DISASTER AND CLIMATE RISK AND RESILIENCE ASSESSMENT

NSEM NORTH SHORE EMERGENCY MANAGEMENT

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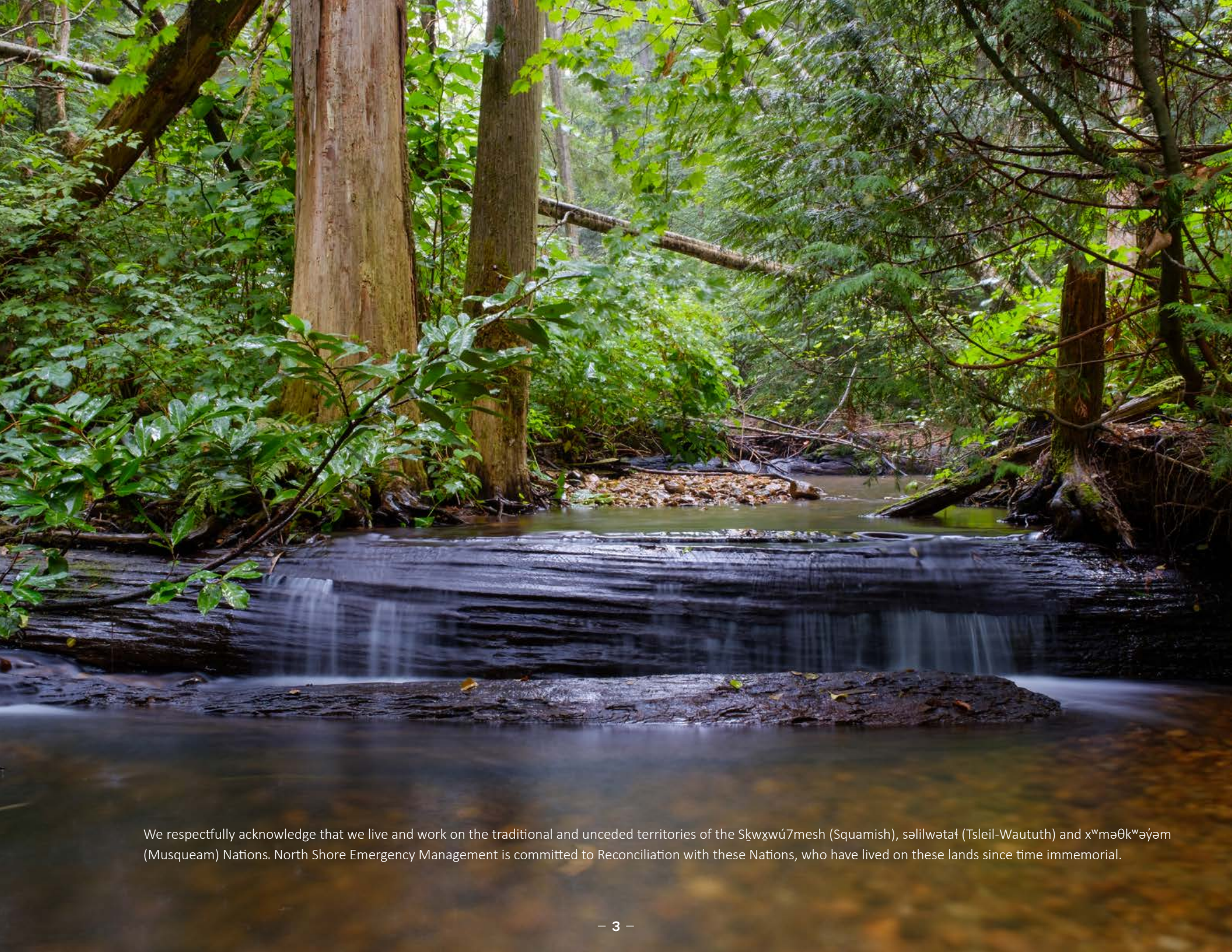


We respectfully acknowledge that we live and work on the traditional and unceded territories of the Sḵwx̱wú7mesh (Squamish), səlilwətaɬ (Tsleil-Waututh) and xʷməθkʷəy̓əm (Musqueam) Nations. North Shore Emergency Management is committed to Reconciliation with these Nations, who have lived on these lands since time immemorial.

LIST OF ACRONYMS

IN ORDER OF APPEARANCE

CNV	City of North Vancouver
DNV	District of North Vancouver
DWV	District of West Vancouver
DCRRA	Disaster and Climate Risk and Resilience Assessment
EDMA	Emergency and Disaster Management Act
NSEM	North Shore Emergency Management
EMBC	Emergency Management British Columbia
ECCC	Environment and Climate Change Canada
EMCR	Emergency Management and Climate Readiness
RCMP	Royal Canadian Mounted Police
WVPD	West Vancouver Police Department
VCHA	Vancouver Coastal Health Authority
MOTI	Ministry of Transportation and Infrastructure
MV	Metro Vancouver
MWLRS	Ministry of Water, Land, and Resources
ESS	Emergency Support Services
FCL	Flood Construction Levels
IBC	Insurance Bureau of Canada
VFPA	Vancouver Fraser Port Authority
DPA	Development Permit Area
OCP	Official Community Plans
GSC	Geological Survey of Canada
NRCan	Natural Resources Canada
EOC	Emergency Operations Centre
NBC	National Building Code
MoE	Ministry of Environment
IPREM	Integrated Partnership for Regional Emergency Management
PCIC	Pacific Climate Impacts Consortium
HVAC	Heating, Ventilation, Air Conditioning
GVIRP	Greater Vancouver Integrated Response Plan

1 INTRODUCTION

Situated on the unceded, traditional and ancestral territories of the Sḵwx̱wú7mesh (Squamish), səlilwətaɬ (Tsleil-Waututh) and xʷməθkʷəy̓ əm̓ (Musqueam) Nations, the picturesque North Shore region of Metro Vancouver includes the three municipalities of the City of North Vancouver (CNV), the District of North Vancouver (DNV) and the District of West Vancouver (DWV). Geographically located on the northern shore of Burrard Inlet, the North Shore is surrounded by forests, creeks, mountains and ocean. Due to the unique landscape, a number of hazards exist on the North Shore.

A community achieves an elevated level of resilience when its risks are understood and proactively managed, it is adequately prepared for disaster, and it demonstrates an ability to recover after such events have taken place. A key component of preparation is understanding how potential hazards may unfold. A Disaster and Climate Risk and Resilience Assessment (DCRRA; previously referred to as a Hazard, Risk and Vulnerability Analysis) is a foundational tool for emergency management and strategic disaster risk reduction planning. It is used to understand gaps in emergency planning, prioritize and target resources to reduce risk, and support community education and engagement.

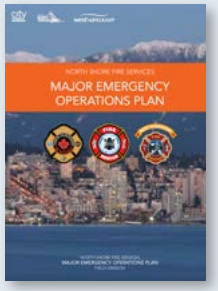
1.1 BACKGROUND

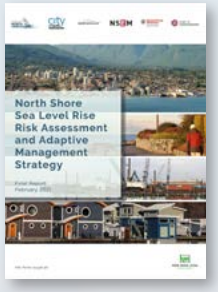
On November 8, 2023, the *Emergency and Disaster Management Act* (EDMA) came into effect, replacing the *Emergency Program Act*. The updated legislation reflects the realities of the modern world including global pandemics, security threats and climate change, and shifts from focusing on emergency response to the four phases of emergency management: mitigation, preparation, response, and recovery.

Under the new legislation, local governments will be required to prepare risk assessments for all potential hazards. This requirement, currently covered within the Local Authority Emergency Management Regulation, will be brought into the new legislation and be in alignment with the Sendai Framework for Disaster Risk Reduction, which includes a priority to better understand disaster risk. Risk assessments will be based on surveys and studies and must, among other things, identify all hazards and evaluate the degree of or risk related to each hazard, as well as potential consequences for people, animals, places and others who may be disproportionately impacted by disasters and emergencies. The role of climate change will also be a consideration in risk assessments. The new legislation calls for respectful inclusion of Indigenous knowledge and local knowledge (e.g., lived experience), as well as results of consultation with local authorities and Indigenous governing bodies.

North Shore Emergency Management (NSEM), as the coordinating agency for the three North Shore municipalities (City of North Vancouver, District of North Vancouver and District of West Vancouver), engaged Ebbwater Consulting Inc. to develop this risk assessment prior to the release of the Province's new legislation. While the inclusion of Indigenous Knowledge was outside the original scope of this assessment, relationships building with Sḵwx̱wú7mesh (Squamish) and səlilwətaɬ (Tsleil-Waututh) Nation is ongoing. NSEM will continue to collaborate with both Nations to incorporate Indigenous Knowledge into future risk assessments on the North Shore as per EDMA requirements.

2 SCOPE AND METHODOLOGY





The North Shore is susceptible to a wide range of hazards and risks including earthquakes, forest fires, landslides, flooding, sea level rise, and extreme weather events, in addition to biological hazards such as pandemics, and human-induced hazards including industrial accidents. Plans and procedures have been developed across the North Shore to reduce disaster risk and improve community resilience. Some examples of these collaborative plans for each hazard are listed below.

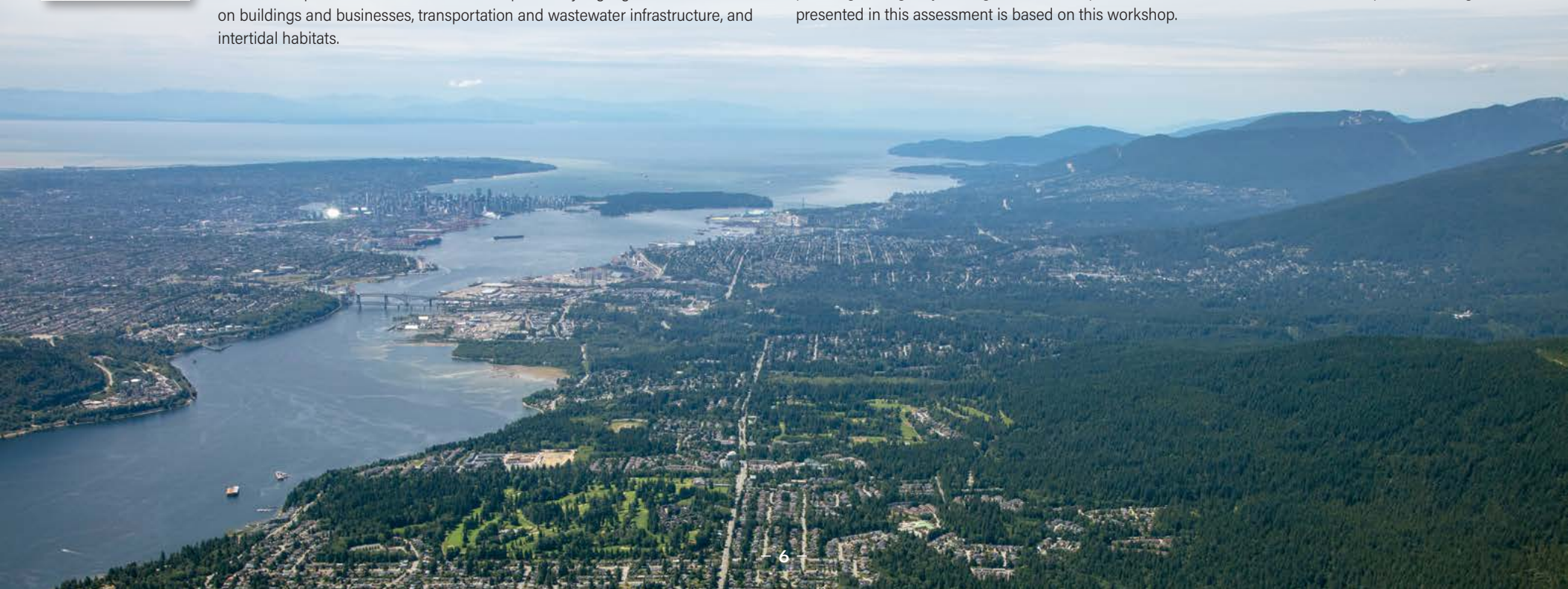
The **North Shore Fire Services Major Emergency Operations Plan** is an example of integrated resilience building on the North Shore. The three North Shore Fire Departments collaborated to form the North Shore Fire Services, and the Major Emergency Operations Plan was developed to provide maximum coordination, streamline communications, and prioritize utilization of resources in the event of a major emergency on the North Shore.

