# Climate Change in the Columbia Basin

January 17–18, 2003
Cranbrook, British Columbia
Canada

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# Acknowledgements

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**BC Hydro**
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BC Hydro is a provincially owned Crown Corporation and is part of the British Columbia Climate Change Business Plan. Although over 90%of the energy BC Hydro generates is from zero emission hydroelectric facilities, BC Hydro is committed to cutting greenhouse gas (GHG) emissions in industry operations and energy use through its Resource Smart program and GHG offset purchases. BC Hydro is confident that it can meet the voluntary goal that 50% of new supply will come from clean electricity sources as defined in the provincial government's energy policy report *Energy for Our Future: A Plan for BC*.

**BC Ministry of Water, Land and Air Protection**:
Water, Air, and Climate Change Branch
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The Water, Air, and Climate Change Branch develops legislation and policies to protect air quality, water quality, and the land. On behalf of the Province of British Columbia, the branch leads the development of a provincial strategy to address global climate change.

**Canadian Climate Impacts and Adaptation Research Network**
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The mission of the Canadian Climate Impacts and Adaptation Research Network is to build a network of researchers and stakeholders that will help to develop credible information on the impacts of climate change in Canada and help to identify adaptation options, in order to anticipate and prepare for changes that are expected during the 21st century.

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The Columbia Basin Trust supports efforts by the people of the Basin to create a legacy of social, economic, and environmental well-being and to achieve greater self-sufficiency for present and future generations.

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CMI promotes, facilitates, and supports research into the ecosystems of the Columbia Mountains of southeastern British Columbia, and makes sure that the results of this research are communicated to the public, land managers, decision-makers, and other researchers.

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The East Kootenay Environmental Society works to protect the diversity of wildlife habitats, the wild lands, the air, the water, and the quality of life of southeastern British Columbia.  EKES has overseen several projects related to climate change.

### *Thanks to Our Workshop Volunteers*

Thanks are also due to our volunteers, who assisted with note-taking at the workshop. Their records of the presentations and the breakout groups added to the quality of this document.

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- Sabrina Curtis
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- Paul Willis
- Jim Vanderwal

And, of course, we want to thank the conference participants, who travelled from all parts of the Columbia Basin, and from Vancouver, Victoria, Burnaby, and Seattle, to share their knowledge and questions about climate change.

# Table of Contents

# Overview of Workshop

Climate change will mean much more to British Columbians than warmer temperatures. It will also mean changes in precipitation and cloud cover, extreme weather events, and changes in other aspects of climate. These changes will affect physical systems, including the movement and availability of water, and related biological systems, including ecosystem function and the distribution of fish, wildlife, forests, and grasslands.

Many regions of British Columbia are experiencing the early impacts of climate change, and in other regions, climate change impacts will become evident during the next few decades. Human activities such as resource management, land use planning, tourism, agriculture, forestry, and infrastructure such as hydroelectric dams and transmission lines, highways, dikes, and municipal water and sewage pipelines will likely be affected.

Communities in British Columbia will be able to adapt to many of the impacts of climate change. In many cases, proactive planning will reduce costs, help communities avoid some of the potential adverse impacts of climate change, and gain some of the potential economic benefits.

The aims of this workshop were to begin the process of educating the public about climate change in southeastern British Columbia, and to begin a dialogue about how communities and stakeholders can begin adapting to a changing climate.

## Objectives for the Workshop

This workshop was a pioneering effort to establish a collaborative relationship between governments, researchers, and communities to deal with climate change adaptation. It was hosted jointly by organizations in the Columbia Basin, by the British Columbia government, and by the Canadian Climate Impacts and Adaptation Research Network.

The collective goals identified by the workshop organizers were to:

- Build community and local capacity to address climate change
- Identify local information needs and potential research partners
- Gain understanding of key regional vulnerabilities

## Workshop Description

The "Climate Change in the Columbia Basin" workshop brought climate change researchers together with resource managers, community leaders, and other stakeholders in the Columbia Basin. On Friday night, 135 workshop participants and 35 "drop-in" members of the public heard two overview talks on British Columbia's changing climate, including the themes of past and present climate change, potential impacts of a changing climate, and why we should prepare for climate change.

On Saturday morning, seven presenters addressed the possible impacts of climate change on the water resources, aquatic ecosystems, wildlife, and forests of the Columbia Basin. In the seven breakout groups on Saturday afternoon, workshop participants discussed how climate change might affect their communities, businesses, and resource interests. These discussions were summarized in a plenary session, and the major points from the discussions form a part of this report.

## About the Presentation Summaries

The summaries that follow are a combination of information provided by authors at the conference, as well as notes taken during presentations. While the summaries do not include charts, graphs, and other visual aids included in the original presentations, each summary includes most of what was verbally presented at the conference, and thus reads much like an oral presentation. Contact information is provided for all presenters, along with the invitation to contact the presenters directly for more details about their projects.

## About the Appendices

- Appendix One is a list of conference participants.
- Appendix Two is a summary of the comments received on the workshop evaluation forms.
- Appendix Three is a list of resources for information about climate change. Some of these resources were mentioned during the presentations, others were sent in by presenters and organizing committee members.

# Workshop Agenda

**Friday, January 17**

| | |
|---|---|
| 7:30 pm | ***First Nations Welcome***<br>Chief Sophie Pierre, Ktunaxa Kinbasket Tribal Council |
| 7:35 | ***Mayor's Welcome***<br>Mayor Ross Priest of Cranbrook |
| 7:40 | ***Opening Remarks***<br>Kindy Gosal, Columbia Basin Trust |
| 7:45 | **Twenty Thousand Years of Climate Change in the Columbia Basin:  What's New This Time?**<br>Philip Mote, Climate Impacts Group, University of Washington |
| 8:30 | **Potential Impacts of Climate Change, and Why We Should Respond,** Stewart Cohen, Adaptation and Impacts Research Group, Environment Canada |
| 9:15 | **Questions & Answers** |
| 9:30 | *Adjourn* |

**Saturday, January 18**

| | |
|---|---|
| 8:30 am | ***Opening Remarks***<br>Kindy Gosal, Columbia Basin Trust |
| 8:45 | **Effects of Climate Change on Pacific Northwest Rivers**<br>Alan Hamlet, Climate Impacts Group, University of Washington |
| 9:30 | **Impacts of Climate Change on Aquatic Ecosystems**<br>Bill Green, Canadian Columbia River Inter-Tribal Fisheries Commission |
| 10:00 | **El Niño and the Pacific Decadal Oscillation**<br>Philip Mote, Climate Impacts Group, University of Washington |
| 10:15 | *Coffee Break* |
| 10:30 | **Predictions on Potential Impacts of Climate Change on the Grasslands of the Columbia Basin**<br>Don Gayton, Forest Research Extension Partnership |
| 10:50 | **Effects of Climate Change on Wildlife Populations**<br>Bob Forbes, Fish and Wildlife Branch, British Columbia Ministry of Water, Land and Air Protection |
| 11:15 | **Potential Changes in Forest Cover and Fire Danger in the Columbia Basin**<br>Ross Benton, Canadian Forest Service, Pacific Forestry Centre |
| 11:40 | **Climate Change and Range Expansion by the Mountain Pine Beetle**<br>Allan Carroll, Canadian Forest Service, Pacific Forestry Centre |
| 12:00 pm | **Adapting to Climate Change:  What Can We Do?**<br>Jenny Fraser, Climate Change Section, BC Ministry of Water, Land and Air Protection |
| 12:30 | *Lunch, provided* |
| 1:15 | **Working Groups**<br>Participants will work in groups to discuss the assigned questions |
| 2:15 | *Coffee break* |
| 2:30 | **Plenary Session:**<br>**Group Findings –** Synthesis of the working group discussions.<br>**Next Steps --** Building partnerships, continuing the dialogue on preparing for climate change |
| 4:00 | *Closing Remarks*<br>Kindy Gosal, Columbia Basin Trust |

# Presentation Summaries

## 1. *Twenty Thousand Years of Climate Change in the Columbia Basin: What's New This Time?*

Philip Mote
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In the last 20,000 years, vast ice sheets and unimaginably colossal floods have swept the Columbia River Basin.  As the ice sheets receded, waves of new kinds of vegetation swept the Columbia Basin as the climate warmed.  More recently, the Columbia Basin has been altered by human settlement and the once-mighty river has been transformed into a sedate chain of lakes.

Now a new change is coming to the region:  human-induced climatic change.  So what evidence is there that the region's climate is changing?  How might our climate change in the future?  And, finally, what will these changes mean?

### *Evidence of Regional Climate Change*

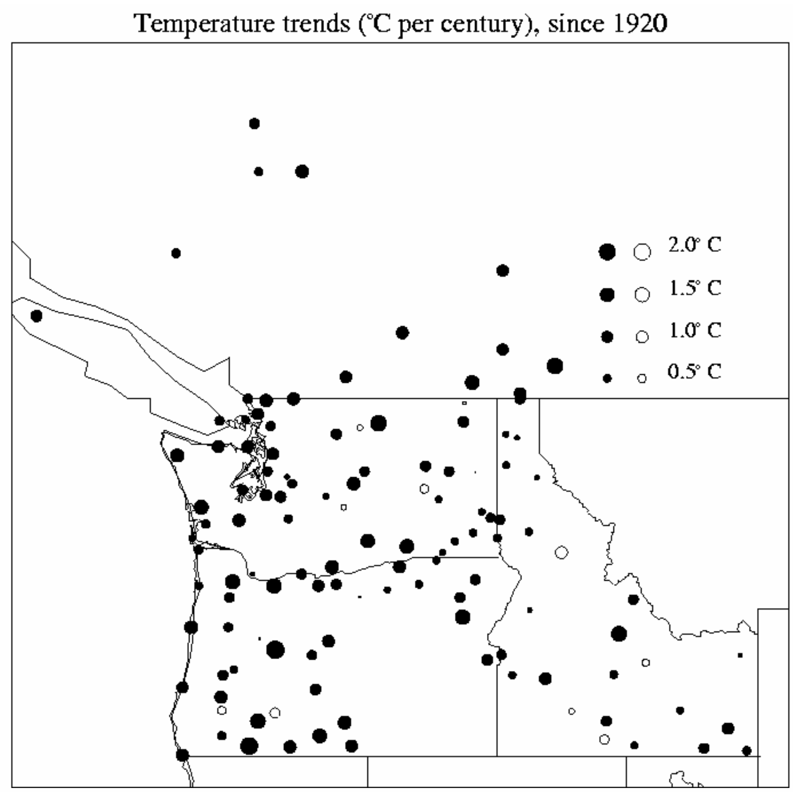
To understand climate change today, we need to turn clock back about 20,000 years. This valley was under a couple of thousand feet of ice, and this fact reminds us that climate change since then has occurred fairly rapidly.  Looking at land satellite images of eastern Washington State, we can see on the landscape giant boulders a great distance from their source, and evidence of a waterfall with water no longer in it.  Initially, these landscape features puzzled researchers.

More recent research on information from the 1930s and onward shows that likely an ice dam formed near what is now Lake Missoula.  Water flooded suddenly, coming through the Columbia Mountains gap at speeds of up to 70 miles per hour, scouring topsoil and depositing it near Wallusap, creating an agriculturally rich area.

One of the ways we research climate change is to drill holes in the lake floor and count pollen grains at each level.  Thirteen thousand years ago, we know that a certain species of pine existed in large numbers.  Then about 10,000 years ago, alder dominated, and we know that alder is a species that follows fire.  Between 6,000 and 10,000 years ago this area was very dry, with few trees.  Then about 300 years ago, cedar took over.

We can also find a record of past climate from geoducks. Some geoducks live over 150 years, and can provide a window on climate for the period before we had thermometer records. Graphs at Protection Island using geoduck growth data show climate change. Looking at the mean chronology for all the sections that I have measured so far, we see a strong increase in geoduck growth at Protection Island between about 1850 and the late 1870s. The only other period where the growth curve was higher was in the last few years.

Now, consider global climate change. What we see from a record of global temperature taken from surface observations on ships and land from 1860 to 2000 is that the average surface temperature has increased quite steadily year by year.

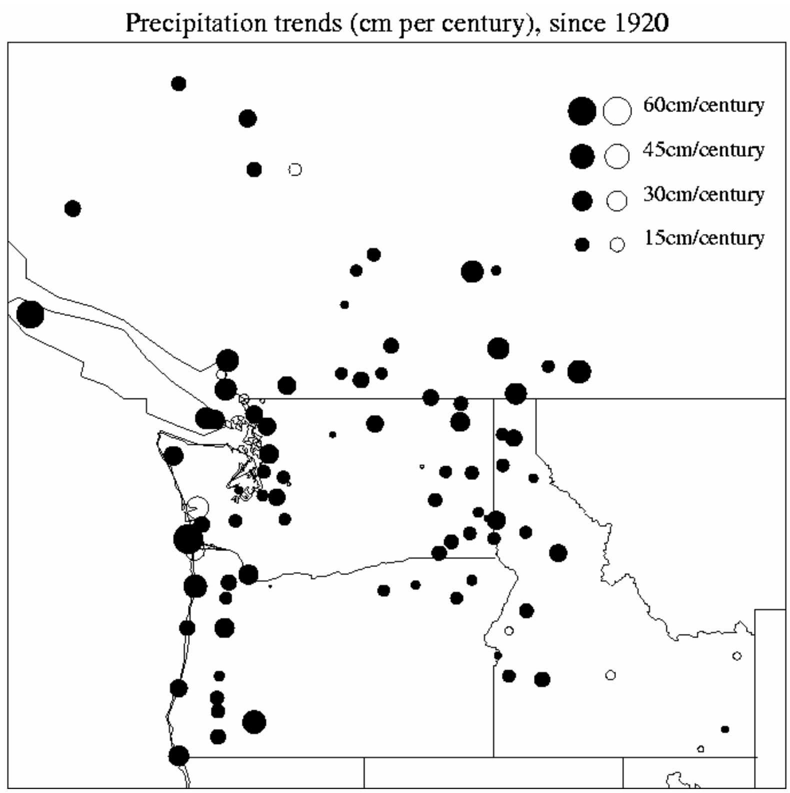



I refer to a map showing annual temperature trends (°C/century) from 1901 – 1999 plots where we have made temperature observations over the last 100 years. Note that there are vast gaps in the data in Africa, Asia, and China. There are extensive observations across the globe showing a steady increase in temperature.

Even if we discard the temperature record, nature is speaking to us. Temperature has increased by 0.6 °C ± 0.2°C over last 100 years. Permafrost is melting. Glaciers are melting. Arctic ice is thinning. Antarctic ice is breaking up. Plants are blooming earlier and leafing up earlier. The frost-free season is longer in many places.

Fifteen major glaciers around the world are all receding. Most glaciers are receding, except where precipitation has increased sharply and is sometimes responsible for glacier growth. There is ample evidence that the earth's surface is warming.

Let us turn our attention to the Pacific Northwest. Information from weather stations recording back to 1920 is mapped to show temperature trends in °C since 1920. This information has been put together from American and Canadian databases. Almost




all stations show a positive trend. This means nearly every station in the Northwest is warming.

There are far more precipitation stations than temperature stations in British Columbia. If we look at precipitation trends (cm/century) since 1920, trends over the last 50 years have been positive. Absolute trends are shown here, but relative trends also show a large increase in precipitation. In maps showing timing of spring snowmelt (1948 – 2000) in the west, we can see that trends are toward earlier freshet. This same study looked at lilacs and honeysuckles and found that they are blooming earlier. A study of trends in snowpack, through the example of maximum snow depth at Snoqualmie Pass, demonstrated that precipitation is increasing, but maximum depth of snow is decreasing—this shows warming.

Okay, it is warming, but how do we know that it is not just another natural cycle?

Well, 150 years ago, humans were travelling by foot, horse or train. But now people get around in sport utility vehicles. These vehicles are not even required to submit to fuel efficiency testing. They get somewhere around 10–12 miles per gallon. We are changing the atmosphere, and evidence shows that rates of warming are unusual. If we try to pin this warming on a natural explanation such as changes in solar effects, volcanoes, or oceans, it just doesn't fit. If we use physics, the last 50 years of warming is consistent with basic human effects from changes in greenhouse gas levels in the atmosphere.

A chart taken from an International Panel on Climate Change (IPCC) report compares the instrumental record of northern hemisphere temperature with temperature reconstructed using data from tree rings and other "proxy" data such as corals, ice cores, and historical records over the last 1,000 years. Viewed in this context, the warming of the 20th century—departures in temperature (°C) from 1961 to 1990 averages—appears to be well outside the natural range of variability. Indeed, the IPCC said that 20th century warming is "likely [judged 66 – 90% chance of being true] to have been the largest of any century during the past 1,000 years."

From this broad view of 1,000 years of data, we can see there was a 30- to 40-year interval between 1860 and 2000 with as much warming as we have seen during the entire 20th century. The 1990s are unusually warm, and warming has occurred faster than in the last 100 years. This increase looks suspiciously like the history of $CO_2$ emissions. When we started digging up carbon and burning it, $CO_2$ started accumulating in the atmosphere. Carbon dioxide levels have increased by 32%. Methane levels have increased by 150% and are rising fast. There is no question that human history is connected. The burden of proof is on those who say climate change not happening, because there is good physical reasoning and good evidence to say that it is.

### *Climate Change in the Future*

I taught a summer school course in which we modelled climate change and tried extreme scenarios such as spinning the earth backwards, wiping out sun, and other fantastical events. What I have realized is that although these were amusing and educational experiments for the students, we are right now conducting an experiment on our own planet and we do not know the outcome.

Based on what we know about climate, if anything, in the last 30 years we should have seen a cooling trend, but we have seen a warming trend. It is possible to simulate the climate of the last 100 years using a climate model (a huge computer program, like a weather prediction model only run for hundreds of years) and incorporating observations of global average temperature, natural influences such as volcanoes, solar variations (some of these are guesses before about 1970—we have better data since then), and human influences such as greenhouse gases and sulphate aerosols. We concluded from such a simulation that humans did not matter much before 1960—the early warming and the cooling were largely natural, and the late-century warming was largely human-caused.

What we can conclude:

- Climate models are useful tools.
- You cannot model increase in warming without including greenhouse gases.

If we look at warming trends in the Northwest, showing 10-year average temperatures, the observed and modelled values are the same as those in the 100-year models above. This underscores that the 1990s were the warmest decade of the 20th century in the Pacific Northwest (as well as globally), by almost 1°C and that the rate of warming from 1970 to 2000 has been roughly what the CGCM1 (Canadian Global Coupled Model) simulates. Looking ahead to the 2020s and 2040s, we examined output from a total of eight climate models, and the average rate of warming is a bit less than 1°C per decade. Even the coolest scenario still shows about 2°C more warming by the 2040s.

The average of all models shows about 0.5°C increase per decade, pointing the way toward a much warmer future.

### *Climate Change in the Columbia Basin – What It Means*

Climate models do not, however, simulate precipitation as well as they do temperature. Eight climate model scenarios showing the estimated change in precipitation from 2000 to 2040 show not much change. One of the biggest problems we do expect is flooding in the west due to rain-on-snow events or earlier warming. Most of the models we looked at also project modest increases in precipitation, mainly in winter. For June through August, most of the models project a decrease in precipitation.

