squamish to White Rock) to work together and share resources in order to strengthen flood management policy and practice. The District of Squamish is a partner in this initiative (Fraser Basin Council, 2016).
- Actions taken by nearby communities include:

- The City of Richmond is planning for sea level rise, and has completed a comprehensive Dikes Master Plan (City of Richmond, 2016).
- The City of Surrey is looking into many different adaptation responses to sea level rise (e.g. Osler, 2016).
- The City of Vancouver has completed a coastal flood protection study and has implemented new policy (e.g., Northwest Hydraulic Consultants, 2014).

Recommended policy directions

Operational

- Support and implement the Coastal Flood Hazard Mitigation Strategy. This includes:
  - Considering strategies that protect, accommodate, retreat from and avoid flood risks for all of the sensitive areas identified in the report.
  - Follow the implementation strategy outlined in the flood hazard strategy. This strategy includes phased requirements for building new and upgrading existing sea dikes to meet Year 2100 SLR conditions, and provisions for raising to year 2200 sea levels.
- Update and adapt the coastal flood risk mitigation strategy frequently (at least every 10 years) to reflect updated climate information and climate projections as they relate to SLR, and development in the region.
- Continue to actively participate in and contribute to the Lower Mainland Flood Management Strategy to promote a collaborative and learning approach to managing SLR on BC's south coast.
- Accommodate SLR through adhering to (and updating as necessary) amended Flood Construction Levels, as established in the forthcoming Floodplain Bylaw (that is being developed as part of phase IV of the Integrated Flood Hazard Management Plan).

Aspirational

- Employ a precautionary approach for ongoing planning and development in areas vulnerable to SLR. This may include:
  - Conserving appropriate land to allow for the construction of flood protection measures (such as dikes) in order to accommodate higher-than-anticipated (i.e., beyond 2m) rates of SLR.
  - Reorienting development centres away from areas vulnerable to SLR and storm surge inundation.
  - Encouraging recreational use, and other activities that do not require significant infrastructure, in areas vulnerable to SLR and storm surge inundation.
- Encourage SLR adaptation measures that concurrently reduce GHG emissions and enhance adjacent environmental values. These may include Green Shores dikes that use bio-engineering to prevent erosion, and conservation efforts that preserve forests and wetlands.
- Promote, enable and incentivize programs that encourage the developments that are more resilient to SLR.

Response

- Establish long term plans for managed responses and retreat from vulnerable areas over long time horizons. Such a strategy may include:
    - Highlighting and acknowledging areas that (within reason) will be protected and not retreated from.
    - Establishing a 'build back better' principle to avoid re-building inappropriate infrastructure in vulnerable areas.
    - Examining the actions of other more vulnerable communities in response to SLR.
    - Managing retreat actions according to Integrated Flood Hazard Management Plan.
    - Prioritizing the removal of critical infrastructure from vulnerable areas.
- Enhance emergency response capabilities

Impact: Increased forest fires

Overview of the challenge

Both the number of and the size of forest fires is increasing, globally and in Canada. This increase is in part related to warmer summer temperatures, drier soils, and longer rain-free periods. Climate change also can lead to ecological changes, such as the mountain pine beetle outbreak, which can kill large amounts of trees and add to fire risks.

Squamish has a rich forestry background, and forestry remains a major employer in the region. People in Squamish also utilize nearby forests extensively for recreation and tourism. As Squamish is surrounded by forests, urban-wildland interface fire (i.e., when a forest fire meets a town) is a significant risk.

Forest fires have been an increasing concern in western Canada for many years now. 2003 was a particularly bad year for BC forest fires, with over 2,500 fire starts and an all-time record number of wildland-urban interface fires. These interface fires, predominantly located in the southern-interior region, forced the evacuation of 45 000 people and resulted in over $700 million in damages (Filmon, 2004). 2014 and 2015 were both bad years for fires in BC, with considerably higher-than-average total hectares burned and total costs (BC Government, 2016). Forest fires near Pemberton in the summer of 2015 led to significant air quality problems, and also raised concerns about Squamish's ability to respond to a major fire event. More recently, the devastating fires in Fort McMurray, Alberta, have served as a sobering wake-up call regarding climate change and wildfire management. Initial investigation of the Fort McMurray fire indicate that it could cost insurers as much as $9 billion (Evans, 2016). This amount does not include short and long term costs to Canada's economy related to the devastating fire.