The **North Shore Sea Level Rise Risk Assessment and Adaptive Management Strategy** was developed on a foundation of technical hazard and risk analyses, focused on how sea level rise related coastal flooding and intertidal area change are increasing risk on the North Shore. The analysis was based on sea level rise projections of up to 2 m above the recent sea level, and the results highlight the need for adaptation across all sectors but specifically highlight the need to focus on buildings and businesses, transportation and wastewater infrastructure, and intertidal habitats.

The **North Shore Resilience Strategy** consists of a framework for understanding resilience and an actionable roadmap for implementation. The goal is to provide a framework for a safe and thriving North Shore, enabling individuals, communities, institutions, businesses, and systems to adapt and thrive in the face of chronic stresses and acute shocks over the long term. The North Shore Resilience Strategy will become a platform to convene partners from the public sector, private sector, non-governmental organizations and institutions, to ignite discussion, elevate understanding of risk and risk reduction, and chart a collaborative path towards increasing community resilience.

The overall approach for the risk and resilience assessment followed Emergency Management and Climate Readiness (EMCR) Hazard, Risk and Vulnerability Analysis Tool, where hazards were identified and researched, consequences were developed with the support of key partners and finally, risk scores were calculated and summarized. Hazard information and hazard scenarios were developed using a desktop approach. This included research through data requests to local governments, the Province, Federal governments, and key public and private sector hazard data providers, internet data searches (e.g., media reports of hazard events, academic literature on losses for anthropogenic hazards, industry and agency reports, and consultation with NSEM staff).

To develop appropriate consequence information that ensures that the assessment accurately reflects the North Shore, municipal staff and partners completed consequence scores for the risk assessment. A workshop was conducted with attendees representing a broad spectrum of roles related to resilience planning, emergency management and response on the North Shore and risk consequence scoring presented in this assessment is based on this workshop.



3 ANALYSIS

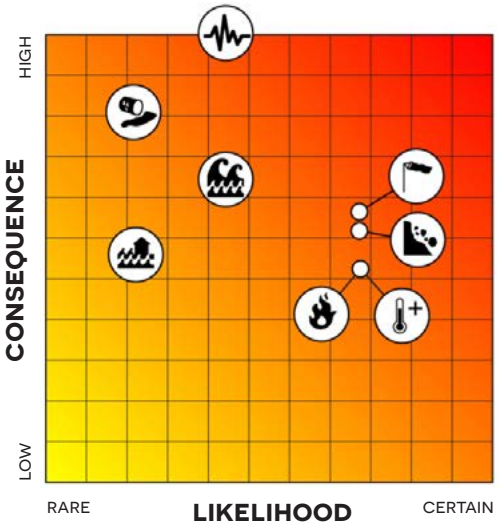
The North Shore is exposed to many natural hazards caused by nature and anthropogenic hazards caused by human activities. This assessment identifies relevant hazards and then analyzes the potential impacts of the hazards on the North Shore.

Climate change can increase the frequency and intensity of some hazards such as clearwater and coastal flooding, extreme heat, and wildfires. Strategic efforts to adapt to climate change such as relocating critical infrastructure and conducting wildfire fuel treatments in the wildland urban interface can reduce the risk of some hazards.

3.1 RISK MATRIX

A risk matrix is a standard graph, with the x-axis ranking likelihood from "rare" to "certain", and the y-axis ranging from "low" to "high". The identified hazards have been plotted in the risk matrix according to their assigned likelihood and consequence rating.

All hazards score at least 5 out of 10 on the consequence scale and rank between 2 and 7 on the likelihood scale. The hazard that has the potential for the largest impact is an earthquake, while windstorms, landslides, extreme heat and wildfire all have the highest likelihood of occurring.



This graphic illustrates risk as a function of the likelihood and consequence.

Rare events with low consequences are considered low risk, whereas more frequent events or higher consequences result in high risk.

This graphic represents the results of scoring provided by North Shore partners for unique planning scenarios and is not representative of all possible risks.

3.2 HAZARD IDENTIFICATION

There are a total of 55 identified hazards on the North Shore. Eight hazards were selected as priority hazards, due to either their likelihood of occurrence and/or their potential impact on the North Shore. The eight hazards are listed in alphabetical order below:

CLEARWATER FLOOD
Clearwater flooding occurs when runoff from snowmelt and watershed runoff overflow the natural channel. It can also occur due to heavy rainfall.

COASTAL FLOOD/ SEA LEVEL RISE
Coastal flooding occurs when ocean water levels are higher than normal as a result of storm surge. Sea level rise is the projected increase in elevation of the sea due to climate change.

EARTHQUAKE
An earthquake is defined as the shaking of the ground due to movement along a fault rupture. This can cause extensive damage and trigger other hazards.

EXTREME HEAT
A heat wave is defined as three days or more of >32 degrees.

HAZARDOUS MATERIAL SPILL
Hazardous materials are substances that are dangerous to humans, animals and/or the environment. A spill can occur on site or during transport.

LANDSLIDE/ DEBRIS FLOW
Landslides are a downward movement of soil, rock or other earth material under the influence of gravity.

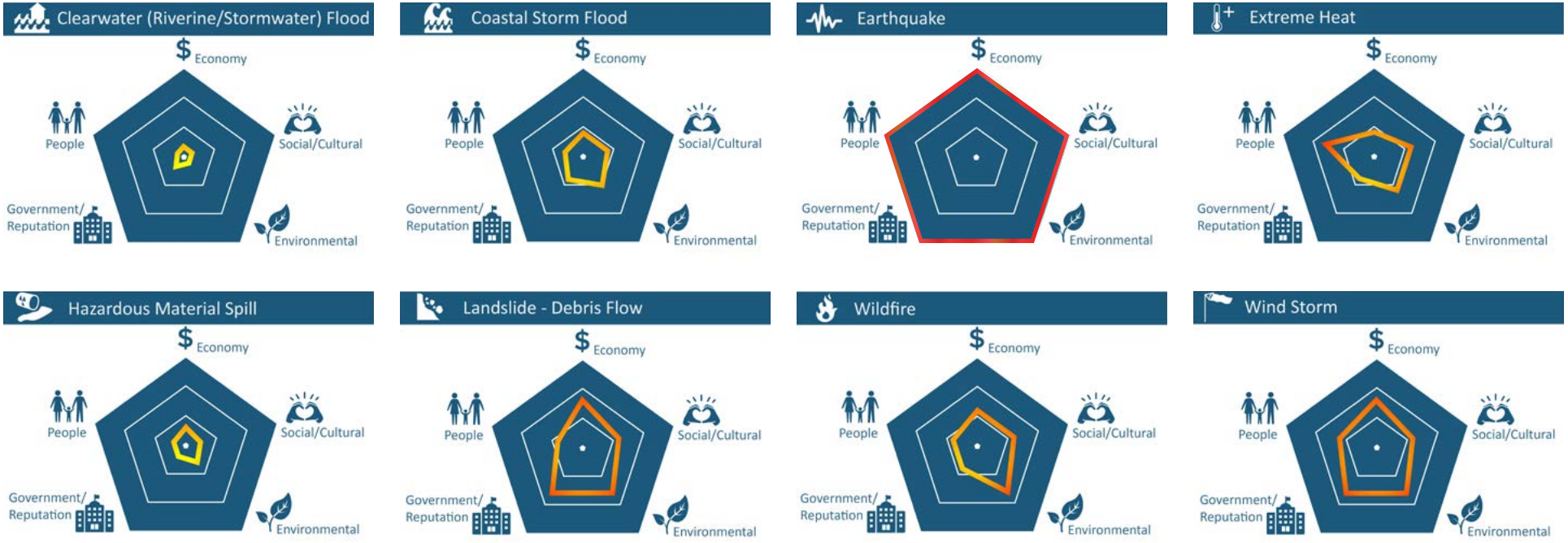
WILDFIRE
A wildfire is an unplanned fire burning on forest or range land that can potentially damage human-made structures.

WINDSTORM
Wind warnings are issued when continual winds are 70 km/hr or greater, or when wind gusts are 90 km/hr or more.

3.3 RISK CONSEQUENCE SCORING

The eight hazards have all been ranked according to their impact on people, economy, social/cultural, environment and government/reputation, and the results are displayed in alphabetical order below. The chart indicates that people, economy, social/cultural, environmental and government/reputation can all be heavily affected by these hazards. To lower the impact these hazards can have, the North Shore needs to be resilient, which means having emergency plans, educating the public and being prepared.

How to read the chart: The centre is the lowest impact possible, and the outer sides are the highest impact. This means the bigger the yellow-orange polygon, the bigger the overall consequence.



3.4 VULNERABILITY

Vulnerability generally describes the susceptibility of a given element at risk to the hazard. The United Nations Office for Disaster Risk Reduction defines vulnerability as the "conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards." Some elements of vulnerability are common across all hazards; social vulnerability (e.g., demographics, socio-economic factors) will affect consequences to all hazards. In addition to vulnerability, the assessment process also considered elements of resilience. While vulnerability looks at the factors that increase a community's susceptibility to damage from a hazard, resiliency is a measure of a community's ability to resist or recover from damage.

3.5 LIKELIHOOD AND TRENDS

The likelihood of a hazard event is a key input to understanding risk, and priority should be placed on hazards that are more likely to occur over those that are unlikely to occur. Hazard trends were defined for each priority hazard and were developed using available credible information. For natural hazards except for earthquake, these were based on known climate projections for major climate drivers (temperature and precipitation), and available literature to support how climate projections will affect the hazard. For example, extreme heat on the North Shore is anticipated to increase over time with global and regional increases in temperature extremes, and debris flows are expected to increase over time due to projected increases in rainfall volumes and intensities that create triggering mechanisms for debris flows. For anthropogenic hazards, attempts to assess trends were made based on available information. For example, for hazardous materials spills consideration of the projected volume of materials stored and transported on the North Shore along with present-day and proposed risk treatments.

3.6 HISTORICAL EVENTS

In order to provide additional information to support the likelihood and consequence of a given hazard on the North Shore, historical information was sourced from municipal staff representing a broad spectrum of roles related to resilience planning, emergency management and response.