The main impact we will see is less snow. From the 2020s through the 2040s, the areas covered by snow are more spread out. We are losing both depth and breadth or extent of the snowpack. We are not just projecting loss of snowpack somewhere out in the future, it is already happening now.

Looking at decline in snowpack and relative trends in snow water equivalent, from 1940 to 1992 we see a largely negative trend in the United States, while in British Columbia we see a largely positive trend.

If we overlay this with data from weather stations measuring precipitation, we see an increase in precipitation, yet a decrease in snow. We are working on quantifying this information, but this clearly shows an overall decrease in snow.

And so there really is no scientific debate about whether the earth is warming. Although there is still some debate about human effects on climate change, there is less and less reason to debate. The rate of warming now far exceeds anything human civilization has ever seen before. Humans are probably responsible for climate change, as changes are unlike anything in the past: we are a force to be reckoned with. Our best guess is that it will be warmer and wetter in the future, but what else will we see? We are watching for extreme events such as flooding and so on.

We still don't know precisely which aspects of climate change are related to human activity, and we won't know for some time in the future.

### *Audience Questions for Philip Mote*

**Q:** Why doesn't the little ice age show up in your graphs?

**A:** There have been other reconstructions of climate over the last few years. Some show the little ice age. If you look at year to year where it is cold and where it is not, you will see a number of years in Europe when it is cold there and not elsewhere. If you look at the whole hemisphere, then it averages out.

**Q:** Your graph of methane showed an increase of 150% emitted into the atmosphere. We are being asked to develop coal bed methane in British Columbia. Will this make us responsible for further climate change?

**A:** Most government and companies are aggressive about capturing the methane rather than allowing it to be released into the atmosphere. There are strong financial incentives to capture the methane.

**Q:** What are your feelings about the Kyoto Protocol?

**A:** I have strongly mixed feelings about it. It is the only game in town. If we walk away, we thumb nose at the international community. But, definitely I am not convinced that it is a good tool for reducing greenhouse gases. My fear is that having committed to Kyoto, while the first 1/2 and 2/3 of cuts are cost-effective, the last 1/3 of cuts to emissions could be very costly and discourage action. But, perhaps more people will jump on board.

**Q:** You said there is no question that the earth is warming. You said the difference is that the works of people are making a huge contribution to climate change. Can the warming be totally explained by human activity, or are there influences working in concert?

**A:** I quote the IPCC: there is evidence that most of the warming over the last 100 years is caused by human effects, but we cannot rule out natural effects. With that burden of proof, we should take some action.

## *2. Potential Impacts of Climate Change and Why We Should Respond*

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Climate change is an important environmental and social concern that is evolving into one of the 21st century's major challenges. Climate change impacts on ecosystems, food and water resources, human settlements, and human health could have significant implications for economic development, and for the future of ecosystems and humanity.

A major international effort is under way to research climate change impacts and adaptation. However, this is a complex research endeavour with many uncertainties. Impacts and adaptation research is a field of considerable breadth, incorporating philosophies, perceptions, methods, and data from throughout the natural and social sciences. We need to ask how such changes should be managed within the context of planning for the many objectives of water users, businesses, and communities.

In an attempt to find answers to several impacts and adaptations questions, we need to start by discussing the following:

- Dangerous climate change—results from International Panel on Climate Change (IPCC) Third Assessment Report (TAR) from Working Group II (WG II addresses vulnerability, impacts, and adaptation related to climate change)
- North America Climate Impacts and Adaptation Assessment—cases from British Columbia
- Why we should respond: expanding the dialogue on climate impacts and adaptation, the Canadian Climate Impact and Adaptation Research Network, British Columbia.

### *Dangerous Climate Change*

First of all, what does dangerous climate change mean? In an overview of the climate change problem, the IPCC has created what we might call a four pillars diagram to illustrate the relationship and interplay between greenhouse gases and aerosols emissions and concentrations, climate change, impacts on human and natural systems, and socio-economic development paths. They attempted to demonstrate where mitigation and adaptation might fit in.

With climate change, natural adaptations will occur, and these adaptations will affect human and natural systems, and influence mitigation strategies. But it is important to emphasize that climate change is not just related to gases and the atmosphere; it is related to all the social and economic reasons people do what they do.

Worldwide trends show that economic and insured losses from weather-related disasters have increased over the last 50 years. Related information on great natural disasters—defined as a disaster (earthquake, storm, flood, etc.) that costs at least a billion dollars US adjusted for today's dollars—also shows an upward trend in the number of all disasters since 1950, and floods in particular.

Insurance specialists and emergency preparedness experts are examining these data and asking why the number of catastrophic events is on the rise. Is the increase in floods due to climate change? Is the increase in disasters because as business or communities we are developing our environment (e.g., highways and hydroelectricity) in a way that is making us more vulnerable than we were 50 years ago? Or are both climate and human development affecting outcomes? The jury is still out, but from the data, clearly some combination of our development choices and changes in climate have led to an increase in the frequency of major weather-related disasters.

Thus we return to the challenge of trying to define dangerous climate change. Scientists are reluctant to define dangerous because dangerous is a value judgement. Scientists can talk about risk, and critical thresholds— what is our ability to adapt to or withstand stress? There is further discussion about how to classify rates and thresholds in climate change: some thresholds are absolute in that they cause immediate stress; some are pre-conditioned and depend on previous experience that the water system or food system has undergone; some are cumulative; and some are coincidental.

Furthermore, how we experience climate change may depend upon exceeding a threshold such as a change in climate averages, or a change in climate variability, or a change in the rate of climate change. Perhaps we can cope with slow climate change better than fast climate change. The challenge of impact research is to define "what if" issues through specific critical thresholds, so we are able to determine at what point we are entering dangerous climate change.

This leads us to vulnerability assessments—for example, how we define and measure a particular water system's vulnerability to climate change. Vulnerability assessments have important implications for our ability to understand the range of, and interactions among, the social, economic, political, institutional, and environmental processes that contribute to the vulnerability of people and places.

They also have implications for our ability to develop and implement effective adaptation strategies to reduce vulnerability, and to manage a set of adaptation strategies in a way that does not exacerbate overall vulnerability. If we are going to undertake a critical review of vulnerability measures used in hazards research, a team approach is essential, with input from economists, engineers, ecologists, and others with varied expertise.

A number of researchers looked at climate change information along with other data, and came up with scenarios in which the temperature could warm anywhere from a degree and a half to six degrees around the world, depending upon what development path we take. The world may take a path that leads to a fast rise in emissions and a six-degree increase, or the world may take a path that leads to a slow rise in emissions and we will see the temperature rise by one and a half degrees. The links between climate change and sustainable development are important.

As researchers we try to come up with indicators, then ask at what point are we going to see risk increase under a number of different indicators, and match them to the temperatures. Ecologists say that we are already seeing changes even at the current temperatures.

Initially, we are going to see "winners" and "losers," depending upon geographic area, economic forces, and so on, but eventually we are going to see losers everywhere around the world. A caveat is that in climate change we really do not know where, on the global temperature continuum, the caution or yellow area ends and the danger or red area begins, but depicting what we think based on existing indicators and data is our attempt to define what is dangerous. And scientists will be unable to address vulnerability, impacts, and adaptation related to climate change with more certainty until more research is performed on the human dimension—that area of climate influence connected with socio-economic development.

### *North America Climate Impacts and Adaptation Assessment*

Compared to regions such as Africa and Asia, North America is generally viewed as a region able to adapt, where vulnerabilities are comparatively low. However, in some areas vulnerabilities are higher than in others, and vulnerabilities are continually affected by regional socio-economic trends, and what we do on the ground. The ice storm in Ontario and Quebec in 1998 is a good example of how development decisions affect vulnerability. While the storm was a meteorological anomaly, it hit major transmission lines running south from large hydrological reservoirs. Had the same storm occurred 40 years ago, the effects would have been much different, as those reservoirs and the concentrated power transmission grid did not exist. Of course there are logical engineering and economic reasons to design energy distribution systems a particular way; but in doing so in Quebec, we changed our vulnerability. The ice storm hit, and many citizens of Montreal and area had to be evacuated.

Other key concerns include:

- Agriculture and crops—some crops would benefit from modest warming, with crop declines due to drought in the Prairies / Great Plains, and potential increases in northern areas.
- Snowmelt-dominated watersheds will experience earlier peaks and lower minimum flows; adaptation would offset some but not all impacts on water users and aquatic ecosystems.
- Some natural ecosystems (e.g., cold-water ecosystems, alpine tundra) will be at risk and effective adaptation is unlikely.
- Sea-level rise would result in increased risks particularly in the US Atlantic coast and Florida.
- Weather-related insured losses and relief payments have been increasing; there is potential for surprise.
- Vector-borne diseases may expand their ranges; public health measures would play a large role in determining health effects.

### *Examples of Climate Impacts and Adaptation in British Columbia*

#### *Water Management and Climate Change in the Okanagan / Columbia*

The Columbia Basin has experienced a great amount of development over last number of years. Local hydrology has changed because of hydroelectric dams, entire towns have been displaced, salmon have been blocked from travelling upstream, sturgeon recruitment is no longer occurring with few juveniles to replace aging fish, First Nations have increasing concerns about water and fish, species concerns exist in the US, and trans-boundary issues are complex. The fact that our research target is now bigger than it was in the past does not make it easier to hit. It presents us with a greater challenge to do research that includes local issues in a relevant way.

Research on climate change impacts on streamflow suggests that we can expect to see rivers peak earlier in the year. We still have some uncertainty, so we refer to high-confidence conclusions and low-confidence conclusions. Changes in total amount of annual and peak flow are known with low confidence, but that rivers will peak sooner is projected with high confidence.

In 1997 and 1998 we interviewed water managers, BC Hydro, and other stakeholders in order to compare their responses with reservoir model results provided by the University of Washington, and determined how their expectations and experiences on the ground matched or differed from the models. We asked whether lower creek and river levels would change how they would manage that water, and if so, how. We compared their responses with the Reservoir Management Model and found great similarities: both the respondents and the model projected a shortfall in irrigation supply, increased risk for cold-water species due to warmer water and low summer flows, and changes in availability of hydroelectricity with a possible need to purchase thermal power. The main difference was that those interviewed projected a need to begin water storage earlier in the year in order to spend less time at prescribed minimum flow levels, while the model showed no change in reliability for flood control.

The Okanagan can be used to illustrate approaches to studying climate change adaptation in the context of other challenges. Population is increasing rapidly, and water is used extensively for irrigation, reaching 80% consumptive use in some communities. If the climate warms, then the growing season will be about 25% longer. This creates advantages for certain crops, but also causes a big increase in crop water demand.

With climate change, we can expect more water in late winter and early spring, and less water in summer. In light of this, we asked water managers to create a list of possible adaptation approaches. Their responses included:

- Intervention – snowmaking, upland dams
- Defensive expenditure – fire protection, buy out water licences
- Price regulation – water pricing, metering
- Regulate land and water use – control irrigation, protect watersheds
- Alternative resource use – small-scale water storage, grey water
- Land use planning – urban densification

This list illustrates the breadth of dialogue necessary when discussing adaptation. We need to include climate change specialists, hydrologists, those involved in agriculture, local water managers, fisheries, BC Hydro, and others with a stake in water and in the landscape. We need to expand dialogue to talk about what water managers might do given the issues and stresses they will face as the climate changes, and to expand discussion of the positive and negative implications of each proposed adaptation strategy. An ongoing study in the Okanagan region is using dialogue with and among water managers to explore various adaptation options to increase available water supplies and slow the increase in demand.

### *Forest Management and Climate Change in Interior and Northern British Columbia*

In addition to climate change effects on water management, British Columbia will see significant effects on forests and forest health, in addition to what we are already facing with mountain pine beetle and fir bark beetle infestations.

Other studies suggest a higher pine beetle hazard in the future, and changes to wildfire frequency. We have seen changes in the amount of forestland that has been burned, but where numbers of hectares burned is now low, we are spending a lot of money to fight fire. So does fire suppression have something to do with increased beetle infestations?

When possible future changes are compared with the current climate, and a modest fire hazard, forest managers will have to consider the possibility that they will be facing both a change in fire hazard and a change in pest infestation levels. At the same time, managers will face forest yield issues: when considering what elevation to plant seedlings, research with lodgepole pine has shown higher that yield would occur when those same seedlings are planted at a higher elevation than in the past. And so, these are interesting adaptation questions: what do forest managers need to do now to address current and future issues of yield, fire, and pests due to climate change?

### *Why We Should Respond: Expanding the Dialogue on Climate Impacts and Adaptation*

Very few economists have tried to estimate the cost of doing nothing. If we do not adapt to climate change, do not do anything about greenhouse gases, and continue as if climate change is not occurring, what will happen? Economists do the best they can with the information they have, but studies are often far too broad, covering entire continents or countries, and fail to look at individual places. Thus, the cost of doing nothing could well be underestimated.

Similarly, we do not know the costs of proactive adaptation. Competing environmental and socio-economic issues can create surprising barriers, or greenhouse gas emission strategies may create side effects that we have not considered. Solving problems linked to climate change is not just about emission production and reduction; it is about development. Currently, we have so many scenarios in front of us that the dialogue is fragmented. Our challenge is to bring the dialogue, listeners, and speakers together, because the complexity of climate change and adaptation means that there is no one boss to direct the process or focus the discussion. There are many levels of government, business, civic, and social authority. Right now groups are doing many things that make great sense to them, but each group is acting separately from the other, and we find ourselves in the situation that we are in, with a pressing need for focused, constructive dialogue to find ways to mitigate, and adapt to, climate change.

Negotiations on the United Nations Framework Convention on Climate Change, and the Kyoto Protocol, have been part of a 20-year effort to find ways to address human-induced climate change. Much of the focus has been on reducing greenhouse gas emissions, but adapting to potential impacts on natural and human systems will complement these efforts by reducing our vulnerabilities to these impacts. Adaptation can affect the nature and severity of climate-related impacts, and improving our understanding of the role of adaptation in climate change has been and will continue to be an important research challenge.

### *Audience Questions for Stewart Cohen*

**Q:** Given the rate of global warming in British Columbia, what is the future of the ski industry?

**A:** That depends upon the elevation of the snowline. Low elevation regions from 800 m to 1000 m are at a greater risk. Snow at higher elevation sites will of course last the longest, but the ski industry also has the capacity to make artificial snow. Studies in Ontario are looking at this right now, and considering at what point a ski hill is no longer viable.

**Q:** If we do not want to admit that climate change is human caused, can we solve this problem? Can we solve this problem without assessing our own consumer patterns?

**A:** As I said earlier, there is no boss to direct us in how to mitigate climate change or adapt to it. Can we be more efficient? Yes. One example of success in getting us to change our habits is the blue box recycling program. Also, gas from landfills is now being converted to energy. There is a lot of talent out there. We really need to make this a question of development, and to integrate the discussion of development and climate change. We need to work with planners. As individuals, we are going to have to make a decision about buying plastic and buying SUVs. These are difficult individual decisions. I do think that we need to elevate the discussion to the level of development.

**Q:** In addition to increases in temperature, will we see an increase in disastrous events? Is there any research on this in southeastern British Columbia?

**A:** It would be worthwhile research to try to do. I am not aware of research on this right now. As for an increase in disasters, Emergency Preparedness Canada would have information on the number of disasters, at least by province.

*Added response from Jenny Fraser*: If events such as tornadoes are infrequent, it is very hard to find a trend. We need to ask whether we are finding an increase in a particular event just because more people are around and we report and notice those events more, or because there are more tornadoes.

*Added response from Stewart Cohen*: Is the number of disasters a question of climate change, or of development choices? Are we taking better care of ourselves now or are we creating new vulnerabilities on the ground? We would have to look at the insurance research to see if recent trends are just an artefact of reporting.

## *3. Effects of Climate Change on Pacific Northwest Rivers*

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The effects of winter climate in the mountains dominate the variability of stream flow in Pacific Northwest (PNW) rivers. For many PNW rivers the seasonal variability of flow is also strongly influenced by snow accumulation and melt. Rivers at lower elevation, such as coastal streams west of the Cascade Mountains, respond directly to precipitation in winter, and runoff essentially follows the timing of precipitation. Moderate-elevation rivers in the transient snow zone behave like rain-dominated streams in fall and early winter, showing a fall peak in streamflow. Then flows dip as precipitation turns to snow in mid-winter, followed by another peak in runoff in spring from snowmelt. These basins have a "dual-peaked" hydrograph.

The Columbia River, by comparison, is a snowmelt-dominated river showing a single peak during the spring freshet. Temperature plays a key role in the timing of flow in snowmelt-dominant and transient-snow river basins. Temperature changes as small 1°C, for example, can have significant impacts on water availability in the summer months even in the absence of changes in winter precipitation or annual flows.

Many uncertainties regarding the exact nature of climate change remain unresolved, but all climate models project increased temperatures over the next 100 years due to increases in greenhouse gases, and this result is projected with relatively high certainty. Even the least sensitive of the Global Climate Models (GCMs) show warming on the order of 3°C by the end of the 21st century for middle of the road emissions scenarios. Regional temperatures in the PNW are also projected to rise, and annual average temperatures are expected to be on the order of 1.7°C warmer by about 2025 and nearly 2.5°C warmer by about 2045, according to recent GCM scenarios. Even in the absence of changes in winter precipitation, these temperature changes have significant implications for PNW water supplies. Simulations of streamflow in the Columbia River, for example, show that winter flows would increase, summer flows would decline, and significant summer droughts would occur two to three times as often in the future as they have in the historic record. In moderate-elevation basins with winter temperatures close to freezing (such as the Cedar River, which supplies two-thirds of Seattle's water) reductions in average summer streamflow of about 25% could occur by the 2020s and by the 2040s severe drought years like 1992 could become the norm in these watersheds.

Because winter precipitation is the primary driver for annual flows, with about 75% of precipitation in most areas falling in winter, relatively uncertain changes to winter precipitation could exacerbate or mitigate the effects of temperature-driven changes in streamflow timing. Changes in summer precipitation may also have impacts, but usually result in relatively minor changes in streamflow.

Many GCMs suggest small increases in winter precipitation in the PNW on the order of 10%, but a few models project more dramatic changes. The British HadCM2 GCM, for example, predicts strong increases in winter precipitation for the PNW (particularly in the 2020s), whereas the German ECHAM4 GCM predicts strong decreases in winter precipitation. The HadCM2 simulations suggest an increased risk of flooding in November and December in moderate-elevation basins and moderate decreases in water supply in summer, whereas the ECHAM4 scenarios imply severe shortages in summer water supplies, with relatively small increases in fall and winter flood risks.

The primary vulnerability of PNW water systems is limited reservoir storage and the historic reliance on natural storage in the mountain snowpack to provide sustained water supplies in the relatively dry summers. In the Columbia Basin, for example, reservoirs can store only about 30% of the annual flow, and some water supply systems in the Cascades can store only 10% of the annual flow. This limited ability to move water from the wet winter to the dry summer makes these water systems vulnerable to the potential loss of snowpack. In systems with large amounts of storage (some hydropower systems in northern British Columbia, for example), the implications of timing shifts in streamflow may be negligible, although these large storage systems may still be vulnerable to significant reductions in average precipitation or changes in the duration or intensity of droughts.