Summary of actions that Squamish is taking

Squamish Fire Rescue can ban or restrict certain types of work during 'high' or 'extreme' forest fire risk ratings. These restrictions are for construction or maintenance activities occurring within 10 metres of the forest interface.

Additional science, community action examples, adaptation information

- Key recommendations from a report investigating the 2013 fires in BC disaster include: fuel treatment projects, requiring slash burning from forestry, assessing wildland urban interface zones, and incentivizing logging to reduce fire hazards (Filmon, 2004).
- In 2008 the District of Vanderhoof undertook a detailed study to understand how the region was vulnerable to changes in forests. Social and economic systems were found to rely on timber values, jobs, environmental values, cultural traditions, tourism and recreation, health, property, and safety. These values were all vulnerable to changes in ecosystem processes (such as fires) and/or ecosystem compositions (such as forest productivity).
- The City of Prince George has a FireSmart program that offers information to residents to protect their homes. The City also has established a community forest that consists of all crown land within City limits. This allows the City to manage these areas with the primary goal of reducing wildfire hazards.
- The Resort Municipality of Whistler has recently invested in planning a defence for the community against a potential catastrophic wildfire. Stakeholders in the region are calling for a major investment in wildfire reduction activities.
- The Squamish-Lillooet Regional District recently received a grant from the provincial FireSmart program to support fire risk reduction in the Upper Squamish Valley.
- The BC Ministry of Forests, Lands and Natural Resource Operations (2016) recently completed a report entitled, 'Adapting natural resource management to climate change in the West and South Coast Regions: Considerations for practitioners and Government staff'. This report provides comprehensive information for how to adapt natural resource management activities (including fish, water and forests) in a changing climate.

Recommended policy directions

Operational

- Participate in a regional fire risk assessment and incorporate the recommendations into long term planning and development for the District. The assessment should include the consideration of projected changes to precipitation and temperature.
- Follow the recommendations in the Community Risk Assessment and identify high hazard areas.
- Require additional interface fire mitigation measures for new developments in these areas, and apply for provincial Strategic Wildfire Prevention Initiative funding to provide support for fireproofing in existing developments.
- Facilitate residents in making their properties more fire smart. (This may include incentives for residents to fire proof their houses.)
- Update the Community Wildfire Prevention Plan.

Aspirational

- Require all new developments and individual housing units with interface area to pass specific fireproofing requirements. This may include buffer areas in greenfield developments. A Development permit area for wildfire hazard may be an appropriate approach to achieve this outcome.

- Begin managing interface areas for lower fire risk levels.
- Reassess the fire-interface hazard risk assessment (currently 'low') in the 'Community Risk Assessment' with future climate projections taken into consideration.
- Participate in an ongoing working group between the District, provincial government, local forestry companies, First Nations and other stakeholders to create and maintain a comprehensive fire risk mitigation strategy. This may lead to changes in policy and practice related to enhance emergency response, changing forestry practices, and/or enabling harvesting in a way that reduces fire risk to areas that are, and will be, developed. Because fires happen at large spatial scales and do not obey political boundaries this topic, by necessity, must extend beyond the geographic scope of the district. This work should build upon the efforts that the BC Ministry of Forests Lands and Natural Resource Operations has already invested into long term fire risk mitigation and response through the 'Sea to Sky Fire Management Planning Project Charter'.
- Centralize and concentrate urban development to decrease the urban-wildland fire interphase. *(Denser development also has important climate change mitigation co-benefits.)*
- Use the outputs of detailed fire simulation modelling (that includes future climate projections) to help determine where development should and should not occur.

Response

- Increase emergency response capabilities to deal with increased forest fires. This may include:
    - Providing additional resources and training to firefighters.
    - Giving District employees (i.e., operations staff) basic training so that they may assist in responding to a forest fire.

Impact: Extreme precipitation

Overview of the impact

Communities are typically built to 'normal' conditions, or to the range of weather and conditions that is expected in that location. Extreme events are unusual by nature, and are thus unexpected. Climate change is leading to an intensification of the hydrological cycle, and climate projections indicate that the levels of extreme events will change significantly more than averages in temperature and precipitation. (IPCC, 2013). This means that precipitation events are changing in both their magnitude and their frequency, and that Squamish can expect to experience more precipitation events that are outside of the normal range that we typically experience, and are thus prepared for.