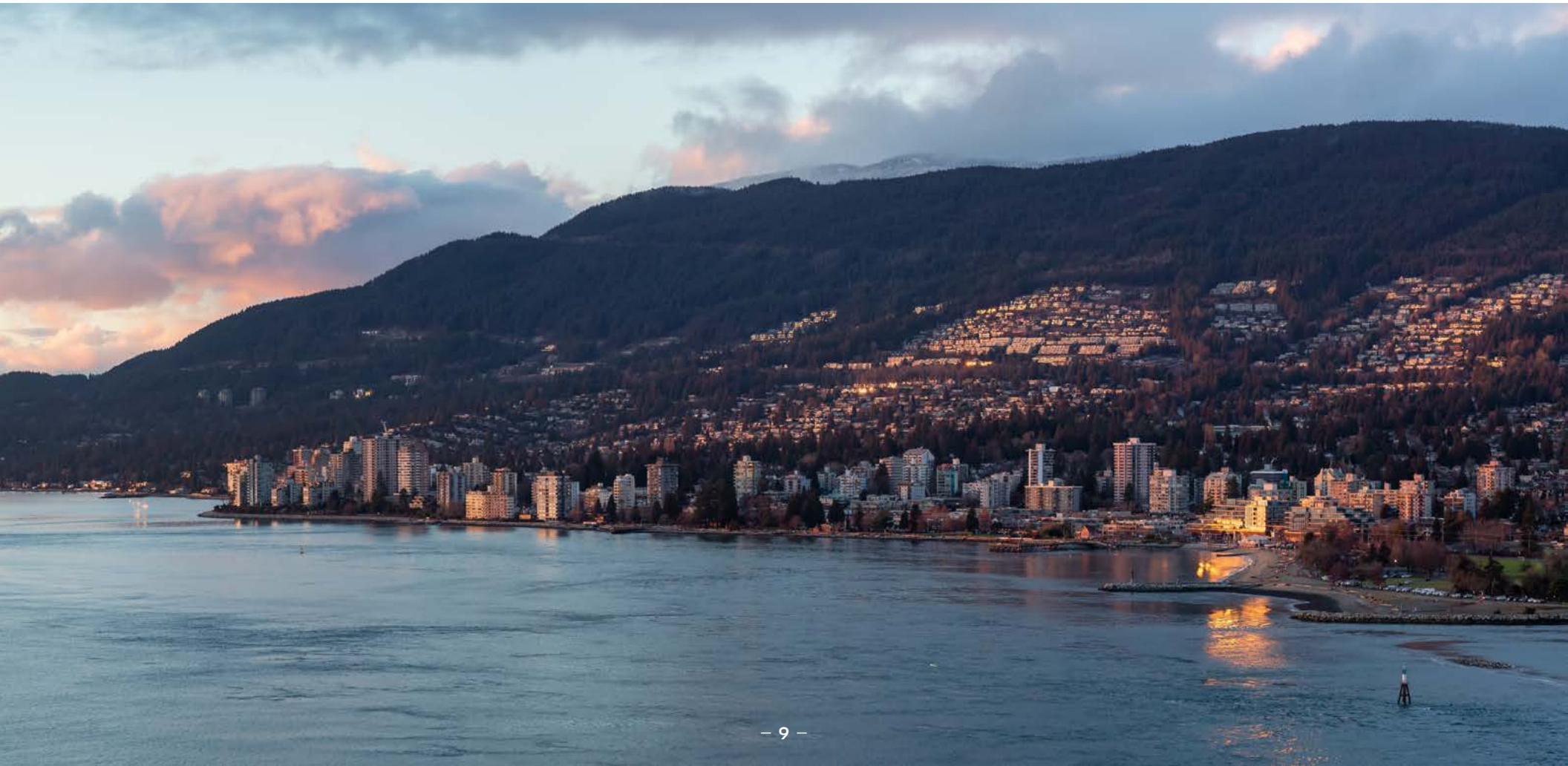
3.7 RISK TREATMENT AND MITIGATION

Risk treatment activities are tools that are actively used to reduce the hazard, exposure or vulnerability to a given hazard. Examples of risk treatment activities include FireSmart or fuel mitigation, shoreline protection strategies, or structural changes to enhance building resilience. This information supports overall understanding of risk and resilience. Mitigation measures are developed based on risk assessments and tolerable risk.

4 CONCLUSION

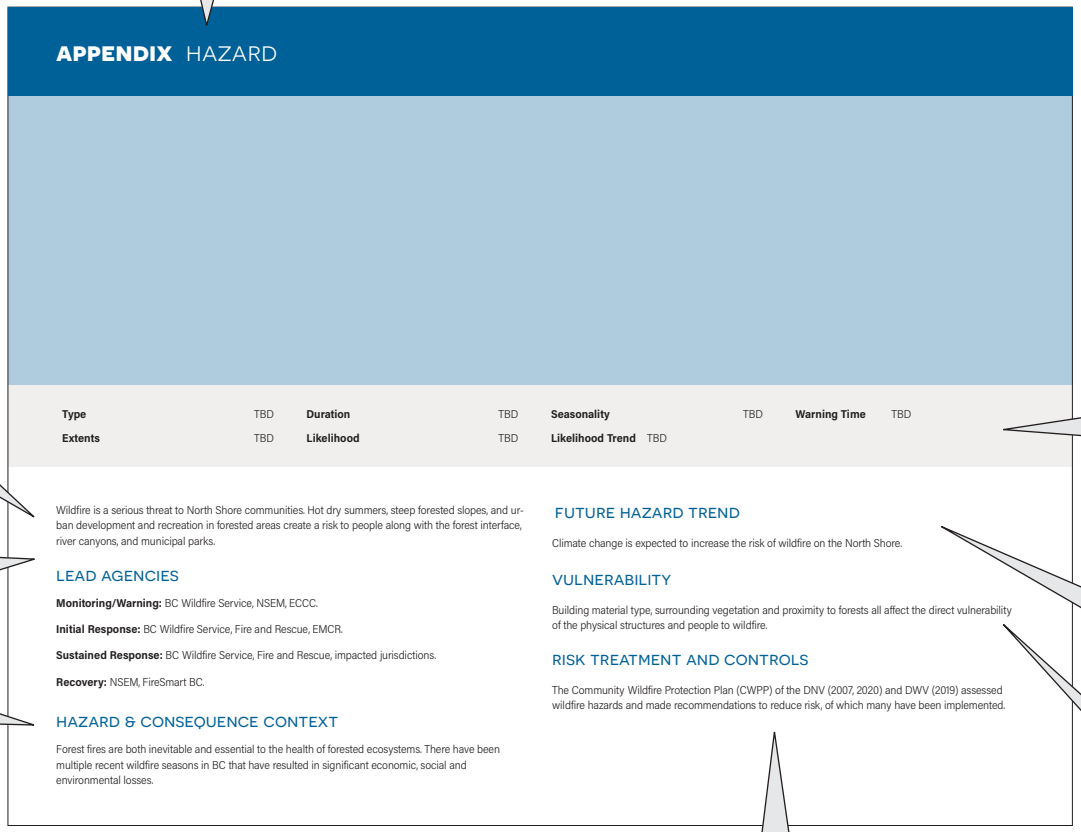
The purpose of this DCRRA is to create awareness of surrounding hazards, inform strategic and emergency plans to mitigate risk, and address vulnerabilities to create resilient communities across the North Shore.

Out of 55 hazards present on the North Shore, eight have been highlighted due to their likelihood of occurring and/or their level of impact. The eight hazards include ***clearwater floods, coastal floods, extreme heat, earthquakes, landslide debris flow, hazardous material spills, wildfires*** and ***windstorms.*** All of these hazards have the possibility of creating a significant impact on communities on the North Shore. Understanding the risks will allow each of the three municipalities to take steps to make future planning and land-use decisions with consideration to hazard mitigation.



NAVIGATIONAL GUIDE

HAZARD NAME



A brief description of the hazard.

Lead agencies responsible for monitoring, response, and recovery.

Local context and history.

HAZARD CHARACERISTICS

- **Type.** The hazard may occur as a shock (time-limited) or be chronic (on-going). For example, earthquakes are typically a shock hazard, while drought or extreme heat is typically a chronic hazard.
- **Extents.** The spatial extent of a hazard can vary from localized to widespread.
- **Duration.** The hazard duration may be very short (minutes to hours) to very long (months to years).
- **Likelihood.** The probability of the hazard occuring.
- **Seasonality.** Some hazards are seasonal (drought, clearwater flood), while others are not (earthquake).
- **Likelihood Trend.** The change in the hazard likelihood over time.
- **Warning Time.** Some hazards have little to no warning time (earthquake), while others have fairly long warning times (drought).

How will the hazard change over time?

What will be affected and why?

What have we done and what more can we do to reduce our risk?

APPENDIX A CLEARWATER FLOOD (RIVERINE & STORMWATER)

Type	Shock	**Duration**	Days - Weeks	**Seasonality**	Fall - Spring	**Warning Time**	Hours - Days
Extents	Localized	**Likelihood**	Likely - Rare	**Likelihood Trend**	Increasing		

Flooding is the overflow of water onto land that is usually dry. This hazard includes river/creek (riverine) and stormwater flooding. Coastal flooding and debris flooding are discussed in Appendix B.

Riverine flooding can originate from snowmelt and watershed runoff from intense/long-lasting rainfall (atmospheric river events). Flooding occurs when river water overflows the natural channel. *Stormwater* flooding in urban areas is caused by heavy rain falling on impervious surfaces. Flooding occurs when this water exceeds drainage infrastructure and/or watercourse capacity. Climate change projections indicate increasing precipitation intensities for the North Shore, which will increase flood risk in the future. The North Shore has significant development along rivers and creeks that are exposed to flooding.

LEAD AGENCIES

Monitoring/Warning: ECCC, BC River Forecast Centre, NSEM.

Initial Response: NSEM, EMCR, RCMP, WVPD, Fire and Rescue, VCHA, impacted jurisdiction(s)/organizations (e.g., Municipalities, First Nations), impacted utilities (e.g., BC Hydro, Telecom, Gas).

Sustained Response: NSEM, VCHA, impacted jurisdiction(s)/organizations, MV, Provincial entities (e.g., EMCR, ESS, MOTI, MWLRS), Federal entities (e.g., ECCC, Public Safety Canada), impacted utilities.

Recovery: NSEM, impacted jurisdiction(s)/organizations/utilities, VCHA, MV, Provincial and Federal entities, community and business improvement associations.

HAZARD & CONSEQUENCE CONTEXT

The North Shore has an extensive watercourse network. Rivers and creeks run from steep mountain terrain through developed areas before entering the tidal Burrard Inlet. The tidal interface means sea levels influence downstream flooding. In particular, the downstream areas of the bigger rivers (such as the Capilano River, Lower Seymour River, Lower Lynn Creek, and Lower Mackay Creek) have extensive floodplains. For instance, flooding along Lower Mackay Creek has previously occurred around Pemberton Avenue.

Analysis for this project indicates approximately 1,890 buildings are exposed to riverine flooding. Flooding can also lead to widespread disruptions, including power outages, road closures and backed-up sanitary systems. In addition, evacuations and damage to homes and contents can cause long-term emotional and psychological impacts.