The Columbia Basin is somewhat unique in the PNW because climate change will likely affect important transboundary issues between Canada and the US. The lack of a formal cooperation mechanism for ensuring instream flow in the lower Columbia Basin in summer, for example, suggests that it may be difficult or impossible for the US to avoid impacts to instream flow in the lower river in late summer if natural flows in the southern part of the basin decline as expected.

### *Quantifying and Evaluating the Effects of Climate Change*

For the 2020s, temperature increases of about 1.7°C are suggested for the PNW, and by the 2040s we could see temperatures increase by 2.5°C on average. The main impact for this area will be loss of snowpack. These changes are most evident in the southern Cascades, where losses of April 1 snowpack could be nearly 50% by the 2040s; however, reductions in basin average snowpack for the Columbia Basin as a whole are present in all the scenarios as well, even for those scenarios that show increases in winter precipitation. In broad terms, basins currently close to the snowline in mid-winter are at greatest risk in the short term, and we expect to see significant impacts in the US earlier than in Canada. These discrepancies in the location, timing, and intensity of impacts suggest increased tension between Canada and the US over water resources in the Columbia Basin.

### *Water Resources in the Columbia River Basin*

The Columbia reservoir system is operated primarily for conjunctive winter hydropower production, and flood control in spring and summer. Reservoirs are currently evacuated in winter and refilled in the spring and summer. Other important uses of the dams and reservoirs include irrigation, instream flow enhancement for fish, river navigation, lake recreation, etc.

Middle of the road climate scenarios for 2040 predict modest reductions in winter power production capability, but more significant reductions in fish flows, particularly in late summer. This suggests intensified tradeoffs between winter hydropower production and attempts to maintain objectives such as instream flow for fish, for example.

For more extreme climate scenarios in which we see increases in temperature and reductions in precipitation, we see increases in drought frequency and severity. Such scenarios create severe challenges in attempting to maintain system reliability for power generation, flood prevention, irrigation, recreation, and fish flows. A recent study also shows that there is no easy way to mitigate these changes in flow by changing reservoir operations. We can isolate and protect one use at a time, but not more than one. By 2050 – 2098, we can no longer correct for additional water uses at no cost to "firm power", and we see definite tradeoffs between winter and summer objectives.

There are several areas of concern for water management in the Columbia Basin:

- Limited reservoir storage available, and little opportunity to build more (storage / streamflow ratios 10% − 30% in most basins—vulnerable to timing shifts)
- Water systems operated closer to their supply limits now than in the past (effective management more important)
- Use of historic streamflow record for long-range planning (not representative of the future)
- Use of statistical streamflow forecasting tools based on 30-year streamflow record
- Inflexibility and fragmentation of water management institutions and entities
- Different changes in Canada and US that may disrupt existing management framework and agreements.

As human population in the region grows, water systems will have to be operated closer to their limits, with emphasis on conservation and demand management. This is precisely why we want water managers to use streamflow scenarios that include climate change as a factor. The greatest impacts to the Columbia system are for the warm/dry scenarios, which produce the strongest reductions in summer streamflows and the greatest increases in drought frequency.

In the lower Columbia Basin, summer streamflows will likely be strongly eroded by climate change. With most of the snowpack and roughly 50% of the reservoir storage in the Columbia in Canada, the need for coordination is clear. Yet currently we have no formal coordination mechanism for maintaining instream flow and reservoir elevations. How do we adapt?

Whether precipitation increases or decreases, we are likely to see reductions in summer water availability due to climate change and increased regional temperatures. The reductions in water availability in these scenarios are likely to exacerbate existing conflicts over water, the impacts of regional growth, and weaknesses in infrastructure, water management practice, and management institutions. Conferences like this one in which different sectors discuss adaptation strategies become all the more important in this context.

### *Audience Questions for Alan Hamlet*

**Q:** (Comment) The conclusion that things are okay in the north and worse in the south seems flawed. Dramatic change in seasonality will change our idea that our snowpack is okay here in Canada.

**A:** It is certainly not my intention to minimize the potential impacts in the north. Changes in snowpack will undoubtedly have profound implications in Canada as well as in the US. My conclusion is based on the hydrologic outcomes of the climate change scenarios. The simulations show that streamflow timing that fills the upper basin is less sensitive than in the lower basin. So Canada is likely to have greater water availability in summer than the US (snowpack plus reservoirs), and will probably be in a better position than the US in this context.

**Q:** The Columbia River Treaty currently results in releases of water from Canadian storage to the US at certain times of year, and these agreements are based upon the historic flow regime. Even if Canada has normal snowloads, are we going to see an increase in the volume of that water going south?

**A:** Our reservoir model does not simulate all the informal coordination interactions between Canada and the US, but it does simulate the basic Columbia River Treaty dam operations. As I see it, the most fundamental problem with regard to climate change is that the Treaty does not have any explicit formal interaction between Canada and the US for delivering water to the US in the summer purely to maintain instream flow. Yet a reduction in the ability to meet instream flow needs is one of the expected impacts of climate change on the US side. The US will want more water in summer to maintain acceptable levels of flow, and Canada will want to keep lake levels high to protect resident fish, recreation, etc. It is not clear how this tension is to be resolved, but if there is a potential mechanism for Canada to make money by delivering water in summer from reservoirs without dramatic impacts to river and lake systems, then both the US and Canada can potentially benefit.

**Q:** (Comment) Downstream benefits are based on original operations of the system without climate change effects. It would seem that as climate warming occurs, while the US will continue to pay downstream benefits based on original calculations, Canada will have to pay more back.

**A:** If Canadian dams increase water released in winter, streamflows will increase in the US, and Canada receives 50% of the benefits. This basic allocation of benefits may remain acceptable in the future, but climate change may alter the timing of these releases, and therefore the specific dollar amounts to each party over the long haul, so allocations between the two partners may need to be adjusted for climate change. It is not clear, however, that more water would necessarily be released from Canadian projects in winter due to climate change. The releases from storage for flood control are dependent on estimates of basin snowpack. So if snowpack declines basin-wide, so will flood evacuation requirements. This could mean less water released from Canadian storage. Is the Treaty going to hold up in its objectives overall? It is not clear, but maybe not.

**Q:** Climate change models predict for 2020 and 2040. What presumptions have you made? Did you model any rain-on-snow events?

**A:** The basis of the scenario I showed today is a middle of the road "consensus forecast" based on four GCMs. All have the same basic premise with regard to emissions scenarios (about 1% per year increase in $C0_2$). The hydrologic model explicitly simulates rain-on-snow events and other short-term hydrologic effects. So these effects are included in the results, although there are considerable uncertainties here with regard to the precipitation changes from the GCMs.

**Q:** (Comment) 2024 is when the Columbia River Treaty can end, which correlates with climate change effects presented in scenarios. Canada may be in a stronger negotiating position then.

**A:** It is possible to renegotiate the treaty at any time but, yes, it is probably more difficult to renegotiate before 2024, and Canada may be in a better negotiating position at that time depending on how things play out. Such things take lots of time to implement, however, and I see a need to create better-coordinated interactions between the two countries before impacts can be fully known.

## *4. Impacts of Climate Change on Columbia Basin Aquatic Ecosystems: A Forecasting Fool's Game*

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I have subtitled my presentation "A forecasting fool's game" because forecasting (in which one is almost always wrong) is even more difficult when we are forecasting effects many, many steps removed from the initial causative factor—in this case, effects on regional fish populations caused by specific global climate scenarios. However, in spite of the risk that our current assumptions and forecasts are likely wrong, I think we can come to some robust conclusions. My key message is that we need monitoring and we need early warning systems. If we are going to be wrong in our assumptions, we need to know, and we need to build monitoring and early warning systems to reduce or avoid the cost and pain of unexpected outcomes.

The first step I took in this analysis was a review of the available climate change scenarios for the Columbia Basin from which we could draw conclusions with respect to the Canadian portion of the Columbia Basin.

After reviewing climate scenarios and models for the Canadian part of the Columbia Basin, there appears to be a consensus that we are likely to see an increase in annual average temperature. Beyond that, there is a wide range of predictions of the magnitude of the change—between 0.5°C and 5°C by 2040. This is consistent with the observation of a 1°C increase in average annual air temperature in the Columbia Basin over the last 100 years.

As for changes in precipitation, there is much less consensus. Due to the extremely heterogeneous nature of even just the Canadian part of the Columbia Basin, any precipitation effects resulting from climate change are likely to be quite varied across the Columbia Basin. We can conclude that we will likely see reduced summer precipitation, and, in winter, more rain and less snow, at least at lower elevations. However, summer precipitation trends for this region show a consistent increase over the last 70 years, so I do not think that we can place too much confidence in the prediction of lower summer precipitation.

In looking at streamflows, we can predict that the summer low flow period will at least be longer (if not necessarily lower) with earlier snowmelt and peak of freshet by 2 – 6 weeks. In glacier-fed streams we will see a transient period in which glacial losses will offset summer low-flow decreases until glaciers are gone or reduced.

I attempted to find out if Columbia Basin streamflow records show any trends that could be attributed to global climate change. In doing this, I felt it important to isolate the possible streamflow effects of the Pacific Decadal Oscillation (PDO). To accomplish this with available records, I compared: (i) the average date of peak flow; and (ii) the cumulative discharge for the August–October period for two PDO "warm phase" periods: 1926−1947 and 1977−1998. I was able to find records covering these periods for only two streams—the Bull River (tributary of the Kootenay east of Cranbrook) and the Columbia River at Nicholson (south of Golden). No significant differences were observed for either the average date of peak flow or cumulative late summer to early fall discharge for these two streams.

Among other possible changes are less ice, later freeze-up, and earlier breakup.

Having reviewed possible changes in streamflows and other water-related variables, let us turn to a consideration of possible aquatic ecosystem effects.

Likely impacts on periphyton communities include a shift from diatom to green algal dominance, and an increase in algal biomass. Changes will be significant only at the higher end of temperature change scenarios.

Impacts on invertebrates could include effects on hatching success, larval growth, adult size and fecundity, number of generations per year, and timing of adult emergence. In general, I think that we can conclude that there will likely be more food for insectivorous fish, but that the species composition of the invertebrate community will be significantly altered.

For salmonids, even small increases in water temperature can cause a wide range of changes: accelerated egg development; altered timing of emergence, growth, and downstream migration of juveniles; reduced food conversion efficiency; altered timing of spawning migration and spawning; increased susceptibility to disease; and a shift in the competitive balance between salmonids and non-salmonids. Salmonids are principally a cold water−adapted grouping, and so any increase in water temperature is likely to have marked effects on salmonid populations.

What follows are some hypotheses that I have developed based on reviewing temperature preference information and available information on stream temperatures in critical periods. I have chosen examples that I think we can generalize from—I avoided extreme scenarios.

Warming impacts in spring could result in reduced cutthroat trout egg/alevin survival. This figure shows water temperatures in the Elk River prior to and during the Westslope cutthroat trout spawning and egg incubation season. As shown, under current conditions, temperatures occasionally exceed and are usually within the high end of the optimum range for egg survival. Under even a moderate spring warming scenario, water temperatures would usually exceed the optimum range for egg survival. For rainbow trout in the transboundary reach of the Columbia River (downstream of Keenleyside dam) water temperatures are currently within the optimum (10–12°C) range within the latter portion of a much extended spawning incubation period. A modest warming scenario will result in temperatures within the optimum incubation range earlier in the season, and therefore a shift towards increased productivity of earlier-spawning fish.

From the Slocan River example, we can hypothesize increased stress and reduced growth during the summer rearing period for all indigenous salmonids. Given current summer water temperature conditions in the Bull River, we can propose a similar hypothesis, particularly with respect to bull trout rearing and pre-spawning maturation.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) lists the upper Columbia white sturgeon population as "a species of special concern." Population estimates indicate a population of approximately 1,400 sturgeon with negligible recruitment over the last 30 years. The sturgeon egg incubation period can start as early as mid-June and extend into August. An increase in egg/alevin developmental abnormalities has been observed when water temperatures exceed 18°C. From the middle of July 1998 to mid-September (not an abnormal year), mean water temperature in the plume of the Pend d'Oreille River exceeded the 18°C threshold. The onset of egg incubation is occurring later and later, with the result that egg incubation is being increasingly confined to a period when development abnormalities are more likely to occur.

For the Revelstoke white sturgeon subpopulation, warming may be a good thing. The sturgeon population is estimated at approximately 50 in the Arrow Lakes, with no apparent recruitment over the last 30 years. White sturgeon are engaging in spawning behaviour, but no eggs have been collected. Temperature conditions are presumed to be unsuitable (too cold) for spawning and egg/alevin development due to the withdrawal of cooler hypolimnetic waters through the Revelstoke dam. Summer warming of the Revelstoke reservoir may bring temperatures into the optimal range for spawning.

In considering temperature conditions in the Wigwam River, which supports a regionally significant bull trout population, we can hypothesize that warmer water temperatures during the fall spawning / early incubation period will result in reduced survival of bull trout eggs and alevins. The optimum range for bull trout egg incubation is from less than 6°C to a maximum of 8°C. Any increase in average water temperature will result in significantly more frequent surpassing of the 8°C maximum. We can also hypothesize that brook trout (which also spawn in the fall and are an introduced species) will be less affected by water temperature increases in the fall because the optimum range for incubation of brook trout eggs and alevins is higher than it is for bull trout eggs/alevins.

Turning to winter, the maximum incubation temperature for mountain whitefish is 6°C. Incubation occurs from early December to late February or early March. Even a 1°C increase in winter water temperatures in the transboundary reach of the Columbia River will result in a substantial reduction in the length of time with suitable incubation temperatures for mountain whitefish.

The optimal range for incubation of burbot eggs is between 4°C and 7°C. For the Goat River population, for example, warming will see a shift more into optimal temperature ranges.

Anticipated lower flows in summer and fall will increase diurnal temperature variability and result in more stress on fish, and of course more direct stress due to higher temperatures as well. One example is Joseph Creek in Cranbrook. Existing and low-flow periods could be extended and we could see even lower flows resulting in more frequent fish kills.

We will also see less river ice, which could increase fishing activity on the Kootenay River and other rivers. This will mean a shorter ice season on lakes, and more food production in lakes over a longer period. With shorter ice seasons we will see reduced winter harvest and reduced winter kill in shallow lakes.

Mitigating temperature increases will be difficult due to a lack of effective mechanisms. We can and should:

- Protect and restore riparian areas to maintain and increase shading
- Redouble conservation and restoration efforts for indigenous fish species through precautionary regulations, no-harvest population strongholds, and education
- Reduce other population stressors (e.g., toxic contamination)

Most importantly, we have to maintain and increase the ability of indigenous species to adapt. So we have also to redouble our effort to maximize genetic diversity for adaptation through precautionary regulation and no-harvest zones, and more public education about indigenous versus non-indigenous species.

***It is absolutely essential that we maintain and restore connectivity of habitat.*** This applies on micro, meso, and macro scales from large dams to culverts under roads. We have to increase our ability to monitor temperature and identify temperature stress. We are doing some of these things now, but we need to do it "more and better."

When mitigating low-flow impacts, there are not many answers other than to conserve water. Again we need to monitor; we need to manage water better. Indefinite water licences make little sense if we anticipate increasing summer and fall water shortages. We are taking some steps to conserve water and to make positive changes to the water licensing system, but we need to do more and we need to do it better.

### *Audience Questions for Bill Green*

**Q:** (Comment) I would like to point out one thing with the Nicholson and Bull River systems—one is glacier-fed and the other not, so it might explain the shifts you showed in your slides.

**A:** I agree that the Columbia system is much more glacially dominated. The other was depicting total flow between August and October. I don't think that is explained by glacial melt.

**Q:** (Comment) Climate change is affecting processes that drive river systems. We need to think about how this is changing process, not species.

**A:** (No answer)

**Q:** What preys on fish in this area?

**A:** Good question and a very important point. With respect to terrestrial animals, studies have been done on burbot in Windermere and Columbia Lakes showing predation by osprey—a good thing for ospreys. Bears prey on kokanee as well.

**Q:** In relation to Bill Green's presentation, it is nice to see suggestions for how to deal with climate change, but who should implement them, how do we do so, and who is providing support?

**A:** That might be a question better left to the afternoon sessions.

**Q:** (Comment) It is a question for the room as well as to Bill Green.

**A:** (Kindy Gosal) This is a good question for the afternoon sessions and speaks to what we need to consider.

**Q:** We are seeing whirling disease in salmonids south of border. With warming trends, will the likelihood of whirling disease increase?

**A:** I don't know enough about whirling disease to answer this question specifically, but generally we expect increased incidence of infectious diseases and parasitism with increased water temperatures.

## 4. El Niño and the Pacific Decadal Oscillation

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*For a more complete presentation of this information, visit http://jisao.washington.edu/PNWimpacts/CDTheme.htm#Sec3*

The El Niño–Southern Oscillation (ENSO) occurs about every 4 years. The Pacific Decadal Oscillation (PDO), at least in the 20th century, has tended to stay in one state or another for 20−30 years at a time. When we look at 20th century climate influences, it is important to keep this in mind. ENSO and PDO both tilt the odds toward slightly warmer, drier winter and spring climate in the Pacific Northwest.

During El Niño, winter storms are more likely to go to the north or to the south. For example, we see more precipitation in southern California during El Niño. Flow in the Columbia River at The Dalles is about 10% lower than normal during an El Niño or warm-phase PDO. Most of the lowest-flow years occurred when both ENSO and PDO were pushing the region toward warm-dry.

Climate stations near Cranbrook show a warming of about 1$^{o}$C in the last 80 years, with largest increases in winter. Precipitation has increased about 30% over that time, mainly in late spring and summer.

One of the things our group has done is describe the influence of PDO on salmon. Results show that cooler PDO coincides with increases in many Pacific Northwest salmon stocks.

Summary of climate change in the British Columbian part of the Columbia Basin:

- Temperature increases but no decrease in snowpack, due to increase in precipitation.
- In the future, expect earlier peak flow and lower late summer flow.
- Rough rule of thumb for the rate of future warming: Decades multiplied by 0.5$^{o}$C equals estimate of temperature increase.
- Precipitation increase mainly in winter.
- Continue to see shifts in timing of streamflow with earlier peak and lower late summer flow.

### Audience Questions for Philip Mote

**Q:** (Comment) I disagreed with two plots—El Niño occurrence and strength. This is difficult to determine. El Niño is modulated by PDO, and we don’t understand that well.

**A:** Mechanisms for PDO are not well understood. Several modelling studies support the hypothesis that PDO is a low-frequency woofer to a high-frequency pounding that lower-latitude ocean gives to the overall system. PDO may be a complicated result of El Niño. Therefore, there is no way to predict. This is important to sort out, because it could turn out that PDO is not a separate entity, but an expression of what is going on in the tropics. We do find some additional useful information from looking at PDO separately, nonetheless.