Extreme precipitation has clear linkages with many other sections of the report (i.e., forest fires, river flows, health, and agriculture) as well as other events that could be effected by climate change (i.e., landslides and snowslides, traffic accidents, road washouts, erosion and stresses on storm-water infrastructure).

Intensity duration frequency (IDF) curves for precipitation are created by analyzing historical data, and are then commonly used by local governments to predict the expected levels of precipitation that will occur over a certain period of time. For example, an IDF curve can tell local planners and engineers what the anticipated 1:5 and 1:20 year storm event should be. These values help local governments plan and design for flooding, storm-water infrastructure, gutter size, etc. However, because of climate change, historical data can no longer be used as 'prologue' for the future.

Summary of actions that Squamish is taking

As noted in the Changing River Flows section, there is a 10% allowance for increased peak river flows as a result of anticipated increased precipitation. There are currently no other actions being undertaken by the District that are directly related to extreme precipitation or storm-water infrastructure.

Additional science, community action examples, adaptation information

- Because extreme events are by their nature rare, it is particularly hard to understand why they occur and how (or if) climate change effects them. The National Academy of Sciences (2016) used both observational and model-based techniques to assess how climate change effects extreme events. The report finds that we can attribute extreme precipitation events to climate change with high confidence, although with less confidence than we can attribute extreme temperature events. The report concludes that it is now often possible to make quantitative statements regarding how much climate change has influenced particular extreme events.
- A recent climate analysis for the City of Vancouver indicated that winter precipitation is projected to increase by 5% in 2050, but summer precipitation is projected to decrease by 19%. This means that the differences between wet and dry seasons will become larger. Further analyses show that the length of dry spells are projected to increase by 23%, while maximum 1:20 year precipitation events are projected to increase by 36% (PCIC, 2016).
- Several municipalities in the lower mainland (e.g., Surrey and Metro Vancouver [BGC Engineering, 2009]) have commissioned consulting reports to develop updated localized IDF curves that consider future climate change.
- Preparation and planning ahead of an extreme event is consistently shown to greatly reduce the costs and suffering incurred during and after a disaster. As an example, Public Safety Canada calculated that the $63.2 million invested in the Manitoba Red River Floodway in 1960 is estimated to have saved $8 billion in potential damage and recovery costs over the subsequent 45 years.

Recommended policy directions

Operational

- Building on the completed regional analysis on peak river flows, collaborate on an investigation of regional trend analysis of intense precipitation events in Squamish and determine if there already has been an increase in extreme events over the past 50 years.
- Collaborate on an investigation of future projected changes in extreme events, and determine whether IDF curves need to be updated in anticipation of future change.

- Require all new infrastructure and developments in the District to consider climate change impacts, which would be informed by climate investigations. This may be done using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) method for assessing infrastructure vulnerability, created by Engineers Canada: https://pievc.ca/

As noted at the beginning of this section of the report, there are general overarching response strategies that should be considered. As these are particularly relevant to extreme precipitation they are repeated here:

- Require all new development to identify the hazards that they are exposed to, and identify measures taken to mitigate these hazards. Part of this assessment should include the consideration of climate change, and its effect on hazard exposure and risk.
- Establish an ongoing multi-stakeholder working group to explore how the District (and surrounding region) can enhance its emergency response capabilities in light of climate change.

Aspirational

- Improve storm drain and catchment capacity to accommodate larger precipitation events.
- Determine and follow best practices surrounding hardscaping, with special attention to ditches and paved areas
- Complete the Comprehensive Emergency Management Plan (

Response

- Engage with local and topical experts to better understand how the community can be prepared to respond to extreme or unusual precipitation events.
- Prioritize drainage pump stations in emergency response plans.

Category 2: Long term priorities

Impact: Changing River Flows

Overview

Attributing changes in the number and size of flooding events to climate change is challenging because flood generation is not solely determined by precipitation and temperature. Precipitation affects flow volumes immediately in rain fed catchments and is delayed in snow/glacier-melt fed catchments. Temperature determines the form of precipitation (i.e., rain or snow) and influences snow and glacier melt, evaporation and moisture conditions. Thus, flood generating mechanisms differ across rainfall, snowmelt and mixed flow regimes. In Canada, decreases in flood magnitude and timing have been found in snowmelt-fed catchments, which is consistent with a reduction in winter snowpack leading to smaller and earlier flood events. In mixed snowmelt/rain-fed catchments, increases were found in the number of larger events and their duration, which is consistent with a reduction in the contribution from snow and increased rain. In rain-fed catchments, annual flood magnitudes increased: the increased flood risk is likely tied to increases in heavy or extreme precipitation events (Burn and Whitfield, 2015).