NORTH SHORE HISTORICAL TIMELINE OF EVENTS

- **The mid-1950s:** Anecdotal record of "fairly extensive flooding on the North Shore." Homes were damaged along the east side of Fell Avenue.
- **1981:** Creeks across North Vancouver experienced high flows, and flooding occurred, e.g., extensive flooding at Seymour River ("Halloween Flood").
- **2006:** Flooding on Mackay Creek.
- **2014:** Combined creek and sewer flooding across the North Shore.
- **2016:** Flooding on Willow Creek in DWV, 22 properties flooded, other properties went without gas and power.
- **2018:** Atmospheric river.
- **2021:** Atmospheric river.

FUTURE HAZARD TREND

Climate change projections from the Pacific Climate Impacts Consortium show a 5% increase in annual total precipitation for the North Shore by the 2050s relative to the 1980s. Precipitation changes vary seasonally, and in the fall, precipitation may increase by up to 11%. Precipitation will also become more intense, with up to 58% more precipitation on very wet days. Clearwater flooding (both riverine and stormwater) will become both more hazardous and more likely. Seasonal snowfall is projected to decrease, which may lead to a reduction in freshet flooding in the spring. Sea level rise will increase the risk of flooding from rivers and creeks where they meet the sea.

VULNERABILITY

The physical vulnerability of structures is primarily dependent on the depth and duration of flooding along with characteristics of construction (e.g., absence/presence of a basement, wood vs. concrete construction).

RISK TREATMENT AND CONTROLS

Municipalities have invested significantly in understanding flood hazards through Integrated Stormwater Management Plans and flood hazard assessments. Assessments have been done for the Seymour and Capilano Rivers, and Mackay, Mosquito, Lynn, Maplewood, Vinson, Brothers , McDonald, Lawson, Marr, Rodgers and Hadden Creeks. This list may be expanded in the upcoming Integrated Stormwater Management Plan for DNV.

Policy and Planning: The District of North Vancouver Creek Hazard Development Permit Area restricts the development of properties adjacent to creeks and rivers with flood risk. The DNV has also implemented flood construction levels (FCLs) for Lynn Creek, Seymour River and Mackay Creek floodplains based on hydraulic modelling from 2014 to the 2080s. FCLs indicate the construction elevations for habitable space for new buildings and are defined by the expected water level from a designated flood event. The District of West Vancouver also requires houses to meet FCLs in lower floodplain areas that overlap with the coastal floodplain area.

Physical Mitigation Works: Where a significant number of properties already exist in the floodplain, physical flood mitigation measures can be used to reduce flood impacts. Measures that have been implemented/recommended for the North Shore include dikes (no standard dikes exist, but Lynn Creek has non-standard dikes/berms, and some standard dikes are planned for Mackay Creek), flood diversion channels (suggested for Maplewood), capacity improvements of undersized structures, natural flood storage (e.g., Seymour River Heritage Park), and property resilience (flood doors, etc.).

Insurance: As of spring 2019, 16 insurers now offer overland flood products to about 77% of Canadian property owners. The Insurance Bureau of Canada (IBC) estimates about 34% of Canadians are now insured for overland flood risk.

Forecasting: Environment and Climate Change Canada provides weather forecasting and warnings for extreme rainfall. This is supported by river gauge data where available. The Province of BC operates a flood warning system through the River Forecast Centre in Victoria.

Emergency Response: During an event, the emergency response may include the evacuation of people from the hazard areas.

Relevant studies on hazard, resilience measures and emergency response across the North Shore include:

- 2003: Seymour River Management Plan
- 2004: Lawson and McDonald Creeks Integrated Stormwater Management Plan
- 2007: DWV, DNV and CNV Emergency Plans
- 2008: Rodgers and Marr Creeks Integrated Stormwater Management Plan
- 2009: DNV and DWV Evacuations guidelines
- 2010: DWV Flood Assessment Study North Vancouver
- 2010: DWV Stormwater Infrastructure Asset Management Plan
- 2013: DWV Five Creeks Integrated Stormwater Management Plan adopted
- 2014: CNV and DNV flood mapping and bridge hydraulic assessments
- 2016: Mackay and Mosquito Watersheds Integrated Stormwater Management Plan
- 2016: Maplewood Village Flood Risk Management Strategy
- 2016: CNV Integrated Stormwater Management Plan
- 2016: North Shore Crisis Communications Plan
- 2017: DWV Vinson, Brothers, and Hadden Creeks Integrated Stormwater Management Plan
- 2017: DNV adopts Climate Change Adaptation Strategy, which provides estimates for hazard trends
- 2019: DWV Five Creeks stormwater flood protection project for stormwater management
- 2019: Major Emergency Operations Plan
- 2020: Lynn Creek Flood Risk Assessment and Reduction Management Plan
- 2023: DNV is currently finalising a district wide Integrated Stormwater Management Plan

APPENDIX B COASTAL FLOOD/SEA LEVEL RISE

Type	Shock	**Duration**	Days	**Seasonality**	All year	**Warning Time**	Days
Extents	Localized	**Likelihood**	Likely - Rare	**Likelihood Trend**	Increasing		

Coastal storm flood hazards arise when ocean water levels are higher than normal as a result of storm activities (storm surge), in combination with tides, waves and wind effects. Sea level rise will increase coastal flood hazards in the future, changing the current occasional flooding ('shocks') to a more chronic hazard ('stressor').

The North Shore has a long waterfront facing the ocean. Most of this coastline is relatively protected within Vancouver Harbour, but DWV in particular has a significantly exposed coastline. Coastal storms can lead to flooding, damage through waves, and debris and erosion.

LEAD AGENCIES

Monitoring/Warning: ECCC, StormSurgeBC, NSEM.

Initial Response: NSEM, ECCC, EMCR, RCMP, BC Ambulance, Fire and Rescue, Coast Guard, VCHA, impacted jurisdiction(s)/organizations (e.g., Municipalities, First Nations, Port of Vancouver), impacted utilities (e.g., BC Hydro, Telecom, Gas).

Sustained Response: NSEM, ECCC, VCHA, impacted jurisdiction(s)/organizations, MV, Provincial entities (e.g., EMCR, ESS), Federal entities (e.g., ECCC, Public Safety Canada), impacted utilities.

Recovery: NSEM, ECCC, impacted jurisdiction(s)/organizations/utilities, VCHA, MV, Provincial and Federal entities, community and business improvement associations.

HAZARD & CONSEQUENCE CONTEXT

Coastal floods generally occur when low-pressure storms coincide with high tides and affect low-lying areas along Burrard Inlet. The storm period may last for several days, but low tides provide some relief to enact emergency response measures. Coastal floods, especially in areas exposed to large fetches (distance across water) generally include powerful and damaging waves.

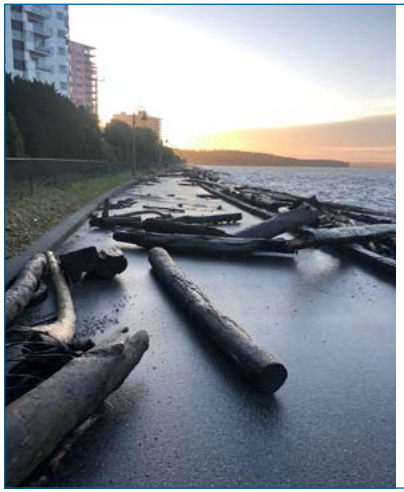
The North Shore has significant development along its coastline, including port terminals, important transport links (Marine Drive and the railway line), houses, businesses, and parks. The main exposed areas reach from Ambleside Park to Lonsdale Quay and from Queensbury Avenue to Maplewood Flats. These two areas include industrial sites with hazardous materials that could potentially be flooded.

A coastal flood could also coincide with a riverine (clearwater) flood, which could lead to increased impacts. This was assessed in the Creek Hydrology Floodplain Mapping and Bridge Hydraulic Assessment for DNV and CNV. This report highlights Mackay Creek as the most impacted area by current sea levels, with many more areas impacted by sea level rise.

The North Shore Sea Level Rise Strategy, an assessment into coastal flooding and sea-level rise that estimates impacts from a 2m sea level rise and a storm with a 0.5% annual exceedance probability would include:

- 2,774 people displaced by flooding
- Over 12,000 people impacted by power outages
- 135 hazardous sites exposed to flooding
- Over 50 historic and archaeological sites exposed to flooding
- Damage to almost 600 buildings, including utility infrastructure, schools and emergency services

For more information, refer to North Shore Sea Level Rise Adaptive Management Strategy: *http://dnv.org/SeaLevelRise*



NORTH SHORE HISTORICAL TIMELINE OF EVENTS

Some of the largest events in recent years occurred in 2012, 2018, 2022, and 2023. The coincidence of a king tide and a coastal storm caused damage to the seawall in West Vancouver from crashing waves. Ambleside's John Lawson Park was flooded, and several footpaths and parks were closed across West Vancouver in late 2022.

FUTURE HAZARD TREND

The sea level is rising due to warming seas and the melting of ice caps and glaciers caused by climate change. The provincial guidance recommends assuming a 1 m sea level rise by 2100 and a 2 m sea level rise by 2200. Continued development will also increase the coastal flood hazard. Narrowing of the shoreline and reduction of habitat reduces the natural ability of the beach to dissipate wave energy increasing erosion and inundation risk. While some scientific studies have indicated possible future increases in the frequency and intensity of coastal storms caused by climate change, there are also uncertainties.

VULNERABILITY

The physical vulnerability of structures is primarily dependent on the depth and duration of flooding along with characteristics of construction (e.g., absence/presence of a basement, wood vs. concrete construction). The salinity and power of coastal flooding generally mean damages are greater than for similar duration slow-rise riverine floods.

RISK TREATMENT AND CONTROLS

Coastal flood mapping was conducted as part of the development of the North Shore Sea Level Rise Risk Assessment & Adaptive Management Strategy. This strategy was developed in partnership with the three North Shore municipalities, the Sḵwxwú7mesh (Squamish) Nation, NSEM and the VFPA. The DWV also completed a flood mapping analysis for a 1 m increase in sea levels by 2100, and a 2 m increase in sea levels by 2200, accounting for wave effects due to increased exposure compared to the rest of the North Shore.

Policy and Planning: Non-structural measures that can be used to manage coastal flood hazards include flood construction levels (FCLs), development permit areas (DPA), and flood and zoning bylaws. The three North Shore municipalities have recognised the need to reduce the impacts of sea-level rise within their Official Community Plans and the CNV and DNV climate adaptation strategies.

FCLs are a key tool in managing flood hazards through policy. FCLs define construction elevations for habitable space for new buildings and structures and are defined by the expected water level from a designated event. In 2014, the CNV raised its coastal FCL from 3.25 m to 4.5 m to ensure enhanced protection from the risk of flooding. The areas defined by this FCL are established as DPA within the CNV OCP. In the DNV, FCLs are based on hydraulic modelling results and vary throughout the floodplain, depending on ground elevation. The DWV adopted a foreshore DPA to manage development within the coastal floodplain area. The DPA established area-specific FCLs for new houses, based on area topography, bathymetry, and site exposure. As part of implementing the recommendations in the North Shore Sea Level Rise Strategy, the DNV is currently developing a coastal DPA and conducting wave analysis. The DPA requires new homes to be built to the FCL.