# 5. Predictions on Potential Impacts of Climate Change on the Grasslands of the Columbia Basin

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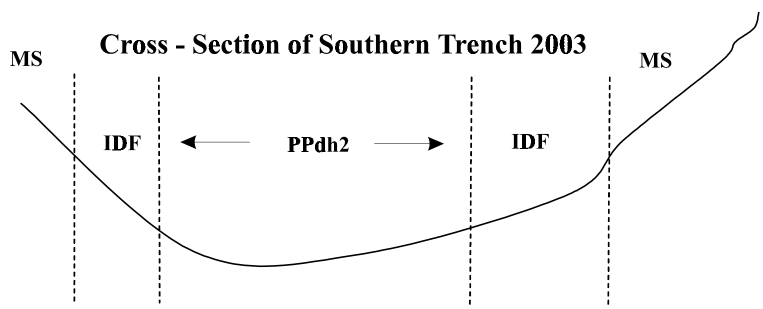
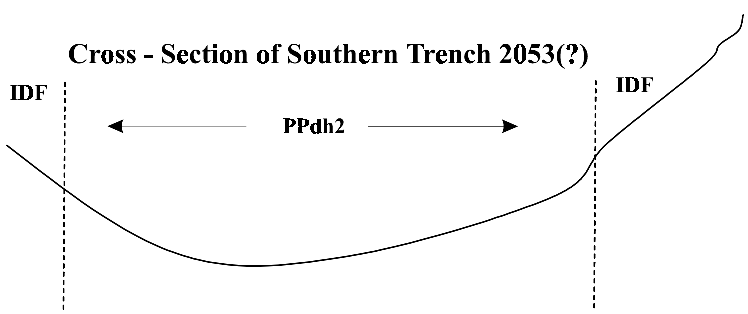
Casual consideration might convince the grassland advocate that global warming's one bright spot is an expansion of native grassland ecosystems in British Columbia's southern Interior. However, if one accepts the principle that high seral ecosystems are resilient and adapt well to change, and low seral ecosystems do not, then we are headed for trouble on the grasslands of the Rocky Mountain Trench, the Boundary country, and the South Okanagan / Similkameen.

Based on climate change evidence to date and scenarios for future change, we can expect warmer summers and warmer winters. The predictions on precipitation seem to be less definitive, but most point to a greater proportion of the total precipitation coming as rain rather than snow. This would suggest an expansion of the geographical extent of the subzones that contain grasslands and dry forests; that is, the Bunchgrass (BG), Ponderosa Pine (PP), and dry Interior Douglas-Fir (IDF) subzones. However, this expansion will occur largely on paper, since virtually all the grasslands of these areas are currently in a low seral state as a result of the interactive forces of overgrazing, suburbanization, forest ingrowth, vehicular impacts, and weed invasion.



The keystone species of the Pacific Northwest Bunchgrass association—of which our grasslands form a part—are bluebunch wheatgrass (*Pseudoroegneria spicata*), rough fescue *(Festuca campestris*), and, in southern areas, Idaho fescue (*Festuca idahoensis*). These grasses, and some of the native perennial broadleaf species associated with them, are the grassland equivalent of old growth—they are slow-growing, deep-rooted, produce seeds only sporadically, and do not tolerate heavy grazing. These are not species with rapid expansion and colonization characteristics, that could promptly seize new niches created by global warming, and secondly, the geographical extent of late-seral grasslands—from which these species might spread—is very small.

My premise is that the net result of a greenhouse gas–induced warmer, wetter, and more variable climate will mean a massive expansion of noxious weeds. The stressed remnants of our Pacific Northwest Bunchgrass community will be pre-empted from expanding into new grassland-adapted niches (valley sides and southwest mountain aspects) by a host of new and existing noxious weeds. The existing grasslands of the Rocky Mountain Trench, which at present are not climatically suitable for large populations of the common grassland weeds Dalmatian toadflax (*Linaria genistifolia*), diffuse knapweed (*Centaurea diffusa*), and spotted knapweed (*Centaurea maculosa*) will likely become prone to substantial invasions of these weeds in a global warming scenario. The grasslands of the Kettle, Granby, South Okanagan, and Similkameen valleys, which currently are climatically suitable to the above suite, will likely become prone to invasions by Medusahead rye (*Taeniatherum caput-medusae*) and burgrass (*Cenchrus longispinus*) and other noxious weeds presently found only to the south of us.

Global warming in the Canadian Columbia Basin will not result in more grasslands, but more weedlands.

Moving up in elevation from the grasslands to the dry forest types of the Columbia Basin, I foresee major ecological problems related to fuel accumulation. These are fire-maintained (NDT4) ecosystems, and forest ingrowth as a result of fire suppression has resulted in a dramatic increase in forest cover, largely Douglas-fir. These trees generally begin to stagnate when they reach pole size, since there are not adequate moisture, sunlight, and nutrients to support this dense tree cover. Under a global-warming scenario, tree stagnation and mortality will accelerate, leading to hazardous fuel accumulations. This fuel accumulation will put the remaining ponderosa pine "legacy" trees at risk of stand-replacement fires, but, perhaps more importantly, the uncontrolled fuel accumulation will have profound implications for the human communities, infrastructure, and habitations that are found within the dry forest zone.

### *Audience Questions for Don Gayton*

**Q:** Have you done any research into grasslands sequestering carbon?

**A:** I have not but I have done some reading. I understand grasslands are not as effective as forests on a per-hectare basis, but more effective than annual crop agriculture.  Our grasslands are a drop in the bucket in the large picture, but regionally, if our grasslands are in good condition, they certainly have good potential for storing carbon.

**Q:** If species like bunchgrass are well established, can they out-compete noxious species?

**A:** Yes, the native bunchgrasses are quite competitive if they are well established and vigorous.

## *7. Effects of Climate Change on Wildlife Populations*

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No one can predict with certainty what will happen in the Kootenay area over the next several decades in terms of wildlife response to climate change.

We expect that there will be a rise in the global average temperature over the next century, probably by about 3°C by 2100. Within the Pacific Northwest, predictions are that the temperature will rise about 1.5°C by 2025 and by about 2.5°C by 2050. This change will influence weather patterns, particularly with respect to precipitation frequency and seasonality. Wildlife habitat types will change in response to these influences.

By 2050, summers in the Columbia Basin will probably be warmer and drier. Winters are expected to be shorter. Wildlife species associations to the south of the Kootenay region will move northward at an unknown rate; wildlife species currently at the southern end of their range will withdraw up slope and northward.

We can look backward in time learn what is ahead of us. The last glaciation ended in this area about 15,000 years ago, leaving a shrub/tundra ecology. We do not know what kind of animals roamed the area, but we know that people were here, so we know that there were faunal complexes associated with these ecologies. About 8,000−5,000 years ago, the climate was warm and dry.

While we do not have good historical climate data for this area reaching back over the past 1,500 years, we do have a fairly good idea of climatic fluctuations in Europe from 1,000 AD to present, and through the historical record there we have some idea of how the ecosystem responded to these changes. Local archaeological evidence shows human dependence on sheep, bison, and elk (grass-dependent species) from 1000 to 1300 AD. The Northern Hemisphere went through a "Little Ice Age" from about 1300 to about 1800−1850. The temperature in central Europe dropped about 0.5° to 2°C. In Europe, mountain snowlines descended at least 100 m below modern levels, the treeline dropped, and agriculture elevations decreased well below the 200 m it had gained during the previous 300 years. We know that similar fluctuations occurred here because North American glacial thrusts and recessions match those of Europe. Locally, bison dropped out of the ecosystem and it is probable that elk populations declined as well. Rocky Mountain bighorn sheep numbers went down. Caribou numbers probably went up as the incidence of alpine ecosystem representation increased; grizzly bear and black bear populations stayed pretty much the same.

Jumping ahead, from 1850 onward, temperature has been increasing, and we can deduce general movement and response by wildlife. So what does this increase in temperature mean? Water tables will decline. Alpine tundra will shrink. The treeline will rise. Mountain caribou habitat could be reduced in the East Kootenay by about 75% by 2050.

What we will see in this area is more generalized grassland habitat, and species more like those we now find in south-central Washington. About 25% of endangered and threatened species are closely associated with grasslands, and their viability will improve with increased grassland availability. Large ungulates like sheep and elk will benefit from predicted habitat changes.

The outlook is not so positive for other species such as caribou, mountain goat, marmot, wolverine, and some bird species such as ptarmigan and grouse. These are species living at the southern extent of their range.

Human activities will continue to have a greater effect on wildlife than natural impacts of climate change. For example, we can expect that agricultural practices will change. What is now simple pastureland could be used to grow grapes or orchards in the East Kootenays, and we would see noxious weed impacts due to grazing in retreating forest areas. We could see more domestic sheep to cope with noxious weeds, which can also have negative effects on contiguous wild sheep populations through disease transmission.

In fact, there is little we can do locally to stop the warming of our climate. We will see changes in wildlife habitat. Human populations and land uses in this area will undoubtedly change in response to warming, and these activities will have an equal or greater effect on wildlife than any results of habitat change. We need to recognize those changes, accept them, and adapt land use practices to consider wildlife. Although grassland and sagebrush vegetation community representation will increase, resulting in an expansion of grassland-dependent wildlife populations, we need to use our influence to adapt land use practices to consider all wildlife.

### *Audience Questions for Bob Forbes*

**Q:** (Comment) Your presentation did not go into lower in the food chain. We should really be talking about species lower down in the food chain.

**A:** Absolutely, you are right. There just wasn't time. There will be effects on the entire food chain.

**Q:** (Comment) In the Triassic Era the dinosaurs were small, while in the Jurassic, the dinosaurs were larger. With trends in climate change, do you suspect the smallest species with highest metabolisms will go by the wayside with a preference for larger species?

**A:** I don't know.

**Q:** (Comment) You have not mentioned the effects of backcountry skiing and so on—for example, the effects of snowmobiling and backcountry recreation on the Revelstoke mountain caribou population.

**A:** My ministry is trying to develop guidelines to manage disturbance levels to wildlife.

## *8. Potential Changes in Forest Cover and Fire Danger in the Columbia Basin*

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### *Models and Scenarios Used*

A variety of models exist from various sources and use a number of different driving criteria. In order to standardize methods and to make results comparable between studies, the Intergovernmental Panel on Climate Change (IPCC) recommends the use of several different models and scenarios for comparing potential outcomes and to provide a mechanism for determining the range of potential results. Given time and resources, this is a goal yet to be achieved for this talk but an attempt was made to compare at least two IPCC scenarios.

There are a wide variety of global circulation models (GCMs) and potential emission and development scenarios to compare potential outcomes and impacts. For the purposes of this study only one model, the current CGCM2 (Canadian Global Coupled Model) was used with two of the more current IPCC Special Report on Emissions Scenarios (SRES) A2-1 and B2-1 development scenarios. A more complete description of the SRES scenarios can be found at the IPCC web site: http://www.grida.no/climate/ipcc_tar/wg3/081.htm.

The SRES A2 scenario assumes a very heterogeneous world with an underlying theme of self-reliance and preservation of local identities. It is a world of continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than the B2 scenario.

The SRES B2 scenario assumes a heterogeneous world with an "emphasis on local solutions to economic, social, and environmental sustainability." It is a world of continuously increasing global population but slower than the A2 scenario. Technological change is less rapid and more diverse, with more local and less global solutions.

This model is somewhat more conservative in its change projections than other potential models. The outputs from the CGCM2 model and scenarios show a middle of the pack scenario in terms of temperature change and middle to low end in terms of precipitation change. For both temperature and precipitation, the model and its scenario outputs are increased over current conditions.

### *Some Background on Method and Data*

So will the forest ecosystems change? In short, yes. Forests evolve with time, climate, and "natural" disturbances regardless of human influence. Paleoecological records show that both the climate and forest types have changed dramatically over time regardless of human influence.

Most forests in the Columbia Basin are relatively long-lived systems (80–100+ years) that are fairly resilient to short-term climate shifts. The first 20 years of a forest are critical for establishment, and then the overstory vegetation moderates the understory climate. Most of the species overlap ranges so that a ready supply of seed source is often available. Getting the stand established is the key.

In British Columbia we have an excellent classification system that incorporates dominant vegetation associations, site geology and topography, and climate known as the biogeoclimatic ecosystem classification, or BEC, zone system. Please note the order of the components in the name, as they also imply the significance of each component in the classification.

There are 14 major BEC zone types in the province and, depending on the zone, several or no subzones. Six of these zones can be found currently in the Columbia Basin.

For this study the following assumptions were made:

- The current major vegetation associations remain intact but, with time, are able to migrate up or down slope and/or north or south.
- Soils do not change quickly but will change over time.
- Given an adjustment to the climatic parameters and enough time, eventually the vegetation associations will adjust to match the climate.

The existing dominant biogeoclimatic zones and their associated forest types in the region include:

- Ponderosa Pine (PP)—ponderosa pine, bluebunch wheatgrass
- Interior Douglas-fir (IDF)—Douglas-fir, lodgepole pine, western larch, paper birch
- Interior Cedar-Hemlock (ICH)—western hemlock, western redcedar, Douglas-fir, western larch
- Montane Spruce (MS)—hybrid spruce, lodgepole pine, pine grass

Montane Spruce is not represented in the analysis but is dominant in the upslope areas of the Columbia Basin, particularly on the terraces above the valley floor in the Rocky Mountain Trench. Other zones in the region include the high-elevation Engelmann Spruce–Subalpine Fir and Alpine Tundra zones.

Two zones new to the Columbia Basin appear with the application of the scenario data: the Bunchgrass zone, which is a much drier zone than is now found in the region and is typified by the vegetation associations found around the Kamloops area; and the Coastal Western Hemlock zone, which is a wetter and somewhat cooler zone than those currently found in the region. It is typified by vegetation associations found around the Haney area of the lower mainland. As we will see shortly, this association is fairly weak and more an artefact of a lack of more comparable existing conditions in British Columbia.

Ten Environment Canada climate stations were selected for use in this study based on their length of record and location within the Columbia Basin. The intent was to gain as much spatial coverage with respect to both longitude and latitude. These sites are fairly limited with respect to the vegetation classifications covered; however, they do provide a general indication of the trends in change in that particular portion of the Columbia Basin.

This table presents the results of the projected change from the current biogeoclimatic or BEC zone type to another based on changes to the climatic parameters at a given study site for the year 2080 and two SRES scenarios.

| Station | Current Classification | SRES A2-1 2080 (Score) | SRES B2-1 2080 (Score) |
|---|---|---|---|
| Warfield | ICH dw | CWH (8) | CWH (11) |
| Castlegar | ICH dw | CWH (8) | CWH (10) |
| Creston | ICH xw | CWH (10) | IDF/PP (11) |
| Cranbrook | IDF dm2 | IDF/PP (12) | IDF (14) |
| Fernie | ICH mk1 | ICH (14) | ICH (15) |
| Nakusp | ICH mw2 | CWH (13) | ICH (13) |
| Invermere | IDF dm2 | BG (14) | BG/IDF (13) |
| Golden | IDF dm2 | IDF/PP (14) | IDF (14) |
| Revelstoke | ICH mw3 | IDF (13) | ICH/IDF (13) |
| Mica Dam | ICH vk1 | CWH (13) | ICH (13) |

The first column of data next to the station name is the current BEC zone and subzone classification. Note that all are either in the ICH (Interior Cedar-Hemlock) or IDF (Interior Douglas-fir) zones. The IDF is the drier of the two of these zones. The subzone classifications indicate drier or wetter, cooler or warmer sites within the zone.

The zone shift analysis was performed by evaluating 16 climatic parameters and giving them a value of 0 or 1, dependent on whether the future scenario value for that element fell within the limits currently defined for a given zone. The individual climatic parameter values were totalled and a score was produced. The maximum score is 16. The closer to 16 the total, the more the climatic conditions resemble a current BEC zone type. Where a study station had a tie score, such as the Cranbrook A2-1 scenario, then both BEC zones are listed. In most cases of a tie, the tie is between two BEC zones adjacent to one another in the vegetation/climate continuum (e.g., the IDF/PP zones, which are drier zones).

Some scores are very low (e.g., 8 for Warfield and Castlegar for the A2-1 scenario). These are reported but not held to be particularly representative of what the new BEC zone would potentially be like. Rather, it suggests that the new vegetation and climate regimes would be unlike anything that currently exists in British Columbia (warmer and wetter than any of the current interior BEC zones).

Most sites do not change or change very little. A few, like Invermere and Creston, change more. Depending on the scenario used, the change may be more or less, or wetter or drier. Invermere either dries out a lot (moving to a Bunchgrass zone) or a little, depending on the scenario. Creston either gets wetter (A2-1 is more like a Coastal Western Hemlock zone) or drier (B2-1 is like an Interior Douglas-fir or Ponderosa Pine zone).

In general, the trend in the Columbia Basin is for warmer and wetter in the southwest. The southeast and midwest (Cranbrook, Fernie, Nakusp, and Revelstoke) do not change much. The middle of the trench (Invermere) gets warmer and drier. The north and northeastern parts of the Columbia Basin (Golden and Mica Dam) do not change much.

### *Impacts on Forest Ecosystems – Potential Vegetation Shifts Due to Climate*

In some areas there is likely to be noticeable change. The areas that are projected to get warmer and wetter than they have been, such as Castlegar, are likely to support a wider variety and amount vegetation than they have in the recent past. Those areas that are getting warmer and drier, such as Invermere, are likely to support a lesser variety and amount of vegetation.

As far as the forests go, we will still see all the same types of trees we see now. Lodgepole pine will continue to be a dominant species. Douglas-fir range is likely to expand somewhat and the spruce on the hillsides may find it more habitable higher on the hill but will still occur. The range of the western larch is likely to expand northward as well as upslope. What will likely change significantly is the mix of trees on a given site, given that some species are able to disperse more effectively than others.

The key factor is management of regeneration. Once a site is actively regenerating and makes it through the first 20 years to reach crown closure (when the forest crown reaches maximum extent), the forest crown moderates the understory environment. After establishment, the forest is fairly resilient to change. The growth and health of the new forest may be either benefited or deterred, based on the changes in the climate.

### *Impacts on Fire Season Length and Severity*

We will see a change in the fire danger risk with a change in climate. Fire danger and weather are very closely linked.

Mike Flannigan, Mike Wotton, Bernie Todd, and others from the Canadian Forest Service lab in Edmonton, where our Fire Research program is based, used the Canadian Regional Climate Model outputs that were based on the original CGCM1 climate model to analyze change in fire danger risk.

In order to create a risk of forest fire, a number of factors must be present, and three are essential: the right weather conditions, a source of fuel, and a source of ignition. To have fire you must have fuels of varying sizes in order to sustain the burn—everything from needles and twigs to branches, logs, and standing timber. Finally, you need a source of ignition, either natural or human-caused.

Weather factors controlling fire risk are temperature, rainfall, humidity, and wind. All these factors are key in drying the forest to a state in which fire can be sustained and spread, as well as maintaining a rate of spread once a fire starts. Mike Flannigan has a 7-day rule regarding fire danger: forests can go from a danger rating of nil to extreme in 7 days if the weather conditions are right (e.g., warm temperatures, no rain, low humidity, a low to moderate wind).