Although precipitation is projected to increase annually in Squamish, increases are greater in the winter. Additionally, precipitation is likely to fall more often as rain than snow, reducing the snowpack that acts as a natural reservoir. Increased evaporation with higher temperatures, extended dry periods, reduced snowpack and glacier melt has been shown to reduce flows in summer and early fall in western Canada (DeBeer et al., 2016). Squamish is potentially at risk of flooding from the Squamish River, the Mamquam River, the Cheakamus River, the Cheekeye River and the Stawamus River. These rivers vary in drainage area, elevation and flood generating mechanisms. Several of these rivers are located in close proximity to major developments, and there are extensive flow controls in place (such as dikes). Summer low-flow events have the potential to have adverse impacts on salmon health, groundwater recharge and recreational opportunities.

Summary of actions that Squamish is taking

The District of Squamish finalized the river flood risk mitigation plan in August 2016 (Kerr Wood Leidal, 2016). The plan provides detailed modeling of different degrees of flooding events (on the Squamish, Mamquam, Cheakamus and Stawamus Rivers) on the community, and outlines what the consequences of these events would be on social, environmental and economic systems.

A number of strategies are proposed to minimize the risk of flooding in the community, including structural options (i.e., building dikes) and planning options (i.e., locating development away from hazardous areas and updating flood construction levels for new development).

As previously discussed, it is challenging to model the watersheds in the lower mainland due to the extreme topography, the high levels of precipitation and the large number of small watersheds. A statistical hydrological analysis was undertaken as part of the Integrated Flood Hazard Management Plan. Provincial guidelines state that, where statistical evidence points towards increases in peak flows, a 20% increase above current events is advised. Where there is no statistical evidence of climate change induced increases in peak flows, guidelines recommend a 10% increase as a precaution. In the case of Squamish's rivers, no statistical evidence of increasing peak flow trends was found, therefore, for each of the models, a 10% allowance over current peak river flows was included to account for future climate change.

There have not been any detailed studies examining changes in low-flow events in summer or fall months in the Squamish area to date.

Additional science, community action examples, adaptation information

- As part of an adaptation initiative supported by Natural Resources Canada, climate downscaling and hydrologic modelling work was conducted for the Fraser, Columbia and Peace Rivers (Schnorbus et al. 2014). Projections for seven sub-basins of the Peace River consistently showed flows increasing from November to May in the 2050s (relative to the 1961-1990 baseline) due to more precipitation falling as rain, and flow decreasing from June to September due to lower snowpacks. Additional analysis of extreme events (performed by PCIC) projected that 1:20 year high-flow events will increase by 2 to 25%, and 1:10 year low-flow events will decrease by 22 to 67% in the 2050s (Picketts, 2015).

- A detailed modelling study on the Fraser River Basin by Shrestha et al. (2012) projected a number of significant changes in river flow. In the 2050s there is expected to be earlier peak discharges (due to earlier snow melts) increased winter and spring run-off and decreased summer runoff. The Harrison Basin, which has a similar range and proximity to the coast as the Squamish Basin, is examined as part of this study.
- BC Hydro has modeled the projected changes in streamflow in many of the river systems within which it has power generating facilities. Analysis for other southern coastal systems such as the Campbell River suggests increasing streamflow in winter months (October – April) and decreases in summer months (May – Sept). In many of these coastal systems there will be a transition toward more rain-dominated hydrology rather than the current mix of snow and rain (BC Hydro, 2013).

Recommended policy directions

- Implement the flood risk mitigation strategy. Of particular relevance to the OCP are land use planning tools, a Development Permit Area and a new Floodplain Bylaw.
- Require all new development to be built in adherence to the flood risk management strategy
- Update and adapt the flood risk mitigation strategy regularly to reflect updates in climate trends, climate projections, and development in the region.
- Update the flood risk management strategy in the future as more information and detailed analytical tools become available. This will likely involve detailed hydrological modelling, including the analysis of extreme flows (both high and low).
- Employ a precautionary approach to development by avoiding expansion of infrastructure, buildings and population in vulnerable areas.