Physical Mitigation Works: Policy measures such as DPAs and FCLs can be effective in reducing existing risk for new development. Whereas physical protection measures can be used to manage the hazard in already developed areas. The DWV Coastal Marine Management Plan provides an action plan to sustainably mitigate the effects of climate change, safeguarding the West Vancouver water-front and shoreline infrastructure. Fourteen projects were completed under this plan between 2006 and 2012. These included:

- Replacing sea walls with soft shoreline protection, such as boulder wave rips, reefs, berms and salt marsh, to reduce wave impacts and erosion
- Increasing sediment deposition to rebuild beaches
- Habitat improvements

Relevant studies on hazard, resilience measures and emergency response across the North Shore include the 2021 North Shore Sea Level Rise Adaptive Management Strategy.

APPENDIX C EARTHQUAKE

Type	Shock	**Duration**	Days (Aftershocks Weeks – Months)	**Seasonality**	All year	**Warning Time**	Seconds - Minutes
Extents	Widespread	**Likelihood**	Rare	**Likelihood Trend**	Static/Uncertain		

An earthquake is defined as the shaking of the ground due to seismic movement along a fault rupture. When a large magnitude earthquake occurs, energy travelling in seismic waves may cause damage to structures, trigger landslides, liquefaction or other geologic hazards. Earthquakes can also cause secondary hazards such as fires, floods, tsunamis, and hazardous material spills. Earthquakes strike suddenly and can damage buildings, property, and infrastructure. Critical services such as health care, transportation, power, water and sewer may be disrupted for weeks or even months.

LEAD AGENCIES

Monitoring/Warning: Natural Resources Canada, NSEM.

Initial Response: NSEM, EMCR, RCMP, WVPD, BC Ambulance, Fire and Rescue, Coast Guard, VCHA, impacted jurisdiction(s)/organizations (e.g., Municipalities, First Nations, Port of Vancouver), impacted utilities (e.g., BC Hydro, Telecom, Gas).

Sustained Response: NSEM, VCHA, impacted jurisdiction(s)/organizations, MV, Provincial entities (e.g., EMCR, ESS, MWLRS), Federal entities (e.g., Public Safety Canada), impacted utilities.

Recovery: NSEM, impacted jurisdiction(s)/organizations/utilities, VCHA, MV, Provincial and Federal entities, community and business improvement associations.

HAZARD & CONSEQUENCE CONTEXT

Southwestern BC is one of the most seismically active regions in Canada. A moderate earthquake capable of causing structural damage has a 10% annual probability of occurrence. The two earthquake sources with the greatest potential to impact the North Shore are a rupture within the Cascadia Subduction Zone off Vancouver Island (which could result in a magnitude 9 earthquake) and crustal earthquakes within the North American Plate close to the Earth's surface in and around the Georgia Strait.

The three primary hazards of earthquakes are ground shaking, liquefaction, and landslides. The pattern and intensity of ground shaking will vary by distance from the earthquake source. Further, different parts of the North Shore will experience variable amounts of ground shaking due to localized geological factors, most notably soft soils on river and creek deltas. Liquefaction occurs when water-saturated soils lose their stiffness and strength and behave like a liquid, spreading laterally and settling vertically.

Landslides are triggered by ground shaking in areas of steep and unstable slopes. In the DNV, more than 60% of homes and businesses were built before 1975, before the introduction of modern building code guidelines for seismic safety. In addition, nearly 45% of all buildings containing five or more businesses are located in older unreinforced masonry buildings, vulnerable to extensive damage in a large earthquake. Economic losses resulting from a major earthquake to DNV alone are expected to be over $5 billion. Similar trends are expected across all North Shore municipalities.

NORTH SHORE HISTORICAL TIMELINE OF EVENTS

- **1946:** Magnitude 7.3 earthquake on Vancouver Island
- **1975:** Magnitude 4.9 earthquake in Georgia Strait
- **1997:** Magnitude 4.3 earthquake in Georgia Strait

FUTURE HAZARD TREND

Current scientific information indicates that earthquake trends are relatively static; however, there is some uncertainty. Further, with continued stress build up, the likelihood for an earthquake to occur increases. Ongoing work on risk mitigation and increased resilience will lead to a general decrease in consequences.

VULNERABILITY

Some areas of the North Shore will be impacted more than others. Hotspots of expected building damage include older neighbourhoods built on deposits of sand and clay along the waterfront and unstable glacial and valley fill deposits (escarpments) along the Capilano, Lynn and Seymour Rivers. Areas closer to the epicentre will also experience increased consequences.

In the event of a major earthquake, all of Southwestern BC will likely be affected. This means resources will be stretched and it may be impossible for outside support to access the area for a few days due to disruption of regional infrastructure. This will have a significant impact on the recovery of the North Shore.

RISK TREATMENT AND CONTROLS

There has been significant investment in understanding and managing earthquake risk on the North Shore. This preparation is key in mitigating earthquake risk.

Policy and Planning: The Profile of Earthquake Risk for the DNV (2015) was a collaborative project with DNV, NSEM, Natural Resources Canada (NRCan) and the University of British Columbia. It included a detailed and technical assessment of earthquake risk and resiliency opportunities in the DNV. Hazard maps have since been updated by NRCan to cover the whole of the North Shore. NSEM has facilitated several earthquake exercises including Shore Shake in 2014, Operation Windshield in 2015 and Coastal Response in 2023. These multi-jurisdictional EOC and field-based exercises provide an opportunity for participants from municipal departments and response agencies to practice and develop emergency procedures in advance of a real-life event. The Great BC Shakeout Earthquake Drills also provide opportunities for public preparedness.

Insurance: Earthquake insurance for commercial and residential consumers is available, however, it is generally considered an add-on for policies. It is assumed that only around half of homeowners in Metro Vancouver have earthquake insurance.

Forecasting: Seismic sensors have been installed in eight municipal facilities that have important functions in disaster recovery (such as operations centres, reception centres, group lodging, etc.) across the North Shore. The sensors measure the amount of shaking that occurs at the facilities and send the data to a platform that compares the shaking with a performance-based assessment of each of the facilities to determine whether or not the facilities can be safely occupied after the earthquake.

Relevant studies on hazard, resilience measures and emergency response across the North Shore include:

1975: National Building Code – The earliest requirement for earthquake-resilient design
1990: Significant updates to National Building Codes for earthquake resilience
2007: DWV, DNV, CNV Emergency Plan
2009: DNV, DWV Evacuation Guidelines
2010: National Building Code – Further significant updates for earthquake-resilient design
2012: NRCan Liquefaction Seismic Study
2012: BC Building Code – Updates to match 2010 National Building Code
2015: DNV Seismic Risk Analysis
2015: Damage Assessment Protocols
2015: DNV Profile of Earthquake Risk
2016: DNV Earthquake Ready Action Plan
2016: North Shore Crisis Communications Plan
2018: IPREM Joint Municipal Regional Disaster Debris Management Operational Plan
2019: Major Emergency Operations Plan
2019: NSEM Operational Readiness Strategy
2023: Exercise Coastal Response - Provincial Earthquake Response Exercise

APPENDIX D EXTREME HEAT

Type	Chronic	**Duration**	Days - Weeks	**Seasonality**	Summer, late Spring, early Autumn	**Warning Time**	Days - Weeks
Extents	Widespread	**Likelihood**	Likely	**Likelihood Trend**	Increasing		

Heatwaves occur when air temperatures are significantly above average for an extended period. HealthLink BC defines a heatwave as "three or more days in a row when the maximum temperature is greater than 32°C." The presence of high overnight low temperatures increases consequences.

Heatwaves increase heat-related illnesses, such as heat stroke, sunburn, heat stress, dehydration, and cardiovascular-respiratory illness. This hazard primarily impacts people with existing vulnerabilities such as the elderly, very young, persons with underlying health conditions, outside workers, and those engaged in physical activity.

During hot and dry weather, smog and reduced air quality also often become a problem, caused by motor vehicle exhaust and increased wildfire activity throughout British Columbia. Reduced air quality can cause and exacerbate asthma attacks, wheezing, and impaired lung function.

Prolonged periods of high heat can also impact ecosystem functioning and lead to water shortages as well as increased energy demands from cooling and prolonged period of drought, which impact trees and plants in urban forest areas. The potential for algae blooms and beach closures increases, reducing cooling access in oceans and lakes.

LEAD AGENCIES

Monitoring/Warning: ECCC, MV, VCHA, NSEM.

Initial Response: NSEM, impacted jurisdiction(s)/organizations (e.g., Municipalities, First Nations), VCHA, RCMP, WVPD, BC Ambulance, impacted utilities (e.g., BC Hydro, Fire and Rescue).

Sustained Response: NSEM, ESS, VCHA, impacted jurisdiction(s)/organizations/utilities, BC Ambulance.

Recovery: NSEM, impacted jurisdiction(s)/organizations/utilities, community and business improvement associations.

HAZARD & CONSEQUENCE CONTEXT

Extreme heat is the leading cause of weather-related death in the United States and has been associated with increased mortality in British Columbia and other Canadian jurisdictions. In late June 2021, British Columbia experienced an unprecedented heat dome, which resulted in record temperatures across many parts of the province over several days. Temperatures reached over 40°C in many parts of the province, and overnight temperatures were also uncharacteristically high.

The Extreme Heat and Human Mortality: A Review of Heat-Related Deaths in B.C. in Summer 2021, a report to the Chief Coroner of British Columbia, identified 457 heat-related deaths in the Fraser Health and Vancouver Coastal Health Authorities during the heat dome.

NORTH SHORE HISTORICAL TIMELINE OF EVENTS

- **2009:** Heatwave with temperatures of up to 35°C in Metro Vancouver and five consecutive days of temperatures over 32°C. High levels of smog were brought on by very hot weather and forest fires across the province.
- **2014:** Extreme heat in July with public safety warnings by health authorities.
- **2017:** Eleven days with extreme heat in the Lower Mainland.
- **2018:** Four heat warnings and three special weather statements were issued by Environment Canada for the Lower Mainland, and a total of 19 days were counted with extreme heat.
- **2021:** Heatwave with temperatures reaching in the high 40s in parts of BC, resulting in numerous deaths, especially among elderly people.

FUTURE HAZARD TREND

Pacific Climate Impacts Consortium (PCIC) future climate projections show average annual temperatures in the region will likely increase by 2.9°C, and the average number of hot summer days (above 30°C) will likely increase from 2 to 13 days by the 2050s, in comparison to the 1980s baseline. The temperature on extremely hot days is also projected to increase from 33°C to 38°C. Due to the mountainous nature of the North Shore, this temperature change varies across the region.

In addition, summer precipitation will likely decrease by 18% by the 2050s. These hotter, drier summers mean heatwaves are likely to increase both in frequency and severity. Associated air quality hazards are also likely to increase.

VULNERABILITY

The elderly, very young, and persons with underlying health conditions are particularly vulnerable to extreme heat. During the 2021 heat dome in British Columbia, 616 deaths were directly attributed to heat. The majority of those who died were older adults with compromised health due to multiple chronic diseases and who lived alone. Indicators such as old age, social isolation, chronic illnesses, and poverty can increase vulnerability to extreme heat. Homeless populations are also very vulnerable.