Can we control any of the factors that affect fire risk? Not greatly, but we can limit their impact to a certain extent. Weather factors are, at present, beyond our control. Modifying a potential fuel source is possible using intensive stand management techniques and the controlled use of fire. Ignition sources (particularly from lightning) are also largely out of our control. If a fire starts, we then need to evaluate the potential risk of letting it burn or the degree of response and resources required to suppress it.

Using the Canadian Regional Climate Model output we can illustrate the potential change in the length of fire season under a 2X $CO_2$ Scenario. Much of the Columbia Basin falls in a zone where the length of the fire season is increasing by 38–52 days. The fire season in the southwest portion of the Columbia Basin is projected to increase in length to a lesser extent.

Why is this important? Consider the costs of maintaining readiness of fire crews and equipment or the costs due to forest closures due to fire risk not only for harvesting or stand maintenance but for recreational use as well.

The seasonal severity rating (SSR) is a means of aggregating the daily fire weather index into an annual value for the whole fire season. Comparing the change in SSR allows for a more meaningful evaluation of the impact of a changing climate on fire danger.

A map of northwestern North America, using the Canadian Regional Climate Model scenario outputs, shows the potential change in the seasonal severity rating from a 1X $CO_2$ to a 2X $CO_2$ concentration. The Columbia Basin has a broad range of change—from almost no change, or even a slight decrease in fire danger in the northern portions of the Columbia Basin, to upwards of three times the severity rating in the southwestern portion of the Columbia Basin.

Please keep in mind that the results from the vegetation change analysis and this one are not directly comparable, as they used different models and scenarios. However, the results do show that the different models and scenarios produce a range of change.

Some of the bigger impacts of altered fire regimes are as follows:

- Fires help to accelerate vegetation changes.
- Severe stand-replacing fires profoundly change the age structure of the forest. Any fire will change the forest composition by altering or destroying parts or all of the on-site vegetation and replacing it with something else.
- Fire will aid in species migration by providing a mechanism for removing marginal vegetation, and providing opportunities for new species, better adapted to the new environment, to take hold.
- There are interactions between other agents of change in the forest that may be amplified or reduced. The various interactions between fire and wind, insects, or disease are likely to change with a change in climate.
- Fire is also a competitor for wood. With increased numbers and severity of fires, then the potential amount of timber available for harvest may decrease.

So, is fire a problem or not?

Fire is a natural part of most of the ecosystems in the Columbia Basin and is required for some systems to naturally regenerate. However, the fire season is projected to increase between 38 and 52 days across most of the Columbia Basin. The result is a potential increase in management costs and resources. Increasing numbers of fires also decrease air quality with smoke and particulates. In turn, this may lead to increased health issues for some people in the Columbia Basin.

When examining adaptation to a changing fire environment we need to consider that fire exclusion is not an option. Fire is a natural part of most of the ecosystems in this area and is, indeed, beneficial for regeneration of some species and controlling vegetative competition. The costs to exclude fire would be both prohibitive and counter-productive.

Including fire in the landscape management plan will help to reduce the overall negative impacts of fire. Part of this management plan would include conversion of fuel types from those that sustain large fires to those that don't, reduction of overall fuel loading, isolation of fuels, and creation of "FireSmart" landscapes that manage fuel loading and fuel types, and include strategically located fire breaks (more information on FireSmart planning, particularly for rural communities, can be found at http://www.partnersinprotection.ab.ca/).

In preparation for a changing climate and/or landscape, we need to perform protection-effectiveness studies to determine the most cost-effective risk/protection benefit analyses.

Other significant challenges facing the forests of the Columbia Basin and not addressed here include:

- Changes in timing—will longer summers and shorter winters alter access to the timber? Is a longer, potentially more severe fire season going to reduce summer access and does the shorter winter mean that there will be less time to access the resource in areas where winter harvesting is preferred?
- How will pest survival be altered and will this help or hurt the trees? Allan Carroll will be addressing one of these in a few minutes but there are many others. Will the changes in conditions aid or deter tree growth and vigour? An increase in vigour helps the trees fend off attack; a decrease leaves it more vulnerable.
- Extreme events—whether from direct storm or snow damage to trees, changes in thunderstorm activity, or damage to the resource due to slides or washouts.

To summarize, a changing climate affects both the forest vegetation and fire regime, as neither is mutually exclusive. Any changes in vegetation are not likely to be rapid due to the relatively long lives and resiliency of forest ecosystems. Changes in fire regimes are likely to occur more rapidly but it may be possible to manage this change using existing forest management methods.

## *9. Climate Change and Range Expansion by the Mountain Pine Beetle*

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### *Why Bother with Insects?*

Insects are very responsive to even very small changes in climatic conditions. This is because they are cold-blooded. Every aspect of their life cycle is dependent upon temperature. Insects also have extremely high reproductive rates and tend to be very good dispersers—moving quickly to new habitats, often covering great distances in a single season. Because of these characteristics, researchers have begun to look for evidence of adaptations to climate change in insect populations.

Evidence from several butterfly and cricket species in Britain suggests that there have been behavioural shifts in which insects have begun to exploit different types of habitats or host plants; there have been changes in genetic expression where a greater proportion of dispersing morphs are appearing at the margins of some species ranges; and of course, there have been changes in range expansion itself where populations are expanding into formerly unoccupied areas.

Although there is very good evidence that forests are responding to changing climate, particularly at the treeline, the capacity of insects (and other mobile organisms) to respond to climate change is far greater than most other components of a forest ecosystem. This suggests that in the short term we will begin to see: imbalances such as the appearance of species in habitats they are not normally associated with; the elevation of formerly innocuous species to damaging levels; or even site conversion to shrub or grasslands where disturbance in combination with rapid climate change causes a site to be unsuitable for the regeneration of local tree species. The longer-term is a bit more difficult to conceptualize, but we have no doubt that forests will continue to exist. The community structure within these forests, however, may be entirely new.

Although the general consensus among researchers is that most insect populations will benefit from global warming, an orderly march toward the poles or up mountainsides is very unlikely for several reasons. First, the rate of climate change is a great deal faster than any detected in the past. Second, the way in which each species responds to changing climate is often very different. Finally, and probably most important, the effects of warming are not anticipated to be uniform around the globe. Asymmetry in warming across systems will increase the variability in ecological processes.

From the point of view of a forest insect, we anticipate both pros and cons due to changing climate in the short term. The advantages are:

- Reduced winter mortality
- Increase in thermally benign habitat
- Reduced host resistance (mainly for herbivores)
- Escape from competitors/predators (for highly mobile insects)
- Increased host range due to access to new habitats and resources

The disadvantages are:

- Phenological asynchrony
- Reduction in thermally benign habitat (from excessive warming)
- Shifting or depletion of hosts
- Competition or predation from invasive species
- Dispersal costs to new habitats

What is apparent is that there seems to be no predictable pattern of insect response to climate change. This is not surprising since we have known for years from the fossil record that during the warming period following the last glaciation, the response of species to a changing climate was quite variable. Nonetheless, we may be able to determine general trends in the response of forest insects.

### *Mountain Pine Beetle – Pine Interaction: An Ideal System for Study*

The mountain pine beetle is an ideal insect with which to assess the general impacts of climate change on forests for many reasons. First, as a beetle, this insect is a member of the most common and ubiquitous group of insects on the planet. Second, it belongs to the family Scolytidae, the bark beetles. It is therefore a common component of forest ecosystems, and comprises one of the primary disturbance agents in the coniferous forests of western North America. Third, the mountain pine beetle has a very broad host range, breeding successfully in nearly all native pine species. Fourth, it is widely distributed—occurring from northern Mexico, through a dozen US states, and into three Canadian provinces, although it is mostly restricted to British Columbia. Fifth, the beetle can disperse tens of kilometres in a season. Finally, and most importantly, its distribution is limited almost entirely by climate.

To colonize a tree, mountain pine beetles bore through the bark into the phloem (the region between the bark and the wood). In the process, they release pheromones that initiate a mass attack, which is critical to overcoming a tree's defence. Once mated, females construct a gallery and begin to lay eggs in niches along the edge of the gallery. The eggs hatch about a week after they are laid. Larvae then begin mining outwards into the phloem tissue, developing partially in the fall, then over-wintering until spring and early summer of the next year, when they pupate. Young adults feed for a time before emerging to disperse into the forest to select new hosts.

In British Columbia, large-scale mountain pine beetle outbreaks have occurred four or five times during the last century. It is interesting to note that the relative size of outbreaks is correlated with an increase in the amount of susceptible pine in the province. Given that both lodgepole pine and jack pine are suitable hosts, the mountain pine beetle really occupies only a fraction of its potential range. This is especially curious given that lodgepole pine extends all the way to the Yukon and Northwest Territories. And so this begs the question: What limits the beetle's distribution?

Maps showing the historic distribution of beetle infestations compared with distribution of lodgepole pine indicate clearly that the mountain pine beetle has not been limited by available hosts. Instead, the beetle is limited by two critical aspects of climate. First, where summer temperatures are normally too cool for beetles to maintain a single generation per year, infestations are uncommon. Where infestations have occurred in these areas, they are usually associated with several years of above-normal summer temperatures. Second, where winter temperatures reach -40°C or below for at least 1 day per year, infestations cannot persist, and virtually 100% mortality occurs in a population. Maps showing the historical distribution of the beetle bear this out, and infestations are neatly bounded by the -40°C thermocline.

### *Interaction of Forest Stands and Mountain Pine Beetle Today*

Observations of the current outbreak suggest that it may extend into areas further north and east than usual. The northern limits of the epidemic include Smithers and Fort St. James, and some populations extend as far as the Skeena and Babine Rivers. In the east, a large population is established in Banff and Canmore, and several small, but persistent, populations have been found near Mt. Robson and Jasper, and even into the Willmore Wilderness area of Alberta's northeastern slopes.

Based on this evidence, we have asked the following questions: Has there been a shift in climatically benign habitats for mountain pine beetle during the past 40 years? Have mountain pine beetle populations expanded into these new areas? What do scenarios for the future look like?

To determine if there has been an improvement in climatic conditions for the mountain pine beetle, we have adapted an existing model of the impact of climate on the beetle's infestation likelihood. This model is based upon well-established relationships between climatic conditions and mountain pine beetle fitness. When we run this model we see that, during the last century, climatically suitable habitats have shifted northward and higher in elevation. This shift is most noticeable in southern and central British Columbia, exactly where the outbreak is currently focused.

So the potential range of mountain pine beetle has increased, but has the beetle exploited this shift? To determine if beetle infestations have followed the expansion of climatically suitable habitats, we overlaid maps of the occurrence of mountain pine beetle in the province on a map of historically suitable climate for the species. We then summarized the number of times that infestations intersected habitats in each of five climatic suitability classes (very low, low, moderate, high, and extreme) from 1959 to present. We found that the beetle has already expanded its range considerably. During the last 40 years, the number of infestations in habitats that were normally considered to comprise very low and low climatic suitability increased at an increasing rate—meaning that conditions became more suitable for the beetle with time. Not surprisingly, with an increase in favourable climate, the number of infestations in moderate and high suitability classes increased as well, though only linearly. We were surprised, however, to find a significant decline in recent years in the infestations occurring in the most suitable (i.e., extreme) habitat class.

The decline of mountain pine beetle in the most suitable habitat class may result from a decrease in this habitat type due to harvesting, wildfire, or the beetle itself, or it may result from adverse effects of warm temperatures. If summers are sufficiently warm, beetle populations may be forced into partial multivoltinism (segments of the population have more than one generation per year), which would force cold-susceptible stages to overwinter and interrupt flight synchrony and mass attack success in the following year.

To assess whether the decline in the number of infestations in the historical extreme suitability class was a consequence of a loss of these habitats or degradation in their quality to the beetle, we used the Forest, Range, and Recreation Resource Analysis 2 x 2 km spatial forest inventory (British Columbia Ministry of Forests). We then developed a spatially stochastic age class projection model to estimate stand ages for the pine-dominated polygons for the periods before and beyond 1990, incorporating the effects of fire and harvesting.

Assuming that pines between the ages of 80 and 160 years are most susceptible to mountain pine beetle, we overlaid the projected pine inventory maps on the appropriate maps of historic or future climatic suitability and determined the areas of susceptible pine in each climatic suitability class for each time period, and saw that the area of susceptible pine in each climatic suitability class, including the extreme class, has increased to the present. This means that the decline in the numbers of infestations in these types of habitats has not been a result of a reduction in the amount of habitat, but instead is more likely a result of habitat degradation.

Using a plausible climate change scenario such as the CGCM1 general circulation model of climate change (Canadian Global Coupled Model 1) developed by the Canadian Centre for Climate Modelling and Analysis, we can extend our assessment of climatic suitability for mountain pine beetle into the future.

Our modelling predicts a clear expansion north and east of climatically suitable habitats, suggesting that mountain pine beetle populations will continue to move north and into higher elevations, and that southern habitats may become unsuitable for their resident populations due to seasonal asynchrony as a result of partial multivoltinism. This does not necessarily mean that southern pine forests will not have mountain pine beetle. Researchers with the US Forest Service have recently shown that southern beetle populations are better adapted to warm summers than northern populations, which could mean that southern beetles could move into more northerly areas such as southern British Columbia.

### *Climate Change Implications for Columbia Basin Forest Ecosystems*

If we look specifically at the Columbia Basin, we can predict that the most suitable forests for mountain pine beetle will tend to be restricted to higher elevations. This implies that mountain pine beetle will have access to sensitive habitats such as whitebark and limber pine forests (whitebark pine is critical to rare species such as Clark's Nutcracker and grizzly bear), and in turn this will lead to modified fire dynamics in "new" habitats. We also expect short-term site conversion and altered biodiversity with changes in ecosystem sustainability due to a combination of beetle impacts and an unprecedented rate of climate change.

### *Audience Questions for Allan Carroll*

**Q:** Is there a conflicting or different perspective on how to manage for beetle and fire between industry and government?

**A:** The only viable means of controlling mountain pine beetle is to remove beetles from the population. Unfortunately, this can be done only by removing the trees that they infest. Consequently, management of beetle in British Columbia involves one thing—cutting affected trees. There is no difference between how industry and government approaches this.

**Q:** (Comment) The idea that fire is competing for wood is troublesome. Big business might take advantage of climate change. We need to shift our thinking so that we can incorporate climate change into our forest management and work to prevent insect problems, changing forest practices to mitigate mountain pine beetle and fire.

**A:** The increase in beetle appears to be directly related to our forest management activities; in particular, fire suppression. The fact that we have problems is not surprising, given the amount of mature pine in the province. Effective management of the mountain pine beetle takes a much longer-term view that is difficult to sell. If we can, we should attempt to reduce large contiguous stands of pine on the landscape.

*For more information on mountain pine beetle, visit the web site of the Pacific Forestry Centre, Canadian Forest Service (Natural Resources Canada) at:* *www.pfc.cfs.nrcan.gc.ca/index_e.html* .

## *10. Adapting to Climate Change: What Can We Do?*

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***What is Adaptation?***

*"Adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts.".*

This is the definition provided by the International Panel on Climate Change in its most recent reports. It recognizes that both natural and human systems can and do adapt. It also recognizes that adaptation can be responsive (initiated after change has actually occurred), or it can be anticipatory (initiated in advance of expected change).

The term "climate stimuli" refers to two aspects of climate change: changes in mean or average climate, and changes in climate variability and associated extremes. Their impacts can be harmful, tolerable, or beneficial. Adaptation can help reduce harmful impacts and realize beneficial ones.

In general, systems are adapted to the historic climate regime, and have evolved or developed strategies to cope with historical climate variability. Climate impacts within the coping range are beneficial or tolerable. Climate impacts outside of this range are not tolerable. To give a simple example, there are minimum and maximum temperature requirements for fish habitat. Above or below a certain temperature range, fish die. Within the coping range, fish are able to survive or thrive. To give a more complex example, water management systems are designed to cope with seasonal and year-to-year variability in precipitation and water supply.

There is a difference, however, between adaptation to climate and adaptation to climate change.

Coping strategies that evolved or were designed with historical climate variability in mind may be able to address changes in average climate. They may not, however, be able to address changes in the frequency and severity of climate extremes. Under such conditions, the system becomes more vulnerable. In the short term, this is probably what we are most concerned about.

Natural systems will respond autonomously to new climate conditions. If change is moderate, they may continue to cope, or adjust and recover. If change is more significant, they may undergo a fundamental change, or cease to exist. New natural systems will eventually develop new coping strategies that are suited to the new climate regime.

Human systems can also respond autonomously to climate change, and history provides many such examples. In addition, climate models and other new tools now give us the capacity to project future climate, and the option of planned, anticipatory adaptation. It is also important to keep in mind that in many circumstances, autonomous human adaptation is probably okay.

Adaptation is promoted by:

- Private interests: individuals, households, businesses, corporations, workers
- Public interests: local, regional, provincial, and national governments.

Different players initiate different types of adaptation measures.

Climate impacts vary from one geographical location to another, so most adaptation needs to take place at the local or regional level. This means that communities of place—the people who live in an area—need to be involved.

One of the things we are trying to be clear about, as government, is what we should do and what we need to empower others to do.

Targets for adaptation are:

- Natural systems
- Managed systems
- Human (or social) systems
- Infrastructure and investments

We have talked about natural or biological systems, and during the working groups and the plenary session later this afternoon it would be a good idea to think about human systems.

Through adaptation we want to:

- Enhance the adaptability of vulnerable natural systems, for example, by reducing other (non climatic) stresses—typically a public responsibility in British Columbia.
- Increase the flexibility of vulnerable managed systems, for example, by allowing mid-term adjustments (including changes of activities or location)—an activity that both public and private sectors can initiate.
- Reverse societal trends that increase vulnerability, for example, by introducing setback lines for development in vulnerable areas such as floodplains—typically the responsibility of local governments.
- Improve societal awareness and preparedness, for example, by setting up a drought early-warning system—typically a national program.
- Increase robustness of infrastructure and long-term investments, for example, by extending the range of temperature or precipitation a system can withstand without failure—private sector and businesses do this.

So what we really have is a range of options and players involved in adaptation.

Adaptation measures address a range of time scales:

- Short-term contingency options address extremes associated with climate variability (e.g., emergency drought management, flood forecasting—year-to-year variation).
- Mid-term tactical options address climate variability (e.g., flood-proofing, water conservation measures).
- Long-term options address mean changes in climate (e.g., river basin planning, institutional changes for water allocation).
- Analytical options consider climate change effects at all scales (e.g., data collection, water management modelling).

It is important to keep the following thoughts in mind as we go into working groups and discuss adaptation this afternoon:

- What are our short-, mid-, and long-term needs?
- How do we get there?
- Impacts of climate change
- Vulnerability of systems

There are two broad approaches to adaptation.

The first approach to adaptation focuses on identifying the impacts of future climate change, and measures to address these impacts. This approach emphasizes long-term adaptation needs and planned, anticipatory adaptation. Impact assessment is a complex undertaking, subject to the uncertainties of modelling, and sometimes contradictory data, as some of today's presenters have indicated. It also needs to involve researchers and other experts who know how to work with climate models and scenarios. Community access to impact assessment is primarily through research collaboration.