Impact: Water supply vulnerability

Overview of the impact

Water supply (which includes both water quality and water quantity) is impacted by climate change. These stresses are often exacerbated by development and growth, which place additional demands on water resources. Several regions in BC (including the interior, Western Vancouver Island and the Sunshine Coast) have already been significantly affected by water scarcity, and have been forced to undertake extensive water management planning. Rising temperatures increase evaporation rates and diminish snowpacks and glaciers. Decreases in summer precipitation can also lead to water shortages, even if overall annual precipitation is increasing. Basin scale hydrology models, climate model and river trends are useful for understanding the effects of climate change on water supply.

Squamish obtains all of its water from groundwater wells in the Ring Creek Aquifer near Powerhouse Springs (which is located behind Valleycliffe). Squamish has completed a detailed hydrogeological study as a precursor to the Well Protection Plan. This includes a detailed water budget for the Ring Creek

Aquifer (Piteau Associates Engineering, 2014). Real time monitoring of surface water is carried out by Environment and Climate Change Canada. Data are available for the Squamish River near Brackendale at the Water Office website: http://wateroffice.ec.gc.ca/index_e.html

In the summer of 2015 a major drought swept across Western Canada. This drought brought Vancouver reservoirs down to 69% of their capacity, and forced Metro Vancouver to issue stage 3 water restrictions (which included a ban on watering lawns) for the first time since 2003.

Water conservation is a very effective 'win-win' way to proactively respond to climate change. This is because reducing water use makes a community more resilient to change, and also lowers GHG emissions (as it takes energy to get and use water).

Summary of actions that Squamish is taking

A Well Protection Plan for the Powerhouse Springs water source was completed in 2014 that defines the aquifer and outlines a strategy to protect it. The strategy briefly identifies climate change as a potential hazard to water supply, and notes that a change in the type and distribution of precipitation could affect water supply. According to the report the effects of climate change on the productivity of the wells is not expected to be significant over the next 20 years. The District is taking proactive measures to measure changes in the aquifer by installing 'sentinel' monitoring wells in the aquifer upstream of the well field to monitoring long-term changes to aquifer levels (Piteau Associates Engineering, 2014).

In 2013 Squamish introduced an Outdoor Water Use Bylaw (No. 2254) to limit usage during peak summer months (District of Squamish, 2013). The bylaw outlines 4 stages of water restrictions, from stage 1 (two-days of lawn watering per week) to stage 4 (no outdoor water use). The District also adopted a Water Master Plan in 2015, and has the goal of reducing per capita water use by 15% by 2031 (District of Squamish, 2015).

Additional science, community action examples, adaptation information

- The City of Kelowna has been dealing with water supply issues for a number of years. They have examined many demand side management strategies to reduce both outdoor and indoor water use in the City, to prepare for climate change (Cohen and Neale, 2006). Major strategies considered (and their corresponding indoor and outdoor projected water savings) are outlined in Table 1. The resultant Kelowna Integrated Water Supply Plan integrates these strategies, and other efforts to plan proactively for climate change impacts (Kelowna Joint Water Committee, 2012).

Table 1 Anticipated reductions in Kelowna from various demand side management strategies (adapted from Cohen and Neale, 2006)

Management strategy	Indoor water savings	Outdoor water savings
Public education	**10%**	**10%**
Metering: constant unit charge (i.e. charging the same amount for all water used)	**20%**	**20%**
Metering: increasing block rate (i.e., increasing the charges for excessive water users)	**32%**	**32%**
Xeriscaping standards (i.e., planting and landscaping practices)	**0%**	**50%**
High efficiency appliances and fixtures	**40%**	**0%**
COMBINED: metering, xeriscaping & efficiency	**59%**	**66%**

- Through support from Natural Resources Canada, the 'Rethinking our Water Ways' Guide was created to help communities manage their water supplies effectively in the face of climate change. The resource includes many tools and case study examples of effective planning and management (Fraser Basin Council, 2011).

