Adapting natural resource management to climate change in the Omineca Region:

considerations for practitioners and Government staff

1. About this Series

There is strong scientific evidence that climate change will significantly affect British Columbia's ecosystems.[1] Therefore, adapting natural resource management to climate change is necessary to foster resilient[2] ecosystems that continue to provide the services, products and benefits society relies on.

This extension note is part of a series that uses current climate change research[3] to summarize, for each region, projected climate changes, impacts to ecosystems, and potential adaptation strategies. Where regional information is limited, information is drawn from provincial-scope research.

The intent of this extension note is to inform adaptation of natural resource planning and practices to climate change by providing **best available information**[4] to resource professionals, licensees, and Government staff engaged in: operational planning and practices under the *Forest and Range Practices Act* and other natural resource legislation*;* monitoring effectiveness of adaptation practices; assessing cumulative effects; and, preparing climate change action plans. Endnotes provide references and further sources of information.

2. Provincial Overview[5]

Climate: As a whole, BC has become warmer and wetter over the last century. Winter has warmed the most. Extreme rainfall and dry conditions have increased and snowpacks have decreased. Due to the effects of greenhouse gas emissions already in the atmosphere, climate scientists agree these warming trends will continue. By the end of this century, mean annual temperature in BC could be at least 1.7 to 4.6°C warmer than it was in the last few decades.[6] More winter precipitation will likely fall as rain rather than snow, resulting in lower snowpacks, earlier and more rapid snowmelt, and longer fire seasons.

Regional differences: Northern and southern interior regions of BC are expected to warm more than coastal BC and parts of central BC. Winter precipitation is expected to increase in all regions, but summer precipitation is expected to increase in northern BC and decrease in southern and coastal BC.

Impacts: ***Ecosystems*** will likely undergo both predictable and unpredictable ecological shifts. Climate envelopes (the climate associated with an ecosystem today) for subalpine and alpine areas will diminish in most locations while those for grasslands, shrub-steppe and dry forested ecosystems are expected to expand. In response, ecological communities will disassemble and reassemble—sometimes into novel combinations—as populations decline, move or adapt. Many species, including trees, will not be able to migrate quickly enough to keep pace with shifting climate. During this transition, ecosystems will be strongly influenced by disturbances and invasive plants. ***Natural disturbance*** dynamics will change: likely changes include increased fire and drought in southern and coastal BC, increased storms and windthrow on the coast, and more frequent and extensive mortality due to bark beetles, defoliators and diseases across BC. Invasive species will increase. ***Hydrological regimes*** will shift due to increased evaporation, altered vegetation communities, increased storm frequency and magnitude, decreased snow accumulation, seasonal changes to precipitation, and accelerated ice melt followed by diminished glacier extent.

Adaptation: Many climate change adaptation strategies are similar across BC. With the exception of assisted migration, most strategies are not new, but rather are elements of ecosystem management that require broader application. Strategies to reduce risks to forest ecosystems include **promoting resilience** by maintaining or increasing diversity at all scales, **guiding ecological transformation** by maintaining landscape connectivity and assisting migration, **combating detrimental change** by controlling invasive plants and excessive disturbance, and **limiting cumulative effects** of multiple land-use activities. Strategies to reduce risks to forestry-dependent communities include **increasing monitoring** of change, **strategically harvesting** at-risk forests, managing fire in wildland-urban **interfaces**, increasing capacity of **infrastructure** to withstand extreme events, and **increasing community capacity** to respond to change (e.g., by economic diversification).

3. Description of Region

The Omineca region has varied physiography, including the vast rolling interior plateau, isolated mountain groups, wide river valleys, rugged mountain ranges and large lakes. At the broadest scale, the central plateau and mountain groups experience different climatic, and thus disturbance, regimes than the rugged Rocky and Columbian mountain ranges to the east. This division represents enduring features that will shape ecosystems in any climate (see Figure 1, next page). Currently, the climate in the north differs from that of the central plateau; however, the boundary between these sub-regions may shift as it is not based on an enduring topographical feature.[7]

The region lies mostly within the Sub-Boreal Interior ecoprovince, with a portion of the Northern Boreal Mountains to the north, Central Interior ecoprovince to the south, and Southern Interior Mountains to the southeast. Current biogeoclimatic (BEC) zones[8] in the Omineca are predominantly SBS with ESSF at higher elevations, with BWBS and SWB taking over in the Northern Boreal Mountains, and ICH occurring in moist south-eastern valleys. Alpine ecosystems (BAFA) are common in the north and southeast portion of the region. For more information on BEC zones in this region, visit BEC WEB.

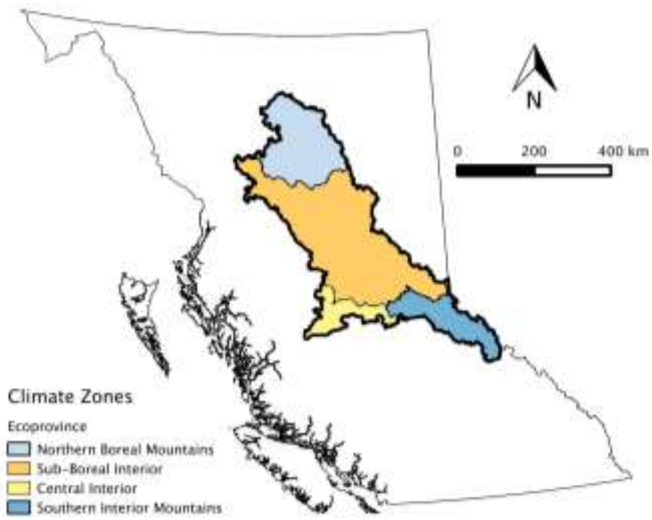

Figure 1. Climate zones, based on ecoprovinces, within the Omineca Region. Spatial data from DataBC.

4. Climate Change Projections

Our understanding of climate change is improving continually as models are improved with new research and methods. Projections in this document are derived from the Pacific Climate Impacts Consortium's regional climate summary for the Omineca Region, its Plan2Adapt tool for projecting future climate conditions, and ClimateBC.[9]

The climate in the Omineca Region has changed over the past century and is expected to continue to change. About 2°C of warming has occurred during the 20th century, with most warming in winter, including a half-degree per decade in extreme minimum temperatures. Projections suggest the region may warm, on average, an additional 1.3 to 2.7°C by the end of this century, similar to moving from Prince George to Princeton (2.6°C warmer).

Significance of Increasing Temperatures

While it is normal for temperatures to vary considerably between seasons or from day to night, even a fraction of a degree rise in temperatures, when averaged over decades, is significant for ecosystems. For example, the mountain pine beetle epidemic was triggered by a series of warm winters that accompanied an increase in average temperature of less than one degree over a century. Climate is changing an order of magnitude faster than Canada's tree species can migrate or adapt.[10]

Precipitation varies from relatively dry in the Central Interior to wet in the inland temperate rainforest in the southeast. Current winter precipitation is less than 300mm at lower elevations, but up to 1,400mm at high elevations in the Rocky Mountains. Over the entire Omineca, annual precipitation has generally increased over the past century, but has decreased in winter over the past 50 years. Winter precipitation is projected to increase (in common with the entire province), but projections for summer precipitation are highly uncertain, with potential increases or decreases. The increased temperature means that, even with increased precipitation, moisture availability will decrease in summer.

Summary of climate projections for the Omineca for the 2050s*

Climate variable	Change in Omineca[11]	Variation within region
Temperature		
Mean (°C)	+1.8 (1.3 to 2.7)	Consistent
Summer (°C)	+1.5 (1 – 2.6)	Fairly consistent
Winter (°C)	+1.9 (0.4 – 3)	Fairly consistent
Precipitation (%)		
Annual	+8 (2 to 15)	Fairly consistent
Summer	+1 (-8 to 9)	Increase in north; decrease in south
Winter	+9 (-2 to 18)	Fairly consistent
Snowfall (%)		
Winter	+2 (-7 to 10)	Increase in north; decrease in south
Spring	-54 (-71 to -10)	Fairly consistent; smaller change in north
Snowpack	Decrease	
Frost-free days	+19 (11 to 30)	Fairly consistent
Growing Degree Days	+223 (136 to 379)	Smaller change in north
Extreme weather	More heat waves, heavy precipitation and windstorms[12]	

*Based on 1961-1990 baseline. Projected changes in temperature continue to increase past 2050. Source: PCIC's Plan2Adapt tool. Projections are based on a combination of A2 and B1 emissions scenarios, where A2 represents roughly business as usual and B1 represents a more optimistic scenario with about ½ of emissions of business as usual. Median of 30 projections with range (in brackets) showing the 10th to 90th percentile of projected changes.[13]

Increased Variability and Extremes: Focusing on mean changes in temperature and precipitation can obscure important changes in climate variability and extremes. Climate projections are based on mean temperature and precipitation per season and do not reflect potentially large changes in variability. Even with constant variability, the frequency of extreme events will increase much more than a small change in mean temperature or precipitation would suggest.

Climate Variability and Extreme Events

Seemingly small increases in mean values of climate variables can substantially increase the probability of an extreme event. For example, increasing the mean by one standard deviation can lead to a more than 10-fold increase in extremes so that a 1 in 100 year event (e.g. flood) can become a 1 in 10 year event.[14]

5. Impacts to Ecosystems

Ecosystem Climate Envelopes

Climate envelopes describe the climatic conditions associated with currently mapped biogeoclimatic (BEC) subzone/variants.[15] These envelopes help scientists and resource professionals integrate climate variables and visualise the potential extent and implications of climate change, but they **do not** predict what future ecosystems will look like for several reasons. First, ecosystems do not move as a unit; second, current climate projections are based on average climate values, ignoring the extreme events that can shape ecosystem structure and composition; third, climate envelopes do not capture site-scale shifts well. **Nonetheless, projections can help estimate the relative stress that climate change poses to an ecosystem and its potential to recover to a new functional state.**

Climate envelopes are projected to shift upslope and northward across BC, resulting in expansion of some existing lower valley and plateau ecosystems as well as creation of novel ecosystem assemblages. By the 2050s, climate envelopes for current Omineca BEC zones are predicted to shift about 60 – 200 m upward in elevation and 10 - 170 km northward (Figure 2).[16] High elevation BEC zones across the Omineca will likely experience the highest stress, with BAFA and SWB projected to lose over two-thirds of their current area by the 2050s. Conversely, the ICH and BWBS climate envelopes are projected to lose little current area and to expand upslope and to the north.

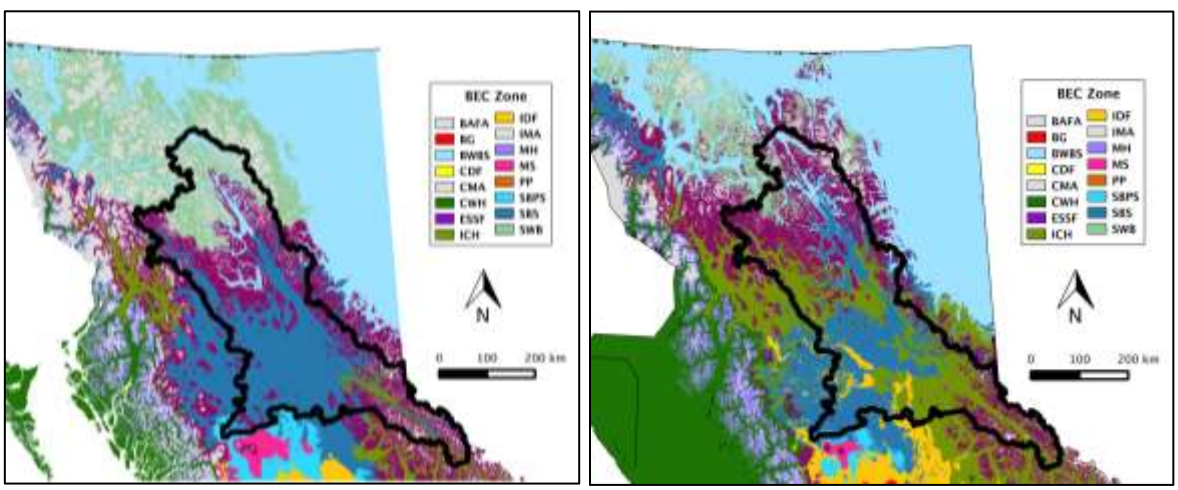

Figure 2. Current BEC zone locations (based on BEC8) and projected future (2041-2070) BEC zone locations. Future map shows consensus of multiple projections. Maps from ClimateBC.

At a smaller site-level scale, the wettest and driest ecosystems may experience soil moisture regime shifts. For example, some wetland ecosystems in the southern interior of the Omineca may become forested over time with decreased availability of summer moisture.

Natural Disturbance

The most profound changes to BC's forests in this century are expected to be the result of more frequent and severe natural disturbances.[17] Changes in **mean climatic conditions** support range expansion of forest pests that are currently limited by climate. Omineca ecosystems are already undergoing massive shifts due to loss of much of the mature lodgepole pine to the mountain pine beetle, and loss of aspen to the aspen leaf-miner and the forest tent caterpillar. The limited number of tree species in the region means that ecosystems may be more sensitive to stand-replacing pest outbreaks than more species-rich ecosystems.

Changes in **extreme weather events** lead to increased abiotic and biotic disturbances. For example, a potential increase in storm frequency and precipitation in mountainous regions will influence flooding, landslides and windthrow. Although the Omineca is less likely to experience severe heat waves than southern portions of the province, periods of relative drought projected for some sub-regions may also make trees more susceptible to insects and disease. Fewer cold snaps facilitate insect outbreaks. The Omineca has not seen significant increases in drought, fire or large slope failures to date. The increased prevalence of disturbance will vary by climatic sub-region, elevation and forest type.

Disturbance	Projected changes
Fire and drought	• Regional analyses do not project substantial increases in fire risk in the Omineca, but **uncertainty** is high due to climatic complexity associated with the jetstream; **fire patterns** (e.g., size, distribution) and **variability** among years **may change**. • **Drought** risk may **increase** on susceptible sites.
Wind and mechanical damage	• A moderate **increase** in fall **windstorms** may damage ecosystems in **mountainous regions** (~2 - 6% increase in speed of high-wind events projected). • **Earlier thawing** in spring might increase **vulnerability to windthrow** in the region's **north**. • **Damage** to trees from **ice and snow** may increase with increased storms and increased freeze-thaw events.
Hydrogeomorphic (flooding and mass wasting)	• **Changed** timing and magnitude of **peak flows** and sediment delivery may affect aquatic ecosystems and fish habitat. • **Increased** seasonal **soil saturation** due to snowmelt and rainfall may **increase mass movement.** • **Loss of forest cover** (due to fire or other disturbances) may **increase** the chance of **mass wasting**. • **Mountain permafrost degradation** and **glacier thinning** may lead to **more** frequent **landslides**. • **Loss of snow** at high elevation may **increase mass wasting** due to increased freeze-thaw of exposed rock.
Insects and disease	• The population dynamics and impacts of many pathogens and insects will change. • **Mountain pine beetle** outbreaks may **expand** into the **north** of the Omineca; **spruce beetles** may **increase** throughout the region. • **Broadleaf defoliators** may **increase** and, combined with drought, increase probability of **regime shifts** from **deciduous parkland to grassland** in some SBS and BWBS ecosystems. • **Pathogens** may increase or decrease **depend**ing on changes to **moisture regimes**. If **drying increases**, **rusts** (including western gall rust) could become **less common**. **Dothistroma needle blight** could become **more prevalent** if **precipitation increases** significantly. **Lodgepole pine** plantations may become more **vulnerable** to **foliar diseases** and **stem rusts**. **Douglas-fir** may become more **vulnerable** to **Swiss needle cast** and other foliar diseases.

Hydrology

The Omineca Region is expected to follow projected provincial trends in hydrology.[18] Increased winter temperatures, increased precipitation, and reduced snowfall in spring (i.e., more rain) will likely shift the hydrological regime from snowmelt-driven to hybrid rain/snow-driven, leading to more frequent rain-on-snow events and smaller spring snowpacks. These changes will affect the timing and magnitude of peak flows, sediment loads, and channel stability, and will reduce summer low flows and increase the low-flow period, with consequent increased risk to fish. As well, earlier thaws and changed peaks pose hazards to infrastructure, including winter roads and bridges.

Loss of vegetation through natural or anthropogenic disturbance, combined with climate change, will create cumulative effects. These cumulative effects may decrease the capacity of a landscape to buffer rainfall, increasing streamflow flashiness and potentially increasing sediment delivery and channel instability.

Cumulative Effects

Cumulative effects are defined as changes to an ecosystem over time caused by a combination of **human activities**, **natural variability** and **climate change**. Assessment of cumulative effects integrates the effects of past, present and foreseeable future events and processes. FLNR has a framework in place to guide assessment of the cumulative effects of resource management and climate change. Such a framework provides the context for informed decisions about which management actions are most likely to succeed.

Feature	Projected changes
Hydrological regime	• **Glaciers** and **permafrost** will **thaw**. • **Shift** from **snowmelt-driven** to **hybrid rain/snow-driven** with more rain-on-snow events. • **Altered timing** of peak and low flows; projections include **earlier** onset of **spring peak** and **lower** late **summer/fall flows**. • Flows may vary more across the region depending on changes to late winter rains.
Peak flows	• Spring **peak discharge** will **change**. • Shift to hybrid regime could lead to **more frequent and flashy** high **flows** during fall. • These flows could disturb the streambed and spawning habitat.
Spring recession	• **Loss** of **snow-driven regimes** could **reduce** the **spring recession** (a relatively stable period of moderate flow and temperature), affecting the sorting and deposition of sediment and profoundly impacting aquatic habitat.
Low flows	• **Smaller spring snowpack** and **earlier** spring **freshet** will **lower** summer **low flows**, **lengthen** the low-flow **period**, and **decrease groundwater storage**. • Loss of **glacial meltwater** over the long term will lower summer low flows. • **Temperature** may **increase** in some streams and lakes, posing **risk** to **temperature sensitive fish**.
Variability	• **Variability** in **peak flow** will likely increase, leading to **unstable stream morphology**.

Flood Return Intervals

Small changes in mean climate can cause large changes in flooding frequency and magnitude. For example, current 50-year floods may become 5-year events and future 50-year floods might be what we now consider a 1,000-year flood.[19]

Biodiversity

Climate shapes species distributions and ecological communities.[20] Populations faced with a changed environment can die out, move, be displaced by encroaching species, or adapt to the new conditions. Many species that are adapted to projected future climates currently live several hundred kilometres distant from that area; only the fastest dispersers will be able to keep up with the pace of change. Most invasive plants and generalist weedy species are well-adapted for broad movement. For some ecosystems, potentially irreversible regime shifts may follow intense disturbances, particularly if invasive plants colonise and block historical successional paths.

Mountain ranges are particularly important for conservation of biodiversity. Relative to gentle terrain, mountains accommodate more climatic zones within close proximity; thus, as the climate changes, populations in lower elevation zones may find suitable climatic conditions by migrating upwards.

Feature	Projected changes
Cumulative effects	• Past human activities have degraded and **fragmented habitat**, making **dispersal** in response to climate-related disturbance more **difficult** for **specialist species**. • Human response to increased disturbance (e.g. extensive **salvage harvesting** following insect and fire disturbances) can **exacerbate impacts** of climate change. • **Old forest** will **decline** due to disturbance and harvesting, threatening associated species. • Without management intervention, climate change will exacerbate the effects of **over-grazing** and **trampling,** which impact **grasslands** and **forest understory** by changing the plant community, destroying the biological crust and opening soil to invasive plants.
Communities	• **Communities** will **reassemble**, often into new combinations, as some established species decline or disappear, new species colonise and interactions change. • Some ecosystems may undergo **regime shifts** (e.g. from **forest to shrubs or grassland**). • Analyses in the adjacent Nadina Forest District suggest **communities of plant and lichen** species in current versus projected climate envelopes **may differ by 80%** at the site level in the **wettest and driest sites**, and by up to 65% at the variant.
Interactions	• **Ecological processes and relationships** among species (e.g. predation, pollination, mutualism) may **uncouple** as the timing of events changes and becomes more variable (e.g., if migration depends on day length, but prey abundance depends on temperature).
Invasive species	• **Invasive species** (plants and other organisms) are expected to **increase** as temperatures and disturbance increase. • Current **indigenous species** may be **less competitive** in the new climate and disturbance conditions, facilitating invasive plant population expansion. • Some ecosystems in the Omineca already have many invasive plant species. **Grasslands and dry forest types** are particularly impacted and will be increasingly vulnerable to **invasive plants** following disturbance, facilitating regime shifts. • Some invasive plants (e.g. **hawkweeds**) are **well-adapted** to establish and spread even without disturbance; **impacts** will be **high** within **expanded IDF and ICH subzones**.

Feature	Projected changes
Wildlife[21]	• Wildlife and trophic interactions (e.g. **predation**) will be particularly **affected** by **changes** in **snowpack and freeze-thaw** regimes. Impacts vary by species. • **Biting insects** and **disease** may **increase** in response to milder weather; for example, winter ticks may increase impacts to moose. • In the northern part of the region, **later green-up** timing could **increase mortality** of young **sheep and goats**.

Trees

Tree distributions will shift gradually in response to climate change due to physiological tolerances, natural disturbance, and competition.[22] There are few tree species in the Omineca, hence low ecological redundancy. Although most tree species will be unable to migrate quickly enough to follow the climate envelopes to which they are adapted, the future climate may be able to support a greater diversity of tree species.

Feature	Projected changes
Physiological tolerance	• Most species in the Omineca seem physiologically resilient. • **Interior spruce** on **dry sites within the SBS** plateau will be **vulnerable** to **drought stress** and related **diseases** due to hotter, drier and longer summers.
Productivity	• **Tree growth** will likely **increase** in some areas due to elevated CO_2 coupled with warmer temperatures. • **Growth potential**, however, may **not be realised** because of **limited moisture** or nutrients, because populations are not adapted to changed seasonality and increased **extreme events**, or because **maladaptation** increases susceptibility to insects and disease.
Natural disturbance	• **Insects and pathogen** outbreaks could **increase mortality** even in healthy rapidly-growing trees. • **Stressed trees** are **more susceptible** to certain insects and pathogens. • Several **deciduous and coniferous** species, including the aspen, lodgepole pine and interior spruce that have defined the interior sub-regions of the Omineca, will likely **suffer diebacks** due to a variety of factors including physiological stress, pathogens and insects.
Competition	• In mixed plantations on **dry sites**, **lodgepole pine** will **out-compete interior spruce**. • **Competition** after natural disturbance may favour **shrubs**.

Uncertainty about climate projections leads to uncertainty about which trees may be best-suited to changing conditions. For example, in some ecosystems, a warmer and wetter scenario may create potential opportunities for species such as western hemlock and western redcedar, given sufficient moisture, while a much warmer scenario could be suitable for Douglas-fir and ponderosa pine. Suitable trees at any given point in time may become maladapted by rotation age, creating additional uncertainty and complexity for management.

Ecological Surprises

Current vulnerability modelling does not include ecological surprises or complex climate-ecological relationships. Simplistic predictions in complex systems cannot replace long-term interdisciplinary research and monitoring.

Range

Rangeland ecosystems will shift in response to climate change due to increased drought, loss of forest due to disturbance and competition. Earlier spring plant growth and a longer growing season may translate into a longer grazing season for livestock. Grasslands are projected to increase in some areas, but community composition will likely change and, without dedicated management intervention, may be overcome by invasive plant species in some areas.[23]

6. Adaptation—modifying management to account for climate change

It is necessary to modify management activities – planning, practices, and monitoring - to address the impacts of climate change on ecosystems. Adaptation strategies will vary depending on the ecosystem, the direction of climatic variables, the degree of certainty in projected changes, the urgency (risk and vulnerability), and the likelihood of adaptation practices achieving desired outcomes. Hence, management activities under a changing climate will need to be flexible and proactive.

This section includes potential adaptation strategies that may help address the current and anticipated impacts to ecosystems described above. These strategies reflect regionally-important **best available information** drawn from research and the input of regional specialists**.** Resource professionals, licensees and Government staff should consider these adaptation strategies as **voluntary non-legal guidance** to inform operational planning and practices.

Almost all of these adaptation strategies are existing elements of good resource management that require broader application. ***As such, they are generally supported by current policy guidance***. Because we manage for multiple resource values, some adaptation strategies may conflict with each other (e.g., maintaining downed wood to sustain biodiversity may conflict with minimizing forest fuels to reduce catastrophic wildfire risks). This will require decisions that balance the benefits and risks to resource values, depending on the priorities for the area in question.

Although some of these adaptation strategies may be perceived as incurring incremental costs or land base constraints, the long-term economic benefits of adaptation to the productivity of timber, forage and other resource values are predicted to outweigh short-term costs. For example, studies in Central BC indicate the economic benefits of diversifying managed forests to reduce forest health risks and increase resilience.[24] And, designing and maintaining roads and bridges to a higher standard will likely minimize repair and compensation costs after flood events. Some adaptation strategies are also potential climate change mitigation or carbon storage strategies (e.g., retention networks, retaining downed wood).

Potential adaptation strategies in this section reference supporting policy guidance, information or tools.

Planning Considerations

Climate change poses at least three broad challenges for practitioners:

- Existing management ***objectives*** may be inappropriate because they were developed without considering climate change and do not generally include objectives for mitigation or adaptation.
- Existing management ***strategies*** are unlikely to achieve existing objectives under a changing climate.
- ***Uncertainty*** about the effectiveness of management strategies will increase.

In addition, slow regulatory or administrative change may pose a challenge to implementing timely management responses to changing conditions. At a broader scale, market forces may pose barriers.

Uncertainty[25]

The impacts of climate change are already present on the landscape and there is substantial scientific evidence that this trend will continue. However, projecting the impacts of climate change into the future is fraught with uncertainty due to the limitations of current ecological and climate models, and to alternative plausible emissions scenarios. Ecological processes that reflect multiple interactions (e.g. shifting species distributions) are more uncertain than processes that correlate strongly with a single variable (e.g. fire hazard and temperature).

Managing in the face of uncertainty requires:

- Recognition of uncertainty (known and unknown sources)
- Information gathering (via monitoring) to reduce uncertainty where possible
- Recognition that uncertainty increases with time span considered
- Acceptance that uncertainty will remain and a decision to either use precaution to maintain a desired value or to put a value at risk

Adaptation requires planning that includes new objectives, new strategies and increased consideration of uncertainty. For example, objectives to maintain biodiversity or timber could be modified to maintain ecological resilience, and strategies to mitigate flood impacts should take into account the higher probability of flooding associated with climate change plus climate oscillations. Practitioners may need more flexibility to handle regime shifts (e.g., if forested ecosystems lose viability). Best management practices for ecosystem management[26] provide an excellent resource.

Practice Considerations

Hydrology

To protect aquatic ecosystems and infrastructure near watercourses, adaptation consists of limiting increases in stream temperature, limiting sediment input (from surface erosion, streambank collapse and landslides), and limiting increases in peak flows.

Potential adaptation strategies	Supporting policy guidance, information and tools
Projected ecosystem change: Increased stream temperature	
• Retain adequate riparian cover next to streams and wetlands ○ Particularly important in temperature sensitive watersheds and along headwater areas	• Watershed monitoring[27]
• Maintain ditches and culverts, and deactivate roads to restore drainage as soon as possible ○ Important on sites that feed streams, particularly in temperature sensitive watersheds	
• Avoid harvesting sites with high water tables ○ Important for sites with high water table that feed streams, particularly in temperature sensitive watersheds	
Projected ecosystem change: Increased risk of landslides and surface erosion (that affect streams or infrastructure)	
• Avoid locating roads and cutblocks on or above unstable terrain • Design and maintain roads and drainage structures to accommodate increased peak flow and sediment transport in areas likely to become wetter: e.g., improve surface on high hazard roads; seed erodible cut slopes; build adequate ditches; replace selected culverts with bridges; limit road density in erosion-prone areas • Manage grazing to maintain functional riparian ecosystems; maintain sufficient riparian vegetation to control grazing	• Interior watershed assessment • Stream crossing quality index • Water quality and livestock grazing BMPs
Projected ecosystem change: Increased peak flows	
• Consider limiting Equivalent Clearcut Area (ECA) to 30 to 50% of THLB in sensitive watersheds • Anticipate increased natural disturbance and manage harvest to stay within ECA limits • Evaluate the hydrological implications of salvaging disturbed stands • Leave live standing vegetation and downed wood barriers next to all riparian areas on rangeland	• Interior watershed assessment • Post disturbance watershed effects[28]

Biodiversity

Adaptation strategies for biodiversity are designed to achieve two objectives: (1) reduce the existing anthropogenic pressures that compound the negative effects of climate change on biodiversity (e.g., reduce harvesting and road access where sensitive values exist), and (2) promote resilient ecosystems at stand and landscape scales.

Potential adaptation strategies	Supporting policy guidance, information and tools
Projected ecosystem change: Loss of old forest habitat and connectivity due to increased tree mortality	

• Create a network of retention areas and corridors at multiple scales
  ○ Include riparian areas, wildlife tree patches, and old growth management areas in retention areas
  ○ Include corridors crossing elevation gradients
  ○ Include habitat for specialized species and communities at risk
	• Biodiversity Guidebook

• Limit salvage in retention network (e.g., partial cut or avoid harvest) ○ Particularly important where stands buffer microclimate or provide large structure	• Chief Forester's retention guidance • Post-disturbance biodiversity management[29]
Projected ecosystem change: Loss of suitable microclimate and soil conditions to re-establish historic ecosystem following harvest (e.g., potential regime shift from forest to grassland)	
• Avoid harvesting sensitive sites ○ Particularly important for bogs, low nutrient "remnant boreal" sites, and dry sites • Partially-cut stands (i.e., retain partial overstory for shelter) on dry sites[30]	• Drought risk assessment tool • Enhancing biodiversity through partial cutting
• Retain large downed wood ○ Particularly important on drier sites	• Wildlife trees and coarse woody debris policies • FREP CWD backgrounder • CWD management • Morice operational trials
• Promote rapid site recovery to appropriate species (e.g., reforest dry sites; retain deciduous trees on moist sites) ○ Particularly important on drier sites	• See Trees section
Projected ecosystem change: Loss of diversity and vigour in young and maturing forests due to maladaptation to changing climate	
• Plant climatically-suited species and genotypes (i.e., facilitate migration)	• See Trees section
• Retain naturally-occurring and regenerating species (including deciduous trees and shrubs) and plant a diverse species mix	• Climate change stocking standards[31]
• Use stand tending to influence successional pathways	• See Trees section
Projected ecosystem change: Increased spread of invasive plants following disturbance	
• Minimize roads ○ Especially important in currently unroaded areas and susceptible ecosystems • Minimize road use (e.g., use gates, deactivate) • Establish competitive vegetation in ditches, on side slopes and other disturbed soil as soon as possible • Follow best management practices for invasive plants	• Invasive plant management practices • Invasive species council of BC • Invasive species working group; IAPP Map, E-Flora BC

• Manage grazing to maintain late seral vegetation communities
  ○ Adjust stocking rates and distribution
  ○ Particularly important near susceptible ecosystems (e.g.
	• Managing rangeland invasive plants

Potential adaptation strategies	Supporting policy guidance, information and tools
grass and parkland ecosystems and riparian areas)	
• Minimize site disturbance, especially multiple disturbances ○ Particularly important on susceptible sites (e.g., dry, grassy sites) • Minimize summer logging on susceptible sites (e.g., dry grassy sites) • Account for invasive plants in site plans	

Trees

Adaptation strategies for trees are designed to increase establishment success, survival and growth potential, and to reduce the negative impacts of natural disturbance resulting from climate change. Adaptation strategies have the potential to shift overall climate-induced impacts on timber supply from negative to positive or neutral. Adaptation could lead to large decreases in projected beetle-related tree mortality over the long term, modest decreases in disease, and modest increases in tree growth. Large decreases in beetle mortality are, however, partly attributable to a changing forest age class structure (i.e., a loss of old trees).

Adaptation may have limited success in reducing fire disturbance because effective fire control in average-weather years can be negated by large disturbances in very dry years. Landscape fire management planning is aimed at reducing these losses as much as possible.

Potential adaptation strategies	Supporting policy guidance, information and tools
Projected ecosystem change: Increased tree growth potential on sites with sufficient moisture	
• Plant climatically-suited species and genetic stock ○ Especially on dry sites or sites facing drought ○ Consider competition in mixed plantations • Establish operational trials to test survival and growth	• Tree species selection tool • FFT assisted species migration guidance • Chief Forester standards for seed use[32] • Climate-based seed transfer interim policy measures • Seed zone maps
• Fertilize sites that have limited nutrients but sufficient moisture	
• Partially cut stands on dry sites to retain shelter and moisture and increase fire resiliency	• Drought risk assessment tool
Projected ecosystem change: Increased disease-related mortality (mainly younger stands)	
• Plant climatically suited species and genetic stock ○ Especially on sites facing drought and areas shifting to wetter climate ○ Develop and plant rust-resistant lodgepole pine	• Forest health and species selection • Regional & TSA forest health strategies
• Increase stand-scale species diversity (e.g., retain and plant a variety of species, including broadleaf); expand breadth of "acceptable" species in young stands • Increase landscape-scale species diversity by planning retention and reforestation at the landscape level; vary species mix and	• Long-term forest health and stocking standards • Guidance on species composition • Guidance on broadleaves • Guidance for FSP stocking standards

Potential adaptation strategies	Supporting policy guidance, information and tools
density	• Mixed species options for FFT • Successional responses[33] • Stocking standards reference guide • Climate change stocking standards
• Minimize mechanical damage from wind, snow and ice	• BCTS windthrow manual
Projected ecosystem change: Increased beetle-related mortality (mainly mature/old stands)	
• Plant climatically-suited species and stock	• See above
• Increase stand-scale diversity	• See above
• Shorten rotations ○ Especially for relatively productive sites most susceptible to disturbance	
• Monitor and control beetle population sources (e.g., sanitation harvesting) ○ Focus on stands where benefit of control outweighs cost to non-timber values	• Regional & TSA forest health strategies • Provincial bark beetle management strategy • Mountain pine beetle action plan • Chief Forester's retention guidance
Projected ecosystem change: Increased fire hazard (all stand ages)	
• Increase fire resilience at the landscape level by creating strategic fuel breaks, prescribing fire, and allowing ecologically appropriate fires in suitable locations to burn under appropriate conditions	• Landscape fire management planning
• Increase fire resilience at the stand level by managing surface fuels, species composition, density, crown base height, crown bulk density and age-class of forest stands • Reduce post-harvest fuels as necessary (e.g., broadcast burning, pile and burn, mulching, chipping) ○ Choose appropriate season and weather for fuel reduction	• Landscape fire management planning • Fire management stocking standards[34] • Fire and fuel management guidelines[35]
• Reduce human-caused fires ○ Control human access during fire season (e.g., via gates)	• Wildfire Management Branch prevention strategy
• Leave fire-breaks (e.g., deciduous strips)	• See above
• Manage fire hazard around communities • Reduce risk in interface areas	• Strategic wildfire prevention initiative[36] • Fuel hazard assessment and abatement • FireSmart program • FireSmart communities

Assisted Migration

When trees are harvested 60-120 years after they are planted, the climate could be 3-5 degrees warmer, exposing the trees to maladaptation and health risks. Moving populations of trees today (assisting migration) from their current location is one potential solution; growth and health are better when seeds are transferred to match the climate in which they evolved. However, trees have complex symbiotic relationships with many ectomycorrhizal fungal species in the soil and in some cases these bonds are tightly linked to local nutrient and climate conditions.[37] Improved understanding of these interactions in specific ecosystems may increase success. Government is leading a large, long-term Assisted Migration Adaptation Trial to understand tree species' climate tolerances. Findings are helping inform Climate Based Seed Transfer policy and tree species selection guidance.

Range

Adaptation strategies for rangelands[38] aim to capitalize on opportunities (e.g., longer grazing season) and to reduce negative impacts (e.g., increased invasive plants and drought stress) of climate change. Steps towards adaptation include revising expectation for rangelands to include climate dynamics, expecting higher variability in productivity, maintaining late seral native perennial grass species on existing grassland sites, adjusting stocking rates to reflect changing productivity, and considering the need for new water developments to sustain livestock drinking water.

Monitoring

To develop adaptation strategies that are more likely to achieve management objectives, practitioners and decision-makers need to understand changes in climatic variables and key ecological responses at relevant spatial scales. In the Omineca, it is suggested that trend monitoring include:

- Climate: temperature, precipitation, snowpack, glacial melt and extreme weather.
- Hydrology: stream flow by watershed, channel stability, forest cover, water temperature, erosion, suspended sediment.
- Disturbance: mass earth movements, insect and disease prevalence by BEC site series, site factors and seral stage, soil moisture and wildfire.[39]
- Tree growth and health.
- Biodiversity: regime shifts, seral stage, habitat supply, species health, invasive plant species and distribution shifts.
- Range: plant communities and condition.

Some of these data are already collected, but are not analysed regularly. A climate network that covers sub-regional variability with sufficient weather monitoring stations will be important.

Moving Forward

Successful regional adaptation will require innovation and collaboration. Shared leaning among practitioners, decision-makers and communities has the best potential for developing suitable adaptation strategies for the Omineca Region that foster resilient ecosystems and sustain natural resources into the future. This document could be a helpful catalyst in collaborative efforts.

Contact for More Information

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[1] Message from the Chief Forester, Future Forest Ecosystems Initiative Strategic Plan (2008)

[2] Ecological resilience is the capacity of an ecosystem to absorb, recover from and adapt to disturbance or stress caused by agents of change (such as climate change and natural resource management); this 'desired outcome' was established under the Future Forest Ecosystems Initiative (FFEI) in 2008, and is further explained in FFEI's scientific foundation (2009)

[3] Current research outcomes are primarily derived from projects under the Future Forest Ecosystems Scientific Council (FFESC) research program, but also including related regionally-relevant research

[4] Adaptation strategies in this extension note are derived from research and do **not** constitute new Government policy, standards, or regulations; they represent best available information and voluntary non-legal guidance for the consideration of resource professionals and decision-makers; where helpful, adaptation strategies include hyperlinks to supporting policy guidance, information or tools

[5] See the report *A Climate Change Vulnerability Assessment for British Columbia's Managed Forests* (Morgan and Daust et al, 2013) for more insight into how climate change is expected to impact BC's forest ecosystems

[6] Projections are based on a combination of A2 and B1 emissions scenarios, where A2 represents roughly business as usual and B1 represents a more optimistic scenario with about ½ of emissions of business as usual (Trevor Murdock, Pacific Climate Impacts Consortium)

[7] For information on how topography and weather systems influence regional climatic variations, see Moore et al, Chapter 3 (Weather and Climate), Compendium of Forest Hydrology and Geomorphology in British Columbia

[8] BEC zone acronyms: SBS = Sub-Boreal Spruce; ESSF = Engelmann Spruce Subalpine Fir; BWBS = Boreal White and Black Spruce; SWB = Spruce Willow Birch; ICH = Interior Cedar Hemlock; BAFA = Boreal Altai Fescue Alpine

[9] These sites provide definitions and calculation details for indices

[10] Johnston et al (for Canadian Council of Forest Ministers), Vulnerability of Canada's Tree Species to Climate Change and Management Options for Adaptation (2009)

[11] Median and range (10^{th} – 90^{th} percentile) from a standard set of Global Climate Model projections (Plan2Adapt)

[12] Based on trends for all of BC

[13] Details of the ensemble PCIC30 are given in Murdock and Spittlehouse, Selecting and using climate change scenarios for British Columbia (2011)

[14] Wigley, The effect of changing climate on the frequency of absolute extreme events (2009) (Climatic Change 97:67-76; DOI 10.1007/s10584-009-9654-7) gives a theoretical analysis; Kharin et al, Changes in temperature and precipitation extremes in the CMIP5 ensemble (2013) (Climatic Change 119:345-357; DOI10.1007/s10584-013-0705-8) gives an analysis based on global climate models

[15] BECWeb includes information on BEC and climate change

[16] Wang et al, Projecting future distributions of ecosystem climate niches: uncertainties and management implications (2012)

[17]For more information, see Chapter 2c (Natural Disturbance) of *A Climate Change Vulnerability Assessment for British Columbia's Managed Forests*

[18] For more information, see summary in Chapter 2b (Hydrology and Aquatic Ecosystems) of *A Climate Change Vulnerability Assessment for British Columbia's Managed* Forests, and Chapter 19 (Climate Change Effects on Watershed Processes in BC) in the Compendium of Forest Hydrology and Geomorphology

[19] See Footnote 14

[20] For more information, see Chapter 2e (Forested Ecosystems) of *A Climate Change Vulnerability Assessment for British Columbia's Managed Forests*

[21] For more information, see Chapter 2f (Wildlife) of *A Climate Change Vulnerability Assessment for British Columbia's Managed Forests*

[22] For more information, see Hamann and Wang, Potential effects of climate change on ecosystem and tree species distribution in British Columbia (2006)

[23] For more information, see Climate Change and BC Range

[24] Dymond et al, Diversifying managed forests to increase resilience (2014)

[25] Fletcher, *Towards a framework to support working with uncertainty in natural resource management (a discussion paper)* (2015)

[26] For example, see Leech et al, Ecosystem management: A practitioners' guide (2009)

[27] Wilford and Lalonde, A framework for effective watershed monitoring (2004)

[28] Redding et al, Natural disturbance and post-disturbance management effects on selected watershed values (2012)

[29] Gayton and Almuedo, Post-disturbance management of biodiversity in BC forests (2012)

[30] Clearcutting may exacerbate adverse environmental conditions for regeneration associated with microclimate (frost, drying winds, and extreme temperatures), soil (lack of soil moisture), etc.

[31] Updates to the Chief Forester's reference guide for FDP stocking standards based on climate change projections (2014)

[32] Refer to Section 8, Page 15

[33] Swift & Ran, Successional Responses to Natural Disturbance, Forest Management, and Climate Change in British Columbia's Forests (2012)

[34] Guidance for designing fire management stocking standards is anticipated for release in December 2015

[35] Silvicultural regimes for fuel management; Interim guidelines for fire and fuel management (ABCFP, 2013)

[36] This web site includes guidance for Community Wildfire Protection Plans, Fuels Management Prescriptions, and Operation Fuel Treatments

[37] Recent research shows effects in coastal ecosystems. Kranabetter, Stoehr, and O'Neill, Ectomycorrhizal fungal maladaptation and growth reductions associated with assisted migration of Douglas-fir (2015)

[38] For more information on managing the effects of climate change on BC rangelands, refer to: (i) Newman et al, Managing for the ecological and socioeconomic effects of climate change on BC rangelands: developing strategic Range Use Plans, Range Stewardship Plans, and range management strategic documents (2013); and, (ii) Range Branch's *Range Management Responses to Climate Change* (to be published in summer 2015)

[39] Provincial fire research and monitoring needs