The 2023 Homeless Count in Great Vancouver report by the Homelessness Services Association of British Columbia identified 168 individuals on the North Shore who are experiencing homelessness in a 24-hour period during a point-in-time count. This number is understood to be the minimum number of people who are experiencing homelessness on a given day. Homeless counts do not provide a full picture of the extent of homelessness; the counts provide useful information on the number and characteristics of the homeless population and how it changes over time. North Shore homeless and tenuously-housed populations are growing, with the 2023 report showing an increase of individuals experiencing homelessness on the North Shore increasing 39% from 2020.

Critical infrastructure failure due to heat extremes, such as power outages, can have cascading impacts on the community and its ability to recover.

RISK TREATMENT AND CONTROLS

NSEM has guides on its website to aid the public in preparing for and managing extreme heat. Simple measures such as spending time in air-conditioned spaces, wearing sun protection, and staying hydrated can dramatically reduce the impacts of the hazard for most people.

Policy and Planning: The North Shore Extreme Heat Initial Response Guidelines outline the actions local governments will undertake during extreme heat events. The guidelines are companions to the Municipal Emergency Plans. The guidelines are activated when ECCC issues a Heat Warning, which in the Lower Mainland is 2 or more days with a forecast maximum temperature greater than or equal to 29°C and forecast minimum temperature greater than or equal to 16°C.

The second level of notification is the Extreme Heat Emergency, which is issued when Heat Warning criteria have been met and forecasts indicate daily highs will substantively increase day-over-day for three or more consecutive days. As part of the extreme weather heat plans, local authority websites and social media platforms are used to communicate information and advice about coping with extreme heat. NSEM will coordinate public communications.

Forecasting: Environment and Climate Change Canada is the lead agency to issue Heat Warning and Extreme Heat Emergency alerts.

Further safety measures that may be implemented under these plans include establishing public cooling centres (public air-conditioned buildings), increasing access to drinking water, using portable water tanks to provide drinking water, and having municipal outdoor workers do foot patrols to monitor for people suffering from heat-related illnesses.

Relevant programs and studies on hazard, resilience measures and emergency response across the North Shore include:

- 2019: CNV, DNV and DWV Jump on a heat pump program that provides single-family homes with heat pump retrofit rebates (heat pumps provide efficient cooling).
- 2022: DNV Climate Ready Rezoning Policy that sets the expectation that all new multi-family developments requiring rezoning integrate mechanical and passive cooling measures into their design.
- 2023: DNV Urban Tree Canopy project to increase shade in urban areas.
- 2023: DNV facilities HVAC assessment to support emergency cooling and clean air shelters.
- 2023: NSEM Extreme Heat mapping project.

APPENDIX E HAZARDOUS MATERIAL SPILL

Type	Shock	**Duration**	Days	**Seasonality**	All year	**Warning Time**	None
Extents	Localized	**Likelihood**	Rare	**Likelihood Trend**	Uncertain		

Hazardous materials are any substances that are dangerous to human health and safety and the environment. These involve toxic gases, radioactive material, acids, chemicals, goods, as well as gas or oil spills. Hazardous material spills can happen on-site or during transport by aircraft, rail, ship or truck.

Hazardous materials could be also released during other hazard incidents, such as earthquakes, debris flow, or flooding.

LEAD AGENCIES

Monitoring/Warning: MV, Ministry of Transportation and Infrastructure, Port of Vancouver, CN Rail, NSEM.

Initial Response: NSEM, EMCR, RCMP, WVPD, BC Ambulance, Fire and Rescue, Coast Guard, VCHA, impacted jurisdiction(s)/organizations (e.g., Port of Vancouver, Municipalities, First Nations, Vancouver Aquarium, Western Canada Marine Response Corporation), MV, BC Ministry of Environment, FortisBC.

Sustained Response: NSEM, VCHA, impacted jurisdiction(s)/organizations, MV, Provincial entities (e.g., EMCR, MWLRS, ESS, MoE, MOTI), Federal entities (e.g., Public Safety Canada, Department of Fisheries and Oceans), other entities identified in Greater Vancouver Integrated Response Plan (GVIRP) for Marine Pollution Incidents.

Recovery: NSEM, impacted jurisdiction(s)/organizations/utilities, VCHA, MV, Provincial and Federal entities, community and business improvement associations.

HAZARD & CONSEQUENCE CONTEXT

The majority of industry on the North Shore is located along the waterfront between the Lions Gate Bridge and the Second Narrows Bridge. Many hazardous substances (e.g., dangerous chemicals and large amounts of fuel) are used, transported, and stored at these facilities. Hazards include fuel and hazardous material spillage, fires/explosions and vessel collisions.

PORT & MARINE HAZARDS

Significant hazardous materials are transported by vessels that dock at industrial facilities in the Port of Vancouver. In addition, tanker traffic passes by the North Shore. In 2018, the Port handled 147 million tonnes of cargo, up 4% from the previous year. Marine facilities on the North Shore include passenger ferries, shipbuilding, storage and handling of chemicals (sulphur, chlorine, etc.), fuel, grains and other

food products, wood pulp, steel and lumber. The North Shore houses nine terminals, four shipyards and two passenger ferry ports. There are a further 12 terminals on the opposite shore and 33 anchorage areas within the inlet.

RAIL TRANSPORT HAZARDS

Another major form of transport of hazardous materials through the North Shore is the railway line that runs along the coast. In addition to serving the port facilities, the rail line transports cargo south through Metro Vancouver and north towards Squamish. Recent rail disasters for illustration are the Lac-Mégantic rail disaster in Québec in 2013, and the Illinois CN Railway derailment in 2009 (where 600 homes had to be evacuated within an 800m radius).

ROAD TRANSPORT HAZARDS

Hazardous materials are transported by road over the Second Narrows Bridge and Lions Gate Bridge (non-commercial trucks only). The major east-west vehicular routes on the North Shore are Highway 1 and low-elevation port side routes, as well as several north-south routes.

NORTH SHORE HISTORICAL TIMELINE OF EVENTS

- **1972:** Grain fire at North Shore terminals.
- **2011:** Chlorine leak at Canexus (Chemtrade) injures four employees.
- **2015:** Pellet fire near Lonsdale Quay.
- **2015:** Oil spill English Bay (MV Marathassa).
- **2016:** Chlorine leak at Canexus injures three employees.
- **2019:** Grain vessel explosion off the shore of West Vancouver.

FUTURE HAZARD TREND

The volume and frequency of hazardous materials being moved through the North Shore are expected to increase. Legislation, technology, practices, and management strategies may mitigate the risk of hazardous materials spills. The Port of Vancouver, rail, and highway transportation industries continue to expand and develop safety technologies and management strategies. These are also likely to continue to improve in future.

VULNERABILITY

Structural vulnerability is largely related to the proximity and type of hazard spill. Construction materials and building density can also affect physical vulnerability; wood materials are more flammable and less structurally rigid than concrete for example.

RISK TREATMENT AND CONTROLS

Policy and Planning: North Vancouver City Fire Department is the lead for large/complex hazmat responses on the North Shore and works with DNV and DWV Fire and Rescue to establish appropriate operational guidelines. NSEM and the Port of Vancouver periodically run hazardous materials spills exercises with emergency responders. The North Shore Environmental Spill Response Guidelines for Land, Air & Freshwater is the primary source for environmental risk treatment and controls. This guideline sets out the roles, responsibilities, and procedures for responding to a hazardous or non-hazardous spill.

The North Shore Environmental Spill Response Guidelines do not cover marine-based spills and Local Authorities have no jurisdiction on port land. The Coast Guard is the lead federal agency responsible for any marine-based spill, often in coordination with the Western Canada Marine Response Corporation. The Port of Vancouver conducts emergency planning and maintains procedures, equipment and personnel to address Port-related emergencies on land and water.

The Greater Vancouver Integrated Response Plan (GVIRP) for Marine Pollution Incidents serves as the guide for multi-agency on-water response to spill events in English Bay and Burrard Inlet. The GVIRP establishes tactical guidance for managing operations in the marine environment in the event of a major pollution incident.

Evacuation: Risk treatments for hazardous material spills include sheltering indoors or evacuations. North Shore municipal evacuation guidelines state the most likely cause of an unplanned evacuation may be a hazardous materials incident.

Emergency Response: The type of hazardous material involved will be a key factor in determining the necessity of an evacuation and the size and speed of the response. North Vancouver City Fire Department Hazardous Materials Team incident management software allows first responders to retrieve information on the type of material to which they are responding and the associated hazards and risks.

Relevant studies on hazard, resilience measures and emergency response across the North Shore include:

- 2003: CNV Stream and Drainage System Protection Bylaw
- 2005: DWV Controlled Substance Nuisance Bylaw
- 2005: DWV Watercourse Protection Bylaw
- 2007: DWV, DNV & CNV Emergency Plan
- 2009: DNV & DWV Evacuations Guidelines
- 2012: DNV Environmental Protection and Preservation Bylaw
- 2015: North Shore Land and Fresh Water Spill Response Guide
- 2016: North Shore Crisis Communications Plan
- 2018: Greater Vancouver Integrated Response Plan (GVIRP)
- 2019: Major Emergency Operations Plan

APPENDIX F LANDSLIDE/DEBRIS FLOW

Type	Shock	**Duration**	Days - Weeks	**Seasonality**	Fall - Spring	**Warning Time**	Hours - Days
Extents	Localized	**Likelihood**	Likely	**Likelihood Trend**	Increasing		

The North Shore Mountains rise from Burrard Inlet and are characterized by numerous steep channels. This terrain, combined with the wet coastal climate, makes the North Shore vulnerable to landslides and debris flow. The magnitude and likelihood of these hazards depend on the slope, soil and geological characteristics. Heavy precipitation events trigger most landslides and debris flow in BC as they saturate the soil and make it unstable. Other weather and climate-related triggers are wind, freeze-thaw cycles and wildfires (as they tend to increase water runoff through the removal of the tree canopy, changes to the soil, and destabilizes the ground by burning out root systems and removing vegetation protection). Human activities such as logging can also increase the likelihood of landslides and debris flow.

LEAD AGENCIES

Monitoring/Warning: ECCC, River Forecast Centre, NSEM.

Initial Response: NSEM, EMCR, RCMP, WVPD, BC Ambulance, Fire and Rescue, VCHA, impacted jurisdiction(s)/organizations (e.g., Municipalities, First Nations), impacted utilities (e.g., BC Hydro, Telecom, Gas).

Sustained Response: NSEM, VCHA, impacted jurisdiction(s)/organizations, MV, Provincial entities (e.g., EMCR, ESS, MOTI), Federal entities (e.g., Public Safety Canada), impacted utilities.

Recovery: NSEM, impacted jurisdiction(s)/organizations/utilities, VCHA, MV, Provincial and Federal entities, community and business improvement associations.

HAZARD & CONSEQUENCE CONTEXT

Landslides are a downward movement of soil, rock or other earth material under the influence of gravity. Landslides are differentiated based on the type of material (e.g., rock, debris, soil) and the type of movement (e.g., slide, fall, flow, avalanche). The most common type of landslide in BC is debris flows which is defined as a saturated slurry of earth, rock, and vegetation, which most often flows in a confined channel. Major landslides and debris flow can be highly damaging, threatening lives and causing the destruction of bridges, roads and buildings. According to the BC Ministry of Energy, Mines and Petroleum Resources, landslides cause more deaths and property damage than any other natural hazard in BC, including flooding and earthquakes.