Recommended policy directions

- Enact, and update as necessary, the Outdoor Water Use bylaw.
- Implement the Well Protection Plan to ensure that new developments do not compromise the District's water supply.
- Expand District Boundaries to encompass the water supply watershed so that land use decision making rests with the District.
- Continue to educate and engage citizens regarding the importance and benefits of water conservation.
- Require new developments to be in adherence to water conservation guidelines. These may include: mandatory metering, xeriscaping and efficiency standards.
- In addition to the Ring Creek Aquifer, perform a detailed water budget analysis of the Squamish water supplies (both those being utilized and those that are available for emergency use [i.e., Stawamus and Mashiter Creek]) to develop a comprehensive understanding of the capacities and vulnerabilities of Squamish's water supply. Based on this increased understanding, update development and land use requirements so that they do not compromise the District's water supply
- Perform a detailed analysis of the impacts of climate change on Squamish's water supply. This will likely require a detailed water budget analysis, and may include analysis of the snowpack and glacier recession.

Impact: Economic development

Overview of the impact

Climate change will directly and indirectly affect businesses and economic development in Squamish. This includes various forms of industry related to forestry, energy, other resource developments, shipping and transportation, and recreation and tourism. The remainder of this section focuses on recreation and tourism. In the future we need to explore how climate change affects other important aspects of Squamish's economy in more detail.

As the 'outdoor recreation capital of Canada', recreation and tourism is essential to the social, cultural and economic health of Squamish. Climate change can impact tourism and recreation in many ways. One of the main ways is by shortening, lengthening or changing the seasons in which activities can be pursued. For example, in the future ski seasons may shorten, but mountain biking seasons may lengthen. Impacts to natural environments (such as salmon habitat or forest ecosystems) can affect people's enjoyment of the outdoors. Impacts to human-built structures like roads, trails and tourism infrastructures also affect people's ability to recreate. Proactive plans for climate change should include considerations for natural systems and how plant and animal species may move and adjust to changing climatic conditions.

Recreation and tourism is another impact category that has clear links with climate change mitigation. Travel (particularly air travel) is a major source of GHG emissions. In the future people may be incentivized to engage in recreational activities that are less impactful (i.e., non-motorized activities) and to travel to destinations closer to home. Recreation and tourism can also serve as an important way to educate and inspire people about the natural environment, and can thus encourage people to be advocates for climate action and environmental responsibility.

Some of the above recommended adaptation actions could have potentially positive effects on recreation and tourism. For example, clearing heavy fuel loads out of interface areas could result in more clear green space with opportunity for new trails. Upgrading the dikes could also provide more space on an already popular recreation route.

Additional science, community action examples, adaptation information

- BC Agriculture and Food Climate Action Initiative (CAI) provides financial and technical support for the agriculture sector to adapt to climate change in BC. The initiative developed a province-wide climate risk and opportunity assessment in 2012, and since then has developed regional assessments and action programs in the Lower Mainland, Cariboo, Okanagan, Peace and Vancouver Island regions.

Recommended policy directions

- Require development proposals to demonstrate that their activity is prepared for and resilient to projected changes in climate before approval.

- Encourage the designation of vulnerable areas (such as low lying areas vulnerable to sea level rise or river flooding) for land uses that do not require extensive infrastructure (e.g., agricultural areas or walking trails).
- Encourage interconnected networks of conserved land to enable natural systems to adapt to climate change.
- Prioritize potentially vulnerable populations (such as elderly citizens, First Nations reserves, and economically depressed areas) in adaptation planning.

Impact: Food security

Overview of the impact

Climate change poses both positive and negative implications for agriculture and food security. Warmer temperatures and longer growing seasons can lead to more productivity, and sometimes even the ability for new crops and species to become viable in an area. Warming temperatures also stress important traditional food sources (e.g., salmon) and can lead to some plant and animal species being no longer suitable in the region. Furthermore, increases in variability and extreme events (e.g., droughts, storms and heat waves) way overshadow the possible agricultural benefit of increasing temperatures and longer growing seasons (Walker and Sydneysmith, 2008). As well, rising temperatures place a higher water demand for crops, especially in later summer when water supply is typically dwindling. Sea level rise can also lead to saltwater intrusion and flooding, which can have significant impacts on food production.

As only about 5% of land in BC is agriculturally viable, food security is both a priority and a concern. This concern is heightened by the fact that a large proportion of imported food to BC comes from drought-prone California.

Agriculture is another sector that provides the opportunity for ‘win-win’ responses to climate change that address both adaptation and mitigation. Producing and consuming food close to home makes us more resilient to unexpected changes and events around the world, and reduces GHG emissions related to food transport. Furthermore, there are many other environmental, economic, cultural and social benefits associated with producing and consuming food locally (*As anyone who has been to the farmer’s market can attest*).