The second approach to adaptation focuses on system vulnerability to climate change, and ways to decrease that vulnerability. It assumes that improving adaptation to historical climate variability and extreme events is a step towards reducing vulnerability to longer-term climate change. This approach emphasizes short- to mid-term adaptation needs, and measures that increase flexibility and resilience. We can characterize these measures as "win-win" or "no regrets" because they convey benefits now and in the future. Examples include increasing storage capacity in water systems already vulnerable to dry years, or restoring native grassland ecosystems. Many of these options are also examples of sustainable development. Communities can pursue such measures now, regardless of climate science.

We need both approaches. The difference between them is that the first approach starts in the future and works backwards to the present, and the second starts in the present and works forward.

What can we do?

- Collaboration
- Communities
- Mandate
- Tools
- Information

It is only recently that policy-makers in Canada have started to recognize that adaptation must be part of an effective response to climate change. We are still very much in the early stages of exploring what this means and how to do it. Governments in particular need better ways to develop and implement adaptation strategies.

We can, however, make a number of general comments:

- **Adaptation will require a collaborative effort.** The cost of modelling and range of responses mean that no one party will be able to go it alone. The speed at which climate change is expected to occur means that we need to share methods, information, and tools.
- Because adaptation should occur at the local or regional level, **communities—and by that I mean communities of place—have an important role to play.** Their needs and concerns, as well as their expertise and resources, are integral to effective adaptation.
- **Government has the responsibility and the mandate to co-ordinate adaptation efforts.** Both the federal and the British Columbia governments have committed to include adaptation in their climate change strategies and plans. Governments in Canada are working together to develop a national adaptation-planning framework.
- **Governments have some tools that can support adaptation.** Both provincial and federal agencies maintain observation networks and have information and data that can support adaptation planning and other initiatives.

Federal resource agencies have significant scientific and technical expertise that can be applied to climate change. The federal Climate Change Action Fund includes $15 million for impacts and adaptation research.

The British Columbia government manages some sectors and regulates others. It has an interest in ensuring that its policies and programs support effective adaptation, and that communities have access to the information and tools they need.

Because adaptation takes place at the local or regional level, we need information relevant to those levels. The Canadian Climate Impacts and Adaptation Research Network is a province-wide network designed to link researchers and communities, and promote impacts and adaptation research.

Communities can make an important contribution to adaptation by identifying their needs, concerns, and priorities to government and other partners. Governments in particular need a better understanding of these priorities in order to develop effective adaptation strategies.

### *About the Afternoon Working Groups*

This morning, we heard from a range of experts about the kind of changes that may occur in the Columbia Basin. I want to stress that your questions and concerns are as important as the expertise we have heard to this point.

This afternoon, Columbia Basin residents have an opportunity to share their reaction to these presentations, and their related knowledge, concerns, questions, and ideas:

- What have you observed about climate in the Basin?
- What human systems are you most concerned about?
- What information do you need to start a plan to address climate change?
- What resources—information, tools, data, expertise—are available in the Basin?

Finally, the afternoon session will give you the opportunity to explore ways of increasing local capacity to adapt to climate change, and local involvement in research and the development of adaptation strategies.

I do want to caution you to resist the urge to try to solve problems such as mountain pine beetle infestation during the workshops this afternoon. I encourage you instead to look at what information you have now, what information you need, and how and where to gain access to the skills and tools necessary to deal with climate change.

# Saturday Afternoon Working Groups

On the afternoon of Saturday, January 18, conference participants were assigned to one of seven working groups (based on stickers on their name tags, hence the titles of the working groups). A facilitator then led each group in a 1-hour discussion focused on the following five questions:

1. How have weather and climate variability and extremes affected your community, business, or agency in the past?
2. How has your community, business, or agency adapted to climate in the past? How effective have these measures been? How could they be strengthened?
3. How might future climate change and the impacts discussed in the morning session affect your community, business, or agency? Which impacts are of most concern to you?
4. What policies, information, tools, and/or skills would help your community, business, or agency prepare more effectively for climate change?
5. Climate change adaptation will be an ongoing process. How can researchers, decision-makers, and communities in the Columbia Basin best continue the dialogue on this topic?

## *Summary of Group Discussions*

### *1. Past Impacts*

Local climate changes observed by workshop participants over the past decade include low snow packs, lower water levels, shorter freezing time of lakes, increased flow variability in the river systems, intensified summer droughts and more frequent storms causing forest blow down. Likewise, changes to wildlife include: decreasing caribou herds (low snow levels do not allow access to tree-growing lichens); changes in fish migration patterns, increased pest infestations (e.g. spruce beetle) and the observation of new bird species in the Columbia Basin. Climate change is also affecting human systems such as: ski hills, backcountry recreation, the forest industry during fire season, and oil field activities. Workshop participants emphasized that the changing climate is just one among many factors affecting the natural and human systems in the Columbia Basin. Land-use decisions, such as dammed rivers, result in decreased land and fish habitat, relocations and impediments to wildlife migration, and increased conflicts between ranchers and fisheries. In addition, increased fire control has substantially changed grassland landscape.

### *2. Past Adaptation*

While many of the adaptations observed by participants have been successful, these successes have sometimes come at a cost to other ecosystems, sectors, or stakeholders. Participants agreed that adaptive measures are strengthened through leadership, planning, and education. Water-level adaptation strategies have included: dams to the Columbia River to reduce local flooding; Cranbrook's water conservation measurements and change to a groundwater supply source; Invermere's water metering, which resulted in a 30% drop in water consumption; the establishment of irrigation systems in Revelstoke to cope with an increased frequency of droughts; and Kimberley's channelling of Mark Creek to eliminate future floods, unfortunately to the detriment of downstream fish. BC Hydro adaptation was limited by obligations to maximize power under the Treaty, and by a fixed planning agenda (e.g., climate change was only recently included in plans, because planning was originally based on a thirty-year cycle of records). Adaptation efforts by the Canadian Pacific Railway are focused on developing early warning systems for extreme weather events.

### *3. Future Impacts*

Participants were concerned about the future impacts of climate change on agriculture, forestry, outdoor industries and human health and safety. An increase in weed species will reduce forage production and reduce health of rangeland. There may be an increase in soil erosion, and a change in the amount of fuel available may lead to more forest fires. Forests and farmland are also prone to more severe damage due to insect infestations, such as the mountain pine beetle. Fluctuation of snow levels will have implications on regional ski operations and backcountry recreation, may lead to a change in frequency of avalanches, and may cause glaciers to recede. Decreasing accessibility to potable water could lead to conflict, while extreme weather events leading to flooding could cause outbreaks of waterborne human pathogens such as *Cryptosporidium*. Participants also expressed concerns about how global trends will affect the Columbia Basin. For example: the consequences of world agricultural production on food security in the Columbia Basin; external demand for water and the potential for water export; and how international trade will impose pressures on the region.

### *4. Effective Preparation for Climate Change*

Workshop participants identified effective education as the single most important preparation for climate change, including both public education and the special training of professionals. Education should develop climate change adaptation strategies. Improved monitoring, government management of public lands and water use, and adaptation-related tax incentives were also discussed as essential by workshop participants. As well, participants cited the need to develop more adaptation tools, such as innovative water recycling systems. Several "no regrets" actions were also highlighted, including management of forest ecosystems involving partial cutting and low intensity thinning, and the extension of agricultural land to capitalize on the Columbia Basin's longer growing season.

***5. Next steps***

On-going dialogue (via a list-serve and future meetings), as well as communication with US counterparts, in order to build a support network professionals involved in climate change issues is essential. Involvement of funding organizations as well as coordination with land-use planners (at the next workshop of the Planning Institute of British Columbia) and other stakeholder organizations, such as the Chambers of Commerce, were cited as important next steps towards regional climate change adaptation. Leadership, teamwork, political direction, and public education are all fundamental to improved climate change adaptation. In particular, research and adaptation strategies must be communicated to the public and to stakeholders in plain language. Finally, incentives for climate change adaptation should be developed and implemented.

*The following pages include points from the discussions, as recorded for each of the working groups.*

## 1. Yellow Group

***Facilitator:***
Mark Johannes

***Participants:***
Stacey Barter
Bill Green
Bill Hickman
Ron Lakeman
Mike Malmberg
Derek Marcoux
Lynn McIntosh
Brian McLaughlin
Peter Ross
Stephanie Smith
Chris Steeger
Lorna Visser

The Yellow Group chose to begin their discussion by establishing the following set of working assumptions:

- Everyone has knowledge and wisdom
- We need and want everyone's knowledge and wisdom
- There are no wrong answers
- Everyone will be heard
- The whole is greater than the parts
- Shoot for overarching questions

- Our input will lead to action

### 1. *Past Effects*

Peter Ross: The Fernie snowpack is lower than average. Gardening impacts such as early frost and longer growing season.

Brian McLaughlin: Hotter seasons and less skiing. Access into forest for industry during fire season an issue, and oil fields cannot do work during climatic extremes.

Chris Steeger: Ymir is a traditional snowbelt. Salmo River is lower than average over the past 13 years according to personal observation. Creates vulnerabilities for fish travelling from pool to pool during winter months. Common snipe observed along the Salmo River.

Peter Ross: Blue Jays have been observed in the Elk Valley, whereas they are traditionally an Eastern species.

Chris Steeger: Birds possibly moving via Rocky Mountain passes into new territory.

Stephanie Smith: Extreme years in the last decade have led to increased flow variability. BC Hydro also more constrained by fish habitat issues.

Mike Malmberg: Includes market availability of power.

Bill Hickman: Unusual frost events in Victoria observed several years ago.

Bill Green: Impacts to ski hills.

Derek Marcoux: Impacts to commercial backcountry recreation.

### 2. *Past Adaptation*

Chris Steeger: Many ski operations are viable due only to the Christmas season and need snow then to operate.

Mike Malmberg: Impacts by weedy species, for example, knapweed invasion and perennial pepperweed. Climate change will allow easier access by weeds, reduce forage production, increase soil erosion, and reduce health and condition of rangeland.

Brian McLaughlin: Undergrowth of forest will result in large fires going through the valley.

Chris Steeger: Catastrophic fires will increase in the Salmo area.

Bill Hickman: Mountain pine beetle will become more of a problem.

Peter Ross: Will the aquifer supply be able to recharge itself with more dry weather?

Chris Steeger: If wells run dry and pumps are damaged, pumps will need to be fixed or replaced.

### *3. Future Impacts*

Bill Green: Cranbrook moved to a groundwater supply.

Mike Malmberg: Conservation was put into place, with on/off watering days.

Brian McLaughlin: Water metering in Invermere resulted in a 30% drop in water consumption.

Peter Ross: Agricultural land will be affected, as there may be less water where the most agricultural activities are now taking place. Protection of agricultural land will be an increasing concern.

Bill Green: What about weed development on agricultural land?

Mike Malmberg: Aggressive weed control program will be required, with hired contractors to develop educational programs about the weed invasion. For example, pepperweed was caught recently.

### *4. Effective Preparation for Climate Change*

Peter Ross: Some people are still building on or near floodplains. We need to reflect on this if flooding is going to be more frequent or severe.

Chris Steeger: Large-scale fire events could take place and affect personal and business property—interface fires. We need to prepare for that.

Brian McLaughlin: Movement of Alberta residents into the East Kootenays region as climate becomes drier east of the Rockies.

Chris Steeger: The Species at Risk Act has an effect. For example, caribou will be "affected" due to lower snowpack and unavailable lichen forage. The need to protect that species will have trickle-down effects on snowmobile clubs, conservation officers, and so on. We need to think about that.

### *5. Continued Dialogue / Next Steps*

Derek Marcoux: Land use planning needs to include climate change or at least consider it.

Brian McLaughlin: We need more resources and more public education about climate change and adaptation, as well as changes in fire suppression methods.

Mike Malmberg: How can we adapt to change, when it is the trend of governments to resist change? We need a shift—maybe stop investing money in trying to stop change, and try to adapt instead, and focus money there.

Chris Steeger: We need an increased awareness of risk, and to take responsibility for our actions.

Mike Malmberg: We need an increased awareness of the linkages between climate change and our actions.

Chris Steeger: We need to lobby government.

## *2. Green Group*

***Facilitator:***
Julia James

***Participants:***
Gordon Ambrose
Ross Benton
Gundula Brigl
Peter Davidson
Ginny Garner
Ben Kangasniemi
Norbert Kondla
Kyle Levy
Llewellyn Matthews
Christopher McCrum
Catherine Prowse
Harry Quesnel
Leanne Reitan
Rick Rodman
Hanna Romano
Heath Slee
Carol Watson
Greg Utzig

### *1. Past Effects*

Peter Davidson: Large fires in the 1920s and 1930s used to keep mountain pine beetle in check, and performed natural forest management. Regular floods in the Elk River took place near Kimberley and Fernie. Encroachment on grasslands is occurring due to climate and management decisions. Climate change has affected renewable resources.

Ginny Garner: Elk Valley flood in 1995. Communities need assistance from government for flood control and to mitigate losses.

Peter Davidson: Need for floodplain legislation to protect communities. Need for fireguards.

Heath Slee:  Impact of dammed rivers—land loss, relocations, fisheries losses. Humans have stopped wildlife migrations.  There have been impacts on the microclimate of this area according to personal recollection.

Gordon Ambrose:  Three-metre wide streams (S3) have been affected; lower water levels or dry creeks in summers; possible rancher/fisheries conflict due to irrigation and flow requirements.

Leanne Reitan:  Loss of areas to use for college level natural resource teaching of students due to poor snow/water conditions; increased salt use on roads; increased number of accidents; high costs for insurance and highway maintenance.

Peter Davidson:  We have lost grassland habitat and species therein.

### *2. Past Adaptation*

Harry Quesnel:  Columbia dams have reduced the amount of flooding in our area.

Heath Slee:  Lack of flooding has reduced natural siltation and fertilization.

Greg Utzig:  Fertilization must now be done to combat the lack of nutrients.  We have also lost salmon migration to the area.

Heath Slee:  Siltation of dams equals no flushing.

Greg Utzig:  Manipulation of the system by dams is beneficial to a certain extent. Who are the net winners and losers in this situation?

Peter Davidson:  We have seen a loss of winter range for animals; treeline displacement has affected wildlife; fire control and range enhancement programs are contradictory.

Norbert Kondla:  Genelle has a well-based, safer, more reliable water supply rather than surface water because surface sources were not reliable.

Harry Quesnel:  Historic lack of people or lack of records may have implications for our climate change predictions and therefore our adaptation decisions based on those predictions.

Greg Utzig:  Better understanding of systems may allow for better adaptations of humans to ecosystems, and may result in more flexibility in the future regarding possible dam removal.

Gundula Brigl:  System resilience has occurred; for example, increased standards of culvert installation in road building due to past flooding and slides.

Peter Davidson:  Forestry has started to use natural disturbance types to design cuts, based upon studies of past disturbances and their effects.

Harry Quesnel:  Should we really base an unknown future on past predictions?

Peter Davidson:  Monoculture in forestry has reduced ecological viability.

Gordon Ambrose:  Is adaptation inevitable?  Will we have knapweed plains like in South Montana?

Gundula Brigl:  Using chemicals that respond to different temperature ranges on roads is a technological adaptation.

Harry Quesnel:  Use the past knowledge to manage the future only if we are confident that past knowledge is correct.

Peter Davidson:  We need to promote natural communities in management areas.

Ross Benton:  Natural communities are changing.  Tembec in TFL 14 is planting different species of trees to accommodate changes in communities, in order to increase diversity on multi-age/multi-species plantations.

Peter Davidson:  Diversity structures are not necessarily being addressed.

Ross Benton:  Should we be looking at setting aside proper tree farms and not managing other landscapes for tree farming?

Harry Quesnel:  We are breaking up age classes and species mix in the forest to accommodate mountain pine beetle.

Rick Rodman:  We need to think outside the box—study floods on the Goat River. Do not build any more dikes, but flood-proof individual buildings.  This is probably cheaper and has less impact on the actual river.  We also need forward-looking zoning standards to avoid flooding situations.

Ginny Garner:  Individuals need to be educated to mitigate issues.  For example, people should fire-proof their property instead of the forest being fire-proofed.

### *3. Future Impacts*

Gordon Ambrose:  Fernie ski hill may have problems due to lack of snow.

Harry Quesnel:  Fluctuations/uncertainty in snow levels will affect the ski industry and the tourism industry.

Heath Slee:  Uncontrolled use of public land by ATVs, snowmobling, etc., may cause wildlife and vegetation impacts.

Greg Utzig:  Systems are interconnected.  Human impacts are amplifying climate/land issues at present.  We should look at how we can mitigate issues.

Peter Davidson:  A higher treeline will reduce the Annual Allowable Cut.

### *4. Effective Preparation for Climate Change*

Ginny Garner:  Bring fire back into ecosystems.

Gordon Ambrose: We are going to get more "not in my backyard" if we start controlled burning.

Harry Quesnel: Fire can be used effectively.

Greg Utzig: Effective partial cutting and thinning combined with low-intensity fires would reduce fire hazard.

Peter Davidson: Money and initiatives for public lands should come from government.

Greg Utzig: Money spent on combating large fires would be better spent on re-introduction of fire ecosystems.

Kyle Levy: Water usage will be a large cost in the future. We need to create the use of water recycling systems.

Peter Davidson: Increased monitoring and research of ground and surface water.

Llewellyn Matthews: The greatest water uses are in irrigation. Use xeriscaping.

Peter Davidson: The Ktunaxa tribe is growing native species for reclamation. These species are not always being used elsewhere; for example there is some hydro-seeding with non-native species. What is sometimes deadly to wildlife can also be palatable to wildlife.

Norbert Kondla: One must be careful with introduction of species or native species on disturbed areas. We should not try to apply the same solutions to every situation.

Heath Slee: The average food travels 2500 to 4000 kilometres from production to plate. We should decentralize food supply to reduce transportation impacts. Longer growing seasons may allow for better growing.

### *5. Continued Dialogue / Next Steps*

Harry Quesnel: We need policies to accommodate long-term change.

Rick Rodman: Source policies are already in existence.

Llewellyn Matthews: Regular regional meetings to exchange ideas and educate communities and individuals.

Leanne Reitan: Make sure that the public is involved in the situation as well.

Peter Davidson: We need the re-establishment of government authority.

Rick Rodman: Industry should have incentives to promote research and development.

Harry Quesnel: Long-term fire management strategies are necessary on a community level. We need more education.

## 3. Gold Group

***Facilitator:***
Jim Vanderwal

***Participants:***
Erin Barley
Gary Birch
Allan Carroll
Stewart Cohen
Chris Hambruch
Colleen Hughes
K. Linda Kivi
Don Low
Correy Matheson
Rob McCrae
Tracey Napier
Gerry Nellestijn
Ross Noble
David Toews

### *1. Past Effects*

No discussion recorded.

### *2. Past Adaptation*

Gary Birch: BC Hydro has not considered climate change much in planning in the past; the annual variability in water supply is considered to be a much bigger issue than the very gradual long term climate change trend. Planning is based on a 30 to 60 year period of inflow records. While the US agencies are looking at including the Pacific Decadal Oscillation and El Niño−Southern Oscillation indices for modelling forecasts, utility planners on both sides of the border still use historical data for planning purposes because the variation in the dataset still encompasses current conditions. Future planning in the Columbia looks out 6 years under the Treaty (AOP). We are noticing a change in spawning time among some fish species which could be related to climate warming, and the timing of winter conditions in the Columbia is shorter and later than it was 10 years ago.