The North Shore has developed in areas of hazard. Based on a high-level analysis conducted for this project, approximately 2,430 buildings are located near steep slopes. There have been several notable events on the North Shore over the past 20 years, and significant investment has been made in understanding and managing this hazard. Landslides and debris flow can lead to secondary hazards, such as flooding from blocked culverts. Significant events can also lead to widespread consequences, including power outages, road closures, and backed-up storm/sanitary systems. In addition, evacuations and damage to homes and contents can cause long-term emotional and psychological consequences.

NORTH SHORE HISTORICAL TIMELINE OF EVENTS

One of the most damaging events in recent years was the storm and subsequent debris flow of November 2014, which resulted in damages to 126 properties and infrastructure along Kilmer and Deep Cove Creeks. The clean-up costs alone were estimated to be over $1.3 million. Other notable events include:

- **1995:** Mackay Creek debris flow.
- **1998:** Holmden Creek debris flow.
- **2003:** Mosquito Creek landslide.
- **2005:** Berkley landslide (1 fatality).
- **2010:** Mosquito Creek landslides.
- **2014:** Kilmer and Deep Cove debris flooding (damage to 126 properties and to infrastructure).
- **2018:** Grouse Mountain debris flow.
- **2021:** Capilano Trail slope failures.

FUTURE HAZARD TREND

Climate change projections by the Pacific Climate Impacts Consortium (PCIC) indicate increasing precipitation intensities over the next decades. As landslide/debris flow hazards are most often triggered by heavy precipitation events, this will likely lead to increasing debris flow hazards.

VULNERABILITY

Landslides and debris flow pose a considerable threat to people and structures. Landslides and debris flow cause fatalities. Structures are generally unable to survive the impact.

RISK TREATMENT AND CONTROLS

Policy and Planning: CNV and DNV have invested significantly in mapping and understanding geohazard, like debris flows, on the North Shore. The most recent study was completed in 2017. The DNV has adopted a long-term mitigation strategy for debris geohazard based on the recommendations in that comprehensive risk assessment.

Development Permit Areas (DPAs): DPAs limit development in hazard areas and require a qualified professional engineer or geoscientist oversight. The DNV has DPAs in place for slope and creek hazards. The creek hazard DPA includes areas with a potential risk due to debris flow, debris flood and flood. The slope hazard DPA includes properties within 20 m of the crest or base of slopes greater than 20 degrees. The DWV has a steep slope DPA for subdivisions and is further exploring steep slope hazard management and regulation on both public and private lands.

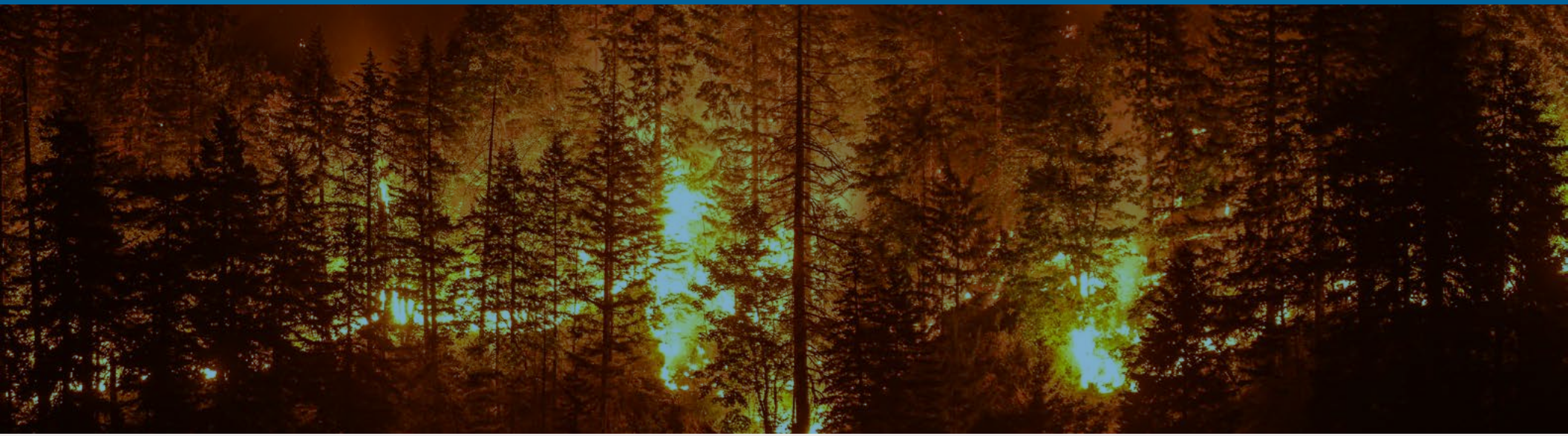
Engineering and Infrastructure Improvements: Slope stabilization measures, debris retention structures and drainage improvements have been installed in target locations across the North Shore, including a debris basin at Mackay Creek, slope stabilization on the Berkley Escarpment, measures along Mosquito Creek (including a debris net, a debris basin and slope stabilization), and debris basins at Thames, Kilmer, Gallant and Mission Creeks.

Education: The North Shore municipalities provide information and education to residents on how to reduce risk when living near steep slopes and creeks and share public messaging when extreme weather conditions are forecasted.

Relevant studies on hazard, resilience measures and emergency response across the North Shore include:

- 1995: DNV Debris Flow in Mackay Creek
- 1999: DNV Debris Flow overview study
- 2003: DNV detailed assessment and mitigation measures for 10 high-risk creeks
- 2006: DNV Berkley Escarpment risk assessment and risk reduction recommendations
- 2007 DWV, DNV, CNV Emergency Response
- 2009: DNV council adopts risk tolerance criteria policy for geohazards
- 2009: CNV conducts city-wide landslide, debris flow and subsidence study
- 2009: DNV, DWV Evacuation Guidelines
- 2010: DNV District-wide landslide risk summary
- 2012: CNV landslide, debris flow & subsidence study for high-risk properties
- 2013: CNV adopts climate change adaptation plan
- 2016: North Shore Crisis Communications Plan
- 2017: DNV Debris geohazard risk and risk control assessment
- 2017: DNV council adopts Climate Change Adaptation Strategy
- 2019: DNV 10-Year Geohazard Risk Mitigation Program
- 2019: DNV culvert inspection program
- 2019: Major Emergency Operations Plan
- 2019: DNV updated Storm Intensity, Duration, and Frequency models with climate change to year 2100, which informs the culvert replacement sizing

APPENDIX G WILDFIRE



Type	Shock	**Duration**	Days - Weeks	**Seasonality**	Spring - Summer	**Warning Time**	Hours - Days
Extents	Localized/Widespread	**Likelihood**	Likely	**Likelihood Trend**	Increasing		

Wildfire is a serious threat to North Shore communities. Hot dry summers, steep forested slopes, and urban development and recreation in forested areas create a risk to people along with the forest interface, river canyons, and municipal parks.

DNV and DWV have large amounts of forested land on their northern boundaries on the mountain slopes between Horseshoe Bay and Indian Arm, as well as along the coast (e.g., Cates Park, Lighthouse Park). Extensive areas of wildland-urban interface exist, where people and structures are susceptible to wildfire from natural and human-caused sources, and structural fires can spread to wildlands.

Historically, the North Shore's wet, coastal climate and rapid suppression regime have limited the occurrence of large fires and resulted in an accumulation of fuels. As we experience longer, hotter and drier summers, wildfire risk will increase.

LEAD AGENCIES

Monitoring/Warning: Metro Vancouver Watershed Protection, BC Wildfire Service, NSEM.

Initial Response: BC Wildfire Service, Metro Vancouver Watershed Protection, Fire and Rescue, NSEM, EMCR, BC Parks, RCMP, impacted jurisdiction(s)/organizations (e.g., Municipalities, First Nations), impacted utilities (e.g., BC Hydro, Telecom, Gas).

Sustained Response: BC Wildfire Service, Metro Vancouver Watershed Protection, NSEM, EMCR, RCMP, Fire and Rescue, impacted jurisdiction(s), impacted utilities, Provincial entities (e.g., BC Parks ESS, MWLRS, MOTI), Federal entities (e.g., ECCC, Public Safety Canada), DNV extended operations unit.

Recovery: NSEM, impacted jurisdiction(s)/organizations/utilities, community and business improvement associations, Provincial and Federal entities, FireSmart BC.

HAZARD & CONSEQUENCE CONTEXT

Forest fires are both inevitable and essential to the health of forested ecosystems. There have been multiple recent wildfire seasons in BC that have resulted in significant economic, social and environmental losses. The 2017 fire season costs for BC were estimated at over $568 million; current estimates for 2023 are well in excess of $720 million..

Wildfires, both local and distant, cause significant air pollution. While this can be unpleasant and unsafe for all, it is of particular concern to infants, the elderly and those with respiratory conditions.

A number of neighbourhoods have limited egress/access or no road access, and special wildfire response, mitigation, notification, and evacuation procedures must be considered. Critical infrastructure, such as electrical and water distribution systems, telecommunications, and transportation, may be damaged or interrupted by wildfire.

The North Shore ESS Strategy for Interface Forest Fire Evacuations estimated in 2015 that exposure to wildfire hazards for the DNV was at 1,077 households and 3,334 people, and for the DWV, at 6,574 households and 17,855 people. Due to this high level of exposure, both the DNV and DWV have made significant investments in understanding and managing this hazard.

Wildfire hazard is influenced by heat and drought with consequences of reduced air quality and potential infrastructure damage. Following a wildfire, reduced vegetation and scorched, water-repellant soil can increase the likelihood of flood, erosion, and debris flow hazards and cause water quality issues from runoff. This could last for 2 years or more after a wildfire.

NORTH SHORE HISTORICAL TIMELINE OF EVENTS

- **1924:** DNV wildfire (252 ha, largest reported wildfire on the North Shore).
- **2018:** Whyte Lake fire (DWV, suspected human-caused, burned 3 ha in Whyte Lake Park and caused the temporary closure of sections of the Baden Powell Trail and the Black Mountain Trail. No structures or infrastructure were damaged.)
- **2019:** Strip Creek wildfire near Horseshoe Bay (DWV, suspected human-caused, burned 4.5 ha, close to Horseshoe Bay in the Squamish Lillooet Regional District, causing traffic delays and lane closures on Hwy 99 and power outages affecting approximately 70 individuals. No structures or infrastructure were damaged.)
- **2020:** Sunshine Falls.
- **2022:** Eagle Ridge fire.
- **2023:** Wildfire in Lynn Canyon led to the closure of the Sea to Sky Trail.
- **2023:** Mount Seymour wildfire (DNV, suspected human-caused, no infrastructure was damaged).
- **2023:** Horseshoe Bay.
- **2023:** Grouse Mountain.
- **2023:** Whyte Lake.

FUTURE HAZARD TREND

Climate change is expected to increase the risk of wildfire on the North Shore. Projections by the Pacific Climate Impacts Consortium (PCIC) indicate that average annual air temperatures will increase (e.g., by the 2050s, daytime highs 3.70°C warmer than today). Further, with warmer air temperatures, invasive species are also spreading, degrading forest health. Human activity is the leading cause of wildfire on the North Shore, and forested areas are increasingly popular with recreational users.