Recommended policy directions

- Develop a comprehensive understanding of regional food production to inform the role that Squamish can play in enhancing food security in the lower mainland.
- Perform a detailed analysis of current and projected agricultural conditions in Squamish. This may include an assessment of changes in growing degree days (i.e., total number of degrees above a temperature threshold over a growing season) and frost free days (i.e. days where temperatures do not go below 0°C) in order to increase our understanding of how agricultural opportunities may change in the region.

- Incentivise and designate appropriate land for agricultural purposes in order to facilitate the maintenance and growth of food production in Squamish. Develop this policy to be complimentary with ALR areas and risk mitigation plans.
- Specifically include impacts to agricultural in related risk assessments (e.g., SLR and flood mapping).
- Partner with First Nations groups in the region to understand, and prepare for, the impacts of climate change on traditional food sources.

Impact: Health

Overview of the challenge

Climate change can affect people's immediate or long term health. In BC, short term events such as heat waves, floods and fires can put people at risk, and long term changes to water supply, air quality and the prevalence of diseases (particularly vector borne diseases) can lead to illness and disease (Ostry et al., 2008). Health interrelates with all of the other impacts identified in this document. Health Canada (2016) notes that climate change can lead impacts related to increased demands on health care services, income loss, and damage to housing and other infrastructure. Vulnerable populations are at greatest risk of negative impacts.

To date there is minimal research or discussion explicitly related to the effects of climate change on the health of the Squamish community.

Recommended policy directions

- Explicitly identify health as a motivator for proactive adaptation to climate change impacts, particularly for issues related to emergency response and recovery.
- Collaborate with health-related organizations to assess how climate change impacts health in Squamish. These include direct impacts (e.g., related to SLR or a heat wave) and indirect impacts (e.g., related to air quality and disease spreading). *(Squamish has to opportunity to become a leader in this topic.)*
- Effectively address other impacts in this document in order to enhance and encourage a health Squamish community.

References

BCG Engineering (2009). Climate Change (2050) Adjusted IDF Curves: Metro Vancouver Climate Stations. Available from: http://www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/ClimateChange2050AdjustedIDFCurves2009.pdf

BC Government (2016). Wildfire Statistics. Available from: http://www2.gov.bc.ca/gov/content/safety/wildfire-status/wildfire-statistics/wildfire-averages

BC Hydro (20213). Potential Impacts of Climate Change on BC Hydro's Water Resources. G. Jost and F. Weber. Available from: https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/about/climate_change_report_2012.pdf

BC Ministry of Forests, Lands and Natural Resource Operations (2016) Adapting natural resource management to climate change in the West and South Coast Regions: Considerations for practitioners and Government staff. Available from: https://www.for.gov.bc.ca/het/climate/knowledge/PDFs%202016/CoastEN160222.pdf

BC Ministry of Forests, Lands and Natural Resource Operations (2012). Cost of Adaptation – Sea Dikes and Alternative Strategies. Available from: http://www.env.gov.bc.ca/wsd/public_safety/flood/fhm-2012/draw_report.html#1

City of Richmond (2016) Flood Protection in Richmond. Available from: http://www.richmond.ca/safety/prepare/city/hazards/flood.htm

Cohen, S. and Neale, T. (2006) Participatory integrated assessment of water management and climate change in the Okanagan Basin, British Columbia. Vancouver: Environment Canada and University of British Columbia.

Dennis, B. and Mooney, C. (2016) Scientists nearly double sea level rise projections for 2100, because of Antarctica. Available from: https://www.washingtonpost.com/news/energy-environment/wp/2016/03/30/antarctic-loss-could-double-expected-sea-level-rise-by-2100-scientists-say/

District of Squamish (2015) District of Squamish Water Master Plan. Available from: http://squamish.ca/assets/water/2015%20Water%20Master%20Plan%20Final%20report.pdf

District of Squamish (2013) Outdoor Use Water Bylaw. Available from: http://squamish.ca/our-services/water-and-waste-water/water-system/water-system-and-reports/outdoor-water-use-bylaw/

Evans, P. (2016) Fort McMurray fire could cost insurers $9B, BMO predicts. Available from: http://www.cbc.ca/news/business/fort-mcmurray-insurance-cost-1.3568113

Filmon, G. (2004) Firestorm 2003: Provincial Review. Available from: http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs/367694/firestorm_report.pdf

Fraser Basin Council (2014) Introducing the Lower Mainland Flood Management Strategy. Available from: http://www.fraserbasin.bc.ca/_Library/Media/backgrounder_lmfls.pdf

Fraser Basin Council (2011) Rethinking Our Water Ways. Available from: http://www.rethinkingwater.ca/_Library/docs/FBC_WaterGuide_FINAL.pdf

Freedman, A. (2016) February obliterated global heat records, NASA confirms. Available from: http://mashable.com/2016/03/12/february-global-heat-record/#ykzqqf_tVEqK

Health Canada (2016) Understanding the Health Effects of Climate Change. Available from: http://www.hc-sc.gc.ca/ewh-semt/climat/impact/index-eng.php

IPCC (Intergovernmental Panel on Climate Change (2013) IPCC 5th Assessment Report, Working Group I, Chapter 2. Available from: https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter02_FINAL.pdf

Kelowna Joint Water Committee (2012) 2012 Kelowna Integrated Water Supply Plan. Available from: http://apps.kelowna.ca/CityPage/Docs/PDFs/Council/Meetings/Council%20Meetings%202012/2012-11-05/Item%20(AM)%204.2%20-%20Kelowna%20Integrated%20Water%20Supply%20Plan.pdf

Kerr Wood Leidal (2016) Integrated Flood Hazard Management Plan. Available from: https://squamish.ca/assets/IFMHP/20160825-RiverFloodRiskMitigationOptionsReport_lowres.pdf

Kerr Wood Leidal (2015). Coastal Flood Hazard Mitigation Strategy and Flood Protection Options. Available from: http://squamish.ca/assets/IFHMP/20150820_REV%20FINAL%20DRAFT_Coastal%20Flood%20Hazard%20Mitigation%20Options%20Report_FULL%20SIZE.pdf

Mantua, N.J. and Hare, S.R. (2000) Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography, 47: 103–145.

Northwest Hydraulic Consultant (2014). City of Vancouver Coastal Flood Risk Assessment. Available from: http://vancouver.ca/files/cov/CFRA-Phase-1-Final_Report.pdf

Osler, M. (2016) City of Surrey: Exploring Adaptation Responses. Available at: http://www.surrey.ca/files/CrescentBeachCoastalMeeting2_CoS.pdf

Ostry, A. et al. (2008) Climate Change and Health in British Columbia. Available from: http://web.uvic.ca/~ostry/selected_publications/rural_health/2008_Ostry_etal_Climate_Change%26_Health.pdf

Picketts, I. (2015) Backgrounder: future climate in northeastern British Columbia. Prepared for the Fraser Basin Council and BC Ministry of the Environment.

Piteau Associates Engineering (2014) Hydrogeological Assessment for Well Protection Plan. Available from: http://squamish.ca/assets/water/2841%20HYDROGEO_ASSESS_FINAL_May.pdf

PCIC (Pacific Climate Impacts Consortium) (2016). Climate Impacts Summary: Vancouver. Available from: https://pacificclimate.org/sites/default/files/publications/VancouverSummary_Final.pdf

PCIC (Pacific Climate Impacts Consortium) (2013). Climate Summary for: South Coast Region. Available from: https://www.pacificclimate.org/sites/default/files/publications/Climate_Summary-South_Coast.pdf

Rappler (2016). Antarctica's melting ice may lift seas a meter by 2100 – study. Available from: http://www.rappler.com/science-nature/environment/127696-antarctica-melting-ice-sea-level-rise-2100

Rodenhuis, D., Bennett, K., Werner, A., Murdock, T. and Bronaugh, D. (2009). Hydro-climatology and future climate impacts in British Columbia. Available from: https://pacificclimate.org/sites/default/files/publications/Rodenhuis.ClimateOverview.Mar2009.pdf

Schnorbus, M., Werner, A. and Bennett, K. (2014) Impacts of climate change in three hydrologic regimes in British Columbia, Canada. Hydrological Processes, 28, 1170–1189.

Squamish Airport (2016) Squamish British Columbia Climate Data. Available from: http://www.eldoradocountyweather.com/canada/climate2/Squamish%20Upper.html

Walker, I. and Sydneysmith, R. (2008) British Columbia: In From Impacts to Adaptation: Canada in a Changing Climate. Available from: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2007/pdf/ch8_e.pdf