Rob McCrae: Is consideration given to environment/wildlife?

Gary Birch: Under the Columbia Treaty, there is no formal recognition of environmental issues. The priorities under the Treaty are (1) consumptive use (2) flood control (3) firm energy (4) reservoir refill within the water year (5) secondary power and other issues. Under the Treaty, we can address other water management issues, but both entities must agree (Canada/US); and both must benefit equally. In the past decade, I can think of about 8 different agreements that have been used to achieve environmental and recreational benefits on this side of the border. Operations of US dams which cause effects in Canada are the responsibility of the Canadian signators of the Treaty. In general BC Hydro and both levels of government address the environmental issues that result from the operation of our dams in Canada through cooperation with the regulatory agencies. VarQ (variable discharge modelling) is being used starting this year for Libby dam operations to address ESA listed species requirements. As a result, more water will be stored in Koocanusa Lake in the spring and early summer.

David Toews: Lots of events are unique. It is hard to marry events to climate change; the challenge is to find examples in longer records. We have to ask, did logging cause or exacerbate this event? We try to adjust planning to avoid such events.

### *2. Future Impacts*

Don Low: From an agricultural perspective, we are going to have more water conflicts; increased demands in Creston for irrigation, including those who traditionally practised "dry farming." Some water sources are already fully subscribed, and we have conflicts between domestic and agricultural water demands.

Correy Matheson: We see conflict with water use in Fernie, controversy about "green spaces," development of golf courses, housing development on floodplains.

Ross Noble: Regarding fire control, we can't afford enough equipment. We do fire preparation planning: we look at a 10-year record and prepare for the seventh worst fire season. We need to plan for crews, but many are university students, and return to school in September. How will we deal with this in future? We are going to see impacts at the forest/urban interface, and communities at increased risk if fire risk goes up—homes have been lost in recent years. We are trying to get fire safety messages out to communities, but people have short memories and deny the risk, the "not in my backyard" mentality prevails.

Linda Kivi: And where does money for fire control come from? Cuts to other services?

Ross Noble: Fire prevention is cheaper than fire fighting, and prescribed burning **has** helped control fire. Some areas are on a 5 to 15-year natural fire cycle, and we have seen 80 years of fire exclusion, so in some forests, natural fuel levels are elevated by six to seven times what they should be.

Linda Kivi: Regarding beetle control, sometimes beetle-free stands are logged as "pre-emptive strikes" just as an excuse for more logging, and this creates community / forest industry conflicts. On a smaller scale, there is evidence of loss of insulation from snow (damaged ground food storage), so what about plant roots, etc.? And, we are seeing increased rain-on-snow events in December causing problems.

### 3. *Effective Preparation for Climate Change*

Allan Carroll: It is hard to tease apart causes of extreme phenomena, differentiate between climate change and forest management practices; we need "normals," baseline information, otherwise we cannot conclude what is "unusual."

Not credited: Have we seen a trend in agricultural practices?

Don Low: Increased efficiency in water use for fruit, but field crops have not changed much—does not seem to be a pressing issue.

Linda Kivi: What incentive is there for farmers to change irrigation practices?

Don Low: How do we value a resource if water is free? Maybe change crops.

Gerry Nellestijn: Bull trout – is there enough water for migration and spawning, is the quality and temperature sufficient? We need to talk to the community about angling practices and needs.

Jim Vandervahl: Do we have any tools to help in the future?

Allan Carroll: We need standardized data and data sharing, to pick up long-term studies that have recently been dropped by governments.

David Toews: The federal government is now charging money for data.

Linda Kivi: We must reduce other stresses on ecosystems, take a conservative approach to land management, leave buffer space.

### 4. *Continued Dialogue / Next Steps*

Rob McCrae: We heard there are "no bosses", but there are bosses, we just need to know who they are.

Ross Noble: Many decisions are political and short-term, for a 4-year political cycle.

Gary Birch: Agencies are getting smaller and more specific, with more specific mandates, as issues are getting bigger.

Ross Noble: For example, the Forest Service has no official obligation to protect homes from fire, but do anyway because of moral obligation.

Don Low: People are ignoring weed control. Weed control should be an environmental, not agricultural, issue.

Gary Birch: Regional districts are divided in their approach to weed control.

Linda Kivi: There are other (non-herbicidal) approaches to weed control, such as planting of native species.

Allan Carroll: We need to cross governmental and bureaucratic boundaries to tackle these issues. For example, fire control should include prescribed burning, water quality issues, pest control, etc.

Rob McCrae: We need to identify the bosses.

Linda Kivi: In a democracy, we are the bosses.

David Toews: We have an advantage in British Columbia, as most land is publicly owned.

## *5. Red Star Group*

***Facilitator:***

Paul Willis

***Participants:***

Wendy Avis
Becky Brown
Paul Chalifour
Bob Forbes
Dave Hale
Michael Keefer
Allison Lutz
Steve Mitchell
Cindy Pearce
Murray Peterson
Mike Robinson

### *1. Past Effects*

Allison Lutz: Seasonal shifts in Nelson, later start to winter and later start to spring. Whitewater Ski Hill is having to adapt operations to the season length.

Cindy Pearce: These effects are true of cat and heli-ski operations as well. We have had two mass wasting and debris slide events across the Trans Canada Highway outside of Revelstoke. Does CP Rail have some strategy for these occurrences?

Paul Chalifour: Perspective by going to the top of any mountain and standing on ocean coral; we are looking at a very small time period of change within a far greater system of change.

Michael Keefer: Moyie Lake hasn't totally frozen this year, and it did not freeze until the end of winter last year. Five years ago, it always used to freeze.

Cindy Pearce:  Irrigation systems company is installed in Revelstoke and operating right down the Rocky Mountain Trench.  His business is doing really well due to all the droughts.

Bob Forbes:  Snowpack is not deep enough, so that caribou cannot reach the lichen higher up on trees, and we have seen significant population declines in caribou. Wildlife populations are entirely dependent upon habitat that is directly affected by climate changes.  Hunting seasons and recreational use of some species have been reduced too.

### *2. Past Adaptation*

Cindy Pearce:  Canadian Pacific is putting in a warning system for debris slides.  The Ministry of Transportation has installed road barriers.

Paul Willis:  Cranbrook has drilled more wells and used water rationing.  Is the answer to drill more wells or to address the problem at its source?

Dave Hale:  Kimberley channelized Mark Creek in order to eliminate chance of future floods, but caused downstream fish problems.

Murray Peterson:  Were changes required on Elk River to deal with flooding in 1995?

Bob Forbes:  There have been adaptations made.

Dave Hale:  We lost 80 cement-fortified bridges during that flood in Fernie.

Paul Willis:  When we are worried about effects of climate change, Bob, your group is trying to purchase more easements on corridors.

Bob Forbes:  For flood prevention, change is always triggered by catastrophe.

### *3. Future Impacts*

Becky Brown:  Jumbo Pass ski opportunities will be affected as the glacier recedes.

Allison Lutz:  Ski hills and snow recreation could be heavily affected.

> Bob Forbes:  Agriculture, pasturing, crops—the biggest challenge these activities will face is water shortages.  We will be growing grapes and orchards above Kootenay River no problem, though.  The Okanagan will have sand dunes.  All we need is 30 more warm days, and we are not that far off.

Paul Willis:  Power generation will be affected.

Michael Keefer:  Urban forests are dying out.

Allison Lutz:  Creston Valley wildlife wetlands will be seriously affected.

Bob Forbes:  Columbia River Valley wetlands between Golden and Invermere will also suffer.  There will be a huge influx of population to the area.

Paul Chalifour:  Foresters are conservative, so forests are considered to be so also. Once we begin to see major changes to the forests, it will be too late to address them.

Michael Keefer:  That Tembec does not plant ponderosa pine is disturbing.

Paul Chalifour:  You cannot tell if forests really have a problem until they are well developed.

Cindy Pearce:  Cedar planted last year probably did not survive this last unusual summer.

Dave Hale:  A lot of work to do to characterize the nature of the problem.  What species do we plant, how to combat beetles.  We want a certain amount of old growth for the next cycle, but these attract beetle.

Wendy Avis:  The forest industry has a lot of opportunity to effect positive change. There does not seem to be much knowledge about doing that.

Paul Chalifour:  Changes in agriculture in our world will have significant impacts on us.

Allison Lutz:  Food security has huge implications.  Those in the north will be obligated to help if those in the south are economically vulnerable.

Bob Forbes:  There are huge implications around water availability as well.

Paul Chalifour:  The external demand for water will have large impacts, even if we can get by with what we have got here in the country and region.

Allison Lutz:  Bulk water exports and international trade—it is scary.

### *4/ 5.  Effective Preparation for Climate Change & Continued Dialogue / Next Steps*

Allison Lutz:  We need to squash media that say global warming is not happening.

Bob Forbes:  We need better communication.

Paul Willis:  Do we have enough climate data?

Michael Keefer:  We always need more data; we also need to change the way we currently do things.

Cindy Pearce:  Modelled results that provide misleading results need to be limited.

Mike Robinson:  We need increased public awareness.

Cindy Pearce:  Human nature is bound by procrastination.  Children creep through cultures, so we should start educating there.  We should try day-in-the-life-of scenarios with professionals to do some serious brainstorming.

Steve Mitchell:  We need long-term planning over the next 5 years.

Cindy Pearce:  Human beings do not rule the universe.

Paul Chalifour:  At least we are talking about change.

Paul Willis:  Where are the planners and elected officials?  Why aren't they here?

Becky Brown:  We need to support and encourage the proactive community in the region to help them break new ground.  That will make it easier for other less proactive communities to follow.

Allison Lutz:  We need incentives and tax reductions connected with climate change—acknowledgement of climate change adaptation on a regional level.  We need local meetings and to start a "list serve."

Becky Brown:  We need to come back to the next meeting with a list of proactive changes made since this meeting.

Bob Forbes: We need to get this into land use planning workshops.

Allison Lutz:  I can bring the summary presentation from this conference to the Planning Institute of British Columbia.

Cindy Pearce:  There is a communications gap between scientists and laypeople.  We must use language that is comprehensive for all.

## *5. Red Dot Group*

***Facilitator:***

Sabrina Curtis

***Participants:***

Ian Adams
Jim Belsham
Casey Brennan
Dave Cattanach
Wayne Choquette
Dorothy English
Paul Galbraith
Doug Hall
Daphne Kelgard
Evan McKenzie
Tamara Mickel
Carrie Morita
Mary Rathbone
Jolene Raggett
Janet Skolka

### 1. *Past Effects*

Casey Brennan: Flood in Elk Valley 1995.

Jim Belsham: Windstorms.

Ian Adams: Heavy snowfalls.

Doug Hall: Two weeks of sustained winds.

Wayne Choquette: We used to have heavy snow and colder temperatures.

Mary Rathbone: We used to be able to skate on Kootenay Lake.

Doug Hall: Six boats sank; Pope and Talbot had a major power outage.

Ian Adams: Increased insurance costs.

Mary Rathbone: West Nile Virus is an effect, just like mountain pine beetle.

Casey Brennan: Fernie ski hill snow is 1 mile lower on the hill than it used to be.

Sabrina Curtis: Recreation values have been affected by climate change.

Dave Cattanach: Drought, reservoirs are down, dust storms, channelization for fish, costs become astronomical.

Casey Brennan: Freshet is earlier now, and there is risk of flood damage to riverbanks and aquatic life.

Wayne Choquette: Deforestation effects.

Carrie Morita: Conflicts with water licensees who are neighbours with one another.

### 2. *Past Adaptation*

Paul Galbraith: Farmers now don't feed the cows until January when they used to have to feed them in November, so costs of feed are down.

Jim Belsham: Water rationing is effective.

Ian Adams: Effective for the short term, but not for the long term.

Dave Cattanach and Mary Rathbone: We are not changing our behaviour.

Jim Belsham: True, but some people have learned that they don't have to overwater.

Mary Rathbone: The trend is away from lawns.

Wayne Choquette: The key is to make individuals feel responsible for responding to climate change; we need to educate.

Mary Rathbone: It is the psychology of humans not to change until we have to.

Jim Belsham: Xeriscaping is very effective.

Mary Rathbone: There are also the effects of social pressure and fashion on our behaviour.

Daphne Kelgard: We can use bylaws to enforce change.

Paul Galbraith: We also need to provide incentives for change.

Dave Cattanach: We are gluttonous with our energy consumption.

Wayne Choquette: I am disturbed by the idea of adapting to climate change. I think we need to change.

Ian Adams: We need to improve our transportation and use town planning.

Jolene Raggett: There are no sidewalks beside the highways in Cranbrook.

### *3. Past Effects*

Casey Brennen: Humans are adaptable but other species will not adapt or some will love the change. The tragedy is that some will not survive. What are the impacts? What are we losing?

Jim Belsham: So you think we could reduce biodiversity to the extreme.

Casey Brennan: I don't know, but it is of number one importance.

Mary Rathbone: Tourism change.

Daphne Kelgard: We want to know it is out there (climate change). We need to examine Canada's identity.

Casey Brennan: You can't sell beetles or grasshoppers. We now sell our tourism. With climate change that will be severely affected.

Jim Belsham: We will also see changes to the fire hazard and water supplies.

Ian Adams: And effects to human health as a result.

Sabrina Curtis: Also effects to quality of life, levels of dust.

Ian Adams: How about the loss of the spiritual aesthetics of wilderness? Familiarity with wilderness is important. I rate it quite high.

Daphne Kelgard: Also economic impacts.

Mary Rathbone: What is going to happen to small communities when the US needs more water?

Wayne Choquette: Water will soon be more valuable than energy.

Mary Rathbone: We may lose drinking water eventually.

Doug Hall: We will have less availability of water from snow, because right now 80 % of our Columbia source is from snow.

Ian Adams: We will also see a loss of glaciers.

Dave Cattanach: That rates water very high in priority.

Paul Galbraith: Species and entire communities are at risk.

Dave Cattanach: What is our role for this loss?

Paul Galbraith: We need to make sure we have connectivity corridors.

Dave Cattanach: For example, right now sturgeon are isolated by hydroelectric dams.

Paul Galbraith: We need corridors through National Parks.

Casey Brennan: If we make a decision without certainty we could be wrong, but we have to act.

Wayne Choquette: It is a question of risk management.

Casey Brennan: We need to engage in adaptive management.

### *4. Effective Preparation for Climate Change*

Daphne Kelgard: We need to start with better city planning.

Dave Cattanach: Also communications and education. We need everyone to be aware of the issues.

Mary Rathbone: Maybe a conference for the unconverted.

Daphne Kelgard: Also educate city councils.

Jim Belsham: There needs to be the political will.

Casey Brennan: The academic community needs to present its information to the Regional District of Central Kootenay and other regional districts.

Paul Galbraith: It seems there is political will with Kyoto.

Ian Adams: We need to get beyond the current conflicts and work with industries that are not addressing climate change or not doing so beyond a certain point. Tax incentives are great.

Wayne Choquette: Use something like GST incentives to encourage change.

Mary Rathbone: What about renovating houses—incentives for R-factor, efficiency? Things like better windows to conserve energy.

Casey Brennan: Or a carbon tax. Mark Shmigelsky tells us Invermere has put in water meters. What we are doing here today helps create political will.

Dave Cattanach: But there really is no boss, political or otherwise. We must take the lead.

### *5. Continued Dialogue / Next Steps*

Carrie Morita: We need to make a summary of our past assumptions that are false now that climate change is occurring.

Casey Brennan: We need a list of thresholds based upon scientific knowledge. We need to get and keep the experts involved.

Daphne Kelgard: I agree, but the community must also get involved to be able to reinforce these discussions.

Casey Brennan: Maybe through public input at council meetings.

Ian Adams: Invermere councillors are here. We also need monitoring.

Carrie Morita: I think we need clear objectives and to use data properly to come to the best, most accurate conclusions.

Ian Adams: What we need is baseline data to work from.

Daphne Kelgard: Yes, and we need to keep citizens involved.

Dave Cattanach: We need a community-based system—to communicate locally to change people's beliefs, and to gel the community around climate change action. We also need a representation of all conference participants' commitment to annual follow-through.

Casey Brennan: And for that we need leadership.

Daphne Kelgard: Citizens need more say in what information gets out and what does not.

## *6. Blue Dot Group*

***Facilitator:***

Anne Edwards

***Participants:***

Bev Bellina
Alan Bond
Maureen DeHaan
Aaron Donahue
Jason Hayes
Kyle Holland
Bob Jamieson

Alice Nellestijn

### 1. Past Effects

Bev Bellina: Windstorms have created a large amount of blow-down–from personal observation, notice increase in wind.

Alan Bond: Spruce beetle affected the blow-down. And, blow-down has affected high-elevation hunting.

Maureen Dehaan: Construction of dams has changed the climate. There is more grey weather, and both Kootenay and Christina lakes used to freeze.

Bob Jamieson: Evidence that avalanches are running less distance than they used to; the Bugaboos are getting less snow, and Kokanee Glacier has receded in the noticeable past, plus there is definitely more grey weather, considering that Cranbrook used to have the most winter sunshine days in the area.

### 2. Past Adaptation

No discussion recorded.

### 3. Future Impacts

Alan Bond: Changes in vegetation. Change in fire seasons. There has been a long lull in the past decade, but there is the potential for multiple bad fire years. Forestry wants more prescribed burns as well. And, more erratic weather swings mean we can expect colder and hotter extremes.

Bob Jamieson: Change in rivers and water flow and use. Change in ecological processes.

Maureen DeHaan: Snow-dependent industries will suffer. We need to get business into the discussion. They don't seem to accept that climate change is happening. Were they not in the loop?

Anne Edwards: Coal industry adaptation will be necessary.

Not credited: What will happen when the glaciers melt? Will we see more water shortages in the summer? Will there be disputes over water resources and more conflict? Fifty percent of water flow to the south comes from the Columbia River, so what we do here will have a great effect on the system.

### 4. Effective Preparation for Climate Change

Not credited: We have to think about hydrology holistically, and consider reservoirs, groundwater, snowpack, etc.

Not credited: Possibility of the space shuttles and rockets affecting the climate.

Not credited: We must not sell our water resources.

### 5. Continued Dialogue / Next Steps

Anne Edwards: We need to talk to the Chambers of Commerce.

Maureen DeHaan: We need to consider zoning, land use planning.

Bob Jamieson: We need to appropriate the climate change message and find a trusted messenger to relay accurate information. We need monitoring, and early warning systems. We need funding and non-funding agencies to get involved ——CBT, BC Hydro, local industry, Environment Canada.

Anne Edwards: Who should be involved; who should deliver the message? Politicians at all levels. We need to cooperate with the US side of the Columbia Basin. Safety issues should be emphasized, and people need to feel responsible. We need to build a support network for professionals involved in climate change issues. We need to create incentives for people to change—social and economic incentives.

## 7. Blue Star Group

***Facilitator:***
Chris Prosser

***Participants:***
Nino Aimo
Bob Campsall
Sharon Cardin
Martin Carver
Joe Chambers
Brian Ferguson
Deborah Griffith
Mark Hall
Alan Hamlet
Melissa Hogg
Dennis McDonald
Carol Molnar
Steve Street
Per Magnus Wallenius

### 1. Past Effects

Bob Campsall: Forest fire is a threat to homes and businesses; droughts are affecting farming and grazing.

Martin Carver: Flooding, low stream flows.

Per Magnus Wallenius: Impacts on ski industry / tourism / recreation (positive and negative effects).

Deborah Griffith: Avalanche and landslide threats, water levels for boating and fishing.

Alan Hamlet: Over-allocation of watersheds, beach erosion in coastal systems.

Sharon Cardin: Pests—farming, forestry, tourism (mosquitoes).

Mark Hall: Health care (e.g., Cryptosporidium outbreaks).

Not credited: We talked about local weather extremes; hydrologic variability; socio-economic impacts; ecosystem impacts; how weather and climate affected the community (i.e., flooding, windstorms, microbursts along foothills of the Rockies that devastated homes along the valley bottoms).

### *2. Past Adaptation*

Sharon Cardin: Lack of adaptation or resistance to adaptation.

Alan Hamlet: Change in length of period used in planning but no recognition of change in kind of variability affecting system.

Mark Hall: Continual learning and education, broadening of perspectives.

Bob Campsall: Laws and legislation—building on floodplains now more controlled, fire management (controlled burns), municipal water restrictions.

Alan Hamlet: Coastal armouring after El Niño, Seattle Drought Contingency Plan, funding, hydro energy.

Mark Hall: Use of alternative energy sources, air quality monitoring.

Martin Carver: Emergency measures program.

Not credited: Planning, policy, management. BC Hydro has provided funding for effects caused by dams. Examples of adaptive measures are also climate change agenda; emergency response; drought contingency planning. We could strengthen these adaptive measures through leadership and planning, and through education.

### *3. Future Effects*

Martin Carver: Low summer stream flows, well being of non-economic species (e.g., amphibians), political insecurity with the US over water and hydro rights, aquifer depletion, need for lifestyle changes.

Per Magnus Wallenius: Cultural aspects of wildlife and fisheries damage, sense of helplessness.

Deb Griffith: Fire risks, water quality.

Nino Aimo: Loss of winter recreation.

Mark: Rate of climate change, inabilities to deal with different value systems and balance competing objectives

Alan Hamlet: Human health problems, reduced water supplies, and socio-economic impacts in general.

Not credited: Ecosystem impacts—hard-hit areas are fisheries, wildlife, river and alpine environments; socio-economic impacts and impacts on water quality and hunting and recreation.

Other impacts mentioned by group:

- Forest fire threat increase
- Flooding
- Impact on ski industry
- Microbursts
- Avalanches
- Low flows affecting water supply and hydroelectric power generation
- Farming/grazing
- Overallocation of water
- Influxes of pests on farms/forests
- Human health issues and economic impacts
- Flooding—outbreaks of *Cryptosporidium*

### *4 / 5. Effective Preparation for Climate Change & Continued Dialogue / Next Steps*

Bob Campsall: Tax incentives, community forums, outreach at a local (not just regional) scale.

Per Magnus Wallenius: Legislation.

Alan Hamlet: Funding for public outreach, mass communication; water supply and use database, collaboration across boundaries to make relevant information available to everyone; establishment of some facility to connect people with questions to the people who know the answers or have the information.

Melissa Hogg: Increased education (especially of children) about preventative and adaptive measures.

Mark Hall: Full cost accounting—actual cost of activities, etc. to the environment.

Martin Carver: Water use education, monitoring of water consumption, and public access to research results.

Sharon Cardin: Measures to empower the communities—put decisions in the hands of the people they affect.

Not credited: Businesses and communities are working on planning time frames and responses to climate change. Management changes are reflecting climate change in the past. Some effective past initiatives include the development of agencies such as Emergency Response in the Invermere area to deal with flooding and forest fire.

Not credited: Issues around hydroelectric power and water supply have been undertaken in the Columbia Basin with some effectiveness.

Not credited: Responses—we need mass communication and education, leadership at all levels, education.

Not credited:  Future impacts are our greatest concern, as is our inability to work in teams.  It is a great challenge to get together as a group and address impacts.  Change is happening so rapidly that e are not able to coordinate our efforts quickly enough.

Not credited:  We lack the economic viability to be able to deal with many impacts and necessary adaptations.

Not credited:  Impacts on ecosystems that support economies and people are a real concern to most people.  Water impacts are also of great concern—we need potable water and water for power generation.

Not credited:  We need policies, leadership in funding, political direction, and education for critical thinking.

Not credited:  We need to coordinate resources, and cooperate on transboundary issues, and we need better transfer of information and scientific data.

Not credited:  Finally, we need outreach and public information in the future to deal with climate change.

# Summary of Comments from Plenary Session

***Stewart Cohen***

How do we sustain this process so that we can turn it into specific tasks with a specific budget and facilitate projects? Maybe this process can provide the transboundary and interdisciplinary approach that we need. There are four major issues that I have heard from the working groups today:

1. Monitoring—if we are going to resurrect monitoring or start new programs, we need to know what indicators we are going to monitor, who will provide ongoing funding, etc.
2. Look at current planning devices and models and test them in a climate change situation to see how they react before we base assumptions on them. For example, using the Great Lakes—a rule curve in a climate change situation showed that the lake would be drained. This shows that changes to the model are necessary.
3. Can we look at the morphology of past events (fire, floods) and learn from what happened during these events?
4. We face an immense challenge of bringing the research and the issues to all levels.

Another issue is communication. An important aspect of communication is accuracy, but how do you know that you are going to be accurate in a prediction? We need to use the word “scenarios” to avoid the problem of creating the impression that what we are modelling is a direct forecast of the future.

Our challenge is making decisions in the face of uncertainty. We need to look at what kinds of institutions plan proactively now, what kinds of challenges they face, and how they deal with them.

And what aspects of uncertainty constrain the decision-making the most? Would it matter if we could narrow the uncertainty of precipitation by 50%? Would that make a difference to Invermere or to BC Hydro? I don’t think we will ever get the uncertainty down to zero.

Finally, it is important to remember that issues are defined as much by those who are involved locally as by those from out of town who organize and present information.

### *Mark Shmigelsky*

I had the opportunity to go to all seven groups. I want to say that everything in terms of impacts and opportunities for change will happen at the local level - landslides, water shortages, everything. These are opportunities for grass roots action. We have been proactive in Invermere. We need to see positive change at the federal and provincial level, but also at the local level. Most people are already doing something from conserving water to turning down the thermostat. No one here has mentioned the cost of doing nothing – it hurts your pocket and it affects the next generation. We did put in water metering in Invermere, and it was at great political cost but we did it and we cut down on consumption by 30% right away. The climate is changing, it is changing now, and it is time to respond.

### *Jenny Fraser*

The part of this conference that I am most interested in is "the next steps we take". What is on our "to do" list and what is do-able now? We face two major challenges—to engage the business community and to engage local municipal governments on this issue. One person in one of the groups came up with the idea of identifying a champion or a leader on this issue, and then to figure out ways to support those people in being champions—for example, helping them to do research, to communicate results and solutions and so on. The challenge is getting someone to step forward and come to *us* to start that dialogue.

Another issue that has come up again and again over the weekend is the need for communication, outreach, and getting information *out there*. Perhaps there is a group who would want to form a committee and come to *us* and tell us the kind of support and materials you would need in order to support that committee and begin working on communication with the public, stakeholders, and everyone you know. Or come to *us* with other challenges.

### *Julia James*

I will take all this information back to our advisory committee at C-CIARN BC. Please go to our website to get more information. I will also send out information on how to join our website and list serve. I will be looking at ways to help you get started on your next steps.

### *Questions and Answers*

Q: I would be encouraged to learn what research other people are doing. How is California dealing with its water shortages? Sharing information is sometimes the starting point.

A: (Phil Mote) The key thing is to try something to model a future climate scenario, even a simple one, and see how that works. The second thing is to use an online tool that water managers use to look at climate change. We are going to have a workshop on this for technical types and those who deal with hydrographs.

Q:  (Comment) Thanks first of all to the USA folks for their involvement.  I hear people say that we need to educate the young, but we need to have the leadership of our political leaders.  I have heard politicians give accounts of the East Kootenay becoming a place where we see golf course after golf course and ski resort after ski resort.  How do we reconcile this with the need for other visions?  I applaud middle managers for being here, and say we need to take this message up to the top.

*Workshop over—discussions continue one-on-one.*

# Appendix One – Workshop Participant List

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# Appendix Two – Highlights from Participant Evaluation Forms

Thirty-six workshop evaluation forms were received from participants. The following are summaries of the comments that address themes and considerations for future workshops, and responses to the statement: "As a result of this workshop I plan to…"

Generally, the respondents were pleased with the workshop. Several people expressed disappointment in the lack of attendance by municipal and regional district staff. As might be expected with attendance from people with diverse interests, some people found the level of information too detailed, and some found it too general.

## *Themes and considerations for future workshops*

- How do we incorporate this information into community plans?
- How do we target local governments and get them to set goals?
- Low workshop registration fee is important.
- Allow lots of time for networking and casual posing of questions to speakers after the presentations.
- Put together another workshop in a few years when more information is available.
- Plenary wrap-up was tedious (going over other flipchart notes from other groups): "There's got to be a better way," for example, provide the comments in a follow-up mail-out, or focus on responses to only the most critical question. Rest of comments get written up in workshop notes for those who are interested.
- Facilitated groups must finish at the same time.
- Regional get-togethers on specific themes would be a good idea.
- Several people expressed a wish for sector-focussed discussion groups.
- Request for a workshop on Ecosystem Implications. Specialists to be hired to provide detailed information on what is likely to happen to ecosystems. Then develop specific actions to address changes.
- Breakout groups provided an opportunity for "mixing" of local residents with the experts.
- There should be a list summarizing the region's progress in adapting to climate change posted at next workshop (i.e., what progress has been made since this workshop).
- Include the viewpoint of a philosopher.
- PowerPoint presentations make it easy to lean on heavy use of graphs, difficult for lay audience.
- Lights should be "on" during presentations so we can see the presenter.
- Hold a workshop titled "A community and business response to climate change in the Columbia Basin." Each sector presents its views and actions. Could be repeated in several towns.
- Include themes related to human health.
- Focus on "action steps" we can all take.
- Longer lunch breaks and longer coffee breaks would allow for more networking.

- Suggested themes—planning for agriculture, understanding the Treaty, and mitigating climate change.
- Include a "day in my life" of someone living in 2050 to show how things might have changed.
- Host smaller sessions in each community on focused themes (e.g., forestry or municipal planning).
- There should be major support for a few communities to break ground in addressing climate change issues—then tell us about it at another workshop, and the rest of the communities can follow their example.

### *Response to the Statement "As a result of this workshop I plan to…"*

- Get other foresters to put climate change on the planning agenda.
- Read more papers on climate change.
- Speak out more about things we don't know (precautionary principle).
- Write an assessment of what climate change means for my company and set adaptation directions, to be distributed within my company.
- Bring climate change to land use planning tables.
- Follow issues more closely now that I have some understanding.
- Include climate change in future municipal planning discussions.
- Include mention of climate change in upcoming naturalist-oriented book.
- Attempt to influence logging practices in my area to include climate change perspectives.
- Build on the contacts I made.
- Open up more dialogue with my town council.
- Keep climate change in mind when designing structures.
- Learn more about what is happening south of the border; maybe we can learn from what has happened there already, not re-invent the wheel. What have they done to influence public actions and attitudes?
- Introduce measures to mitigate the danger of flooding in communities near the Elk River, and restrict development in floodplains.
- Raise concern about adequate fire protection for the accommodation development at Fernie Alpine Resort.
- Will work "Climate Change" into my presentations on protecting communities from forest fires.

# Appendix Three – Recommended Resources for Information on Climate Change

## *Internet Resources*

**Addressing Climate Change – Natural Resources Canada**
http://www2.nrcan.gc.ca/es/es/change_e.cfm
Describes Canadian actions on climate change including the National Action Plan on Climate Change, Kyoto commitments to reduce emissions, and programs focusing on areas where substantial reductions in carbon dioxide emissions can be achieved.

**Agriculture and Agri-Food Canada – Climate Change**
http://www.agr.gc.ca/policy/environment/eb/public_html/ebe/climate.html
Agriculture contributes to climate change through greenhouse gas emissions. However, many agricultural practices may be implemented to reduce these emissions.

**BC Climate Exchange**
http://bcclimateexchange.ca/index.php
The BC Climate Exchange provides a connection to people, resources, and tools for education, outreach, and training on climate change, its impacts, and solutions.

**BC Government Climate Change Home Page**
http://wlapwww.gov.bc.ca/air/climate/index.html
Includes Indicators of Climate Change in British Columbia, emissions information, and much more.

**BC Ministry of Water, Land and Air Protection**
**Indicators of Climate Change 2002**
http://wlapwww.gov.bc.ca/air/climate/indicat/index.html
Excellent information on climate change in British Columbia.

**Canada Centre for Remote Sensing – Climate Change**
http://www.ccrs.nrcan.gc.ca/ccrs/misc/issues/cchange_e.html
Working to improve our understanding about climate change by developing remote sensing techniques to monitor and model environmental and climate change processes.

**Canada Country Study – Climate Impacts and Adaptation**
http://www.msc-smc.ec.gc.ca/projects/ccs/
The Canada Country Study looks at the social, biological, and economic impacts of climate change and potential adaptive responses for Canada.

**Canadian Centre for Climate Modelling and Analysis**
http://www.cccma.bc.ec.gc.ca/eng_index.html
The CCMA conducts research in coupled and atmospheric climate modelling, sea-ice modelling, climate variability and predictability, the carbon cycle, and a number of other areas.

**Canadian Climate Impacts and Adaptation Research Network – British Columbia**
http://c-ciarn-bc.ires.ubc.ca/
The aim of C-CIARN is "to build a network of researchers and stakeholders that will help to develop credible information on the impacts of climate change in Canada and help to identify adaptation options in order to anticipate and prepare for the changes that are expected during the 21st Century."

**Climate Change – Climate and Adaptation**
http://adaptation.nrcan.gc.ca/home_e.asp
The Government of Canada's Climate Change Impacts and Adaptation Program provides funding for research and activities to improve our knowledge of Canada's vulnerability to climate change, to better assess the risks and benefits posed by climate change and to build the foundation upon which appropriate decisions on adaptation can be made.

**Environment Canada – Climate Change**
http://www.ec.gc.ca/climate/home-e.html
Government actions on climate change including the Kyoto Protocol, Intergovernmental Panel on Climate Change, and impacts research on weather, ecosystems, health, and way of life.

**Frequently Asked Questions – Meteorological Service of Canada**
http://www.msc.ec.gc.ca/saib/climate/Faq_2002/index_e.html
Answers to common questions about the science of climate change and related issues such as atmospheric ozone.

**Geological Survey of Canada / Natural Resources Canada – Climate Change**
http://sts.gsc.nrcan.gc.ca/page1/clim/
Understanding climate change, the science, and its impacts.

**Global Warning – Knowledge Network Television Series**
http://www.knowledgenetwork.ca/know_tool/globalwarning/index.html
All three television episodes are downloadable as clips. Includes information on how to obtain the video and a classroom guide.

**Government of Canada Climate Change Web Site**
http://climatechange.gc.ca/english/index.shtml
This is the main portal for federal government information on all aspects of climate change.

**Health Canada -- Climate Change**
http://www.hc-sc.gc.ca/hecs-sesc/hecs/climate/index.htm
Find out how Health Canada is addressing the impacts of climate change on the health of Canadians by consulting the site for conferences, events, publications, reports, and links.

**Intergovernmental Panel on Climate Change**
http://www.ipcc.ch/
The Intergovernmental Panel on Climate Change assesses scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts, and options for adaptation and mitigation.

**National Climate Change Process**
http://nccp.ca/NCCP/index_e.html
Describes how Canadian governments are responding to the challenge of climate change.

**National Environmental Indicator Series – Climate Change**
http://www.ec.gc.ca/soer-ree/english/Indicators/Issues/Climate/default.cfm
Selected key statistics on climate change. Documents provide information on the topic and statistical trends for Canada and the world.

**Natural Resources Canada -- Climate Change**
http://climatechange.nrcan.gc.ca/english/index.asp
This climate-change site has sections on news, publications, issues, policies, actions, science and research, and press releases by Natural Resources Canada.

**Natural Resources Canada – Pacific Forestry Centre, Canadian Forest Service**
www.pfc.cfs.nrcan.gc.ca/index_e.html
The Pacific Forestry Centre has a number of initiatives related to climate change, mountain pine beetle, and other forestry research issues.

**Partners for Climate Protection (Federation of Canadian Municipalities)**
http://www.fcm.ca/scep/support/PCP/pcp_index.htm
This website describes their step-by-step program for communities to develop a climate change mitigation program.

**Science and Environment Bulletin -- Climate Change**
http://www2.ec.gc.ca/science/new/climate_e.html
The climate change section of the Science & Environment Bulletin—keeping you up to date on current environment issues.

**Temperature Rising – Teacher Workshops and Resources**
http://www.gvrd.bc.ca/climate/english/index.html
Simon Fraser University, the Government of Canada, the Greater Vancouver Regional District, and the Government of British Columbia, together with other partners, have developed information material on the science of climate change. Includes lesson plans and resources for teachers.

**Tracking Key Environmental Issues – Climate Change**
http://www.ec.gc.ca/TKEI/cc_weather/cc_e.cfm
Describes climate change issues, current Canadian statistics, and Canada's national efforts.

**Transport Canada – Climate Change**
http://www.tc.gc.ca/programs/environment/climatechange/menu.htm
Transportation is the single largest source of greenhouse gas emissions in Canada. The transportation sector thus presents an important challenge for Canada in responding to the Kyoto Protocol.

**University of Washington Climate Impacts Group**
The PowerPoint presentations by presenters Philip Mote and Alan Hamlet are available at:
http://ftp.hydro.washington.edu/pub/hamleaf/bc_climate_change/

For a series of three "white papers" on climate change and water resources in the Pacific Northwest, including the Columbia Basin:
http://jisao.washington.edu/PNWimpacts/Workshops/Skamania2001/WP01_agenda.htm

Free climate change streamflow scenarios for US Pacific Northwest water planning studies:
http://www.ce.washington.edu/~hamleaf/climate_change_streamflows/CR_cc.htm

## *"List-Serves" for Climate Change Information*

**BC Climate Exchange**
http://bcclimateexchange.ca/index.php

Look at the menu on the left hand side for instructions on how to join the list-serve.

**Canadian Climate Impacts and Adaptation Research Network - British Columbia Region**
http://c-ciarn-bc.ires.ubc.ca/

The C-CIARN BC email list is a tool for exchanging information on climate change impacts and adaptation. The posts include announcements for events, funding opportunities and job postings. Any member of the email list can post emails. The list is geared to serve the community of researchers, stakeholders, decision-makers and managers who deal with the impacts of climate change in their work. All are welcome to join by sending a blank e-mail to: IANetwork-