VULNERABILITY

Building material type, surrounding vegetation and proximity to forests all affect the direct vulnerability of the physical structures and people to wildfire. Smoke from wildfires affects air quality. The vulnerability of people to reduced air quality is largely dependent on their overall health and well-being, and their capacity to avoid poor air quality (e.g., by staying in well-ventilated indoor spaces).

RISK TREATMENT AND CONTROLS

Policy and Planning: The Community Wildfire Protection Plan (CWPP) of the DNV (2007, 2020) and DWV (2019) assessed wildfire hazards and made recommendations to reduce risk, of which many have been implemented (fuel treatments, development planning, public education, and wildfire suppression response).

Hazard and Exposure Mapping: The CWPPs provide fire hazard and threat mapping.

Development Permit Areas (DPAs): Wildfire Hazard DPAs are established to reduce wildfire hazards, and ensure new home construction in wildland/urban interface areas minimizes the risk from wildfire hazards to property and people. Wildfire Hazard DPAs include guidelines on the location of structures, using fire-resistant building cladding and roofing materials, incorporating fire-resistant building design elements and construction practices, and selecting fire-resistant landscaping.

Insurance: Most home and business insurance policies currently cover fire damage.

Fuel Management: The DNV has completed 98 ha (100%) of high priority fuel treatments identified in the 2007 CWPP and 26.4 ha (16%) of high priority fuel treatments areas identified in the 2020 CWPP update. DWV Community Wildfire Protection Plan (2019) prioritizes mitigation efforts and prescribe future fuel treatment areas. The DWV completed the first phase of fuel treatment (6 ha) in 2022 and has initiated the second phase (4 ha) in 2023 of high priority fuel treatment areas identified in the 2019 CWPP. The DWV will continue to address high priority areas in 2024 and subsequent years. Fuel management is a key element of wildfire risk reduction, as it reduces potential fire intensity, rate of spread and, spot fire activity. In 2018, Metro Vancouver also conducted fuel treatment between the DNV and the Capilano Watershed. North Shore municipalities encourage residents residing in wildfire/urban interface areas to adopt FireSmart practices to reduce wildfire risk on their properties.

Education: Several of the high-priority recommendations from the DWV, DNV and CNV CWPPs focused on public education. NSEM also has an information page advising people on what to do in

case of a forest fire. Fire bans and danger ratings in parks also help to reduce the likelihood of fire started by human activities. CNV, DNV and DWV Fire Departments undertake seasonal public outreach programs to encourage residents to adopt FireSmart practices.

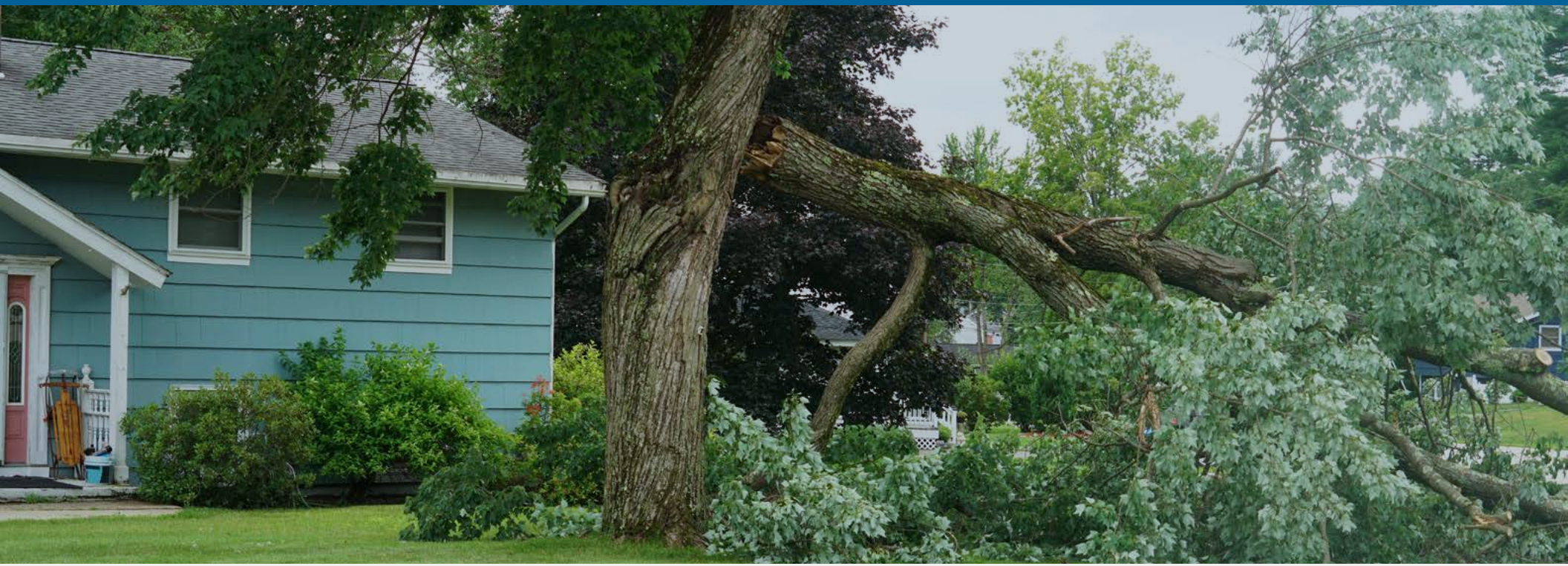
NSEM and all three municipalities provide seasonal information online and through social media.

Warning and Evacuation: The BC Wildfire Service provides information on the location and status of wildfires in BC. Warnings can also be communicated by NSEM through the Alertable System. The North Shore ESS Team is responsible for assisting evacuees, and its resources can currently manage up to 500 evacuees in a single Reception Centre, operating 24/7 for three days.

Relevant studies on hazard, resilience measures and emergency response across the North Shore include:

- 2007: DNV Community Wildfire Plans
- 2007: DWV, DNV, CNV Emergency Plans. North Shore ESS Strategy for Interface Forest Fire Evacuations
- 2008: DNV Grousewood Fuel Management Pilot Project
- 2008: Operation Dry Lightning (emergency response training)
- 2009: DNV, DWV Evacuations Guidelines
- 2013: DNV Wildfire Fuel Management
- 2015: North Shore ESS Strategy for Interface Forest Fire Evacuations
- 2016: Operation Dry Lightning 2 (emergency response testing)
- 2016: North Shore Crisis Communications Plan
- 2018-2019: DNV Community Wildfire Protection Plan update
- 2019: DWV Community Wildfire Protection Plan
- 2019: North Shore Fire Services Major Emergency Operations Plan
- 2019: Operation Dry Lightning 3
- 2019: North Shore Fire Services Major Emergency Operations Plan
- 2020: DNV Community DWV Wildfire Protection Plan (Update) DPA adopted
- 2020: DWV Wildfire DPA adopted
- 2020: CNV Community Wildfire Protection Plan
- 2022: DWV Wildfire Fuel Management
- 2022: DNV Post Fire Rehabilitation Plan (internal use only)
- 2022: DNV Forest Resilience Plan
- 2023: DNV Forest Resilience Plan (internal use only – at present)

APPENDIX G WINDSTORM



Type	Shock	**Duration**	Days	**Seasonality**	Fall - Winter	**Warning Time**	Days
Extents	Widespread	**Likelihood**	Likely	**Likelihood Trend**	Increasing		

Damaging windstorms in coastal BC are often associated with extratropical cyclones from the Pacific Ocean that occur primarily during the fall and winter months. These bring high winds and heavy rain to the North Shore.

Severe winds can down trees and branches, causing power outages, road closures, and traffic disruptions. High winds, debris and falling trees can also cause damage to buildings. Environment and Climate Change Canada issues wind warnings for the North Shore when either of the following are expected:

- Continual winds of 70 km/hr or greater
- Wind gusts of 90 km/hr or greater

LEAD AGENCIES

Monitoring/Warning: ECCC, NSEM.

Initial Response: Impacted jurisdiction(s)/organizations (e.g., Municipalities, First Nations), impacted utilities (e.g., BC Hydro), RCMP, WVPD, BC Ambulance, Search and Rescue, Fire and Rescue.

Sustained Response: ESS, impacted utilities, VCHA, impacted jurisdiction(s)/organizations.

Recovery: NSEM, impacted jurisdiction(s)/organizations/utilities, community and business improvement associations.

HAZARD & CONSEQUENCE CONTEXT

Potentially damaging high winds are relatively common on the North Shore.

One of the worst events in recent years occurred in 2006 and caused devastation across BC's South Coast. Wind speeds of up to 158 km/hr felled trees, damaged houses, cars, and power lines, cutting off power to more than 250,000 homes. This is illustrative of the types of consequences resulting from windstorms on the North Shore.

Environment and Climate Change Canada suggests that 90 km/hr wind speed is a key threshold for damage and that above this threshold, the damage increases exponentially. Above 110 km/hr, a 25% increase in wind speed leads to a 650% increase in expected damage.

NORTH SHORE HISTORICAL TIMELINE OF EVENTS

- **2006:** Windstorm with wind speeds of up to 158 km/hr caused major damage and disruption across Metro Vancouver, including the North Shore.
- **2011:** Windstorm with gusts of up to 100 km/hr knocked down trees and cut power to almost 2,000 homes in West Vancouver.
- **2018:** Windstorm caused power outages and traffic disruption on the Lions Gate Bridge. It was the most damaging storm in BC Hydro's history.
- **2022:** Windstorm caused downed power lines and traffic disruption and closure of Mount Seymour Parkway.

FUTURE HAZARD TREND

Climate change will impact the major ocean and atmospheric circulations, which will result in changes in wind speeds and the frequency of windstorms. However, wind speed and direction are challenging to project, as they are modified by multiple variables, including pressure gradient and topography that create a high variability of wind speed across the landscape (depending on topography, buildings, vegetation, etc.). Many global and regional scale climate models struggle to reproduce and project wind speed at a local level, and thus much uncertainty remains for future trends.

VULNERABILITY

Structural vulnerabilities vary according to construction type (e.g., building height, building materials, and structural connections). Roofs can be particularly vulnerable depending on design and connection to load-bearing walls.

Damages to critical infrastructure such as downed power lines can have cascading impacts on the community and its ability to recover. Other critical services may also be affected, due to power outages or damage to buildings.

RISK TREATMENT AND CONTROLS

Policy and Planning: The North Shore Downed Powerline Response Guidelines is a protocol for the whole of the North Shore for managing extreme weather events that lead to a large number of downed powerlines. This guideline helps facilitate the multi-agency response required to mitigate this impact.

Additionally, several municipal policies exist to support tree health (e.g., improving the species mix and mitigating the risk of disease) and proactively mitigate tree hazards such as tree failure and windthrow (e.g., DNV's Parks and Open Space Strategic Plan (2009), DWV's interim tree bylaw (updated 2020), DWV's draft Urban Forest Management Plan, CNV's Urban Forest Management Plan Technical Report, DNV's Invasive Plant Management Strategy (as invasive species such as ivy contribute to vulnerability for trees).

Relevant studies on hazard, resilience measures and emergency response across the North Shore include:

- 2007: DWV, DNV, CNV Emergency Response
- 2009: DNV, DWV Evacuation Guidelines
- 2015: North Shore Downed Power Line Response Guideline
- 2015: North Shore Downed Power Line Operational Guideline
- 2016: North Shore Crisis Communications Plan
- 2019: Major Emergency Operations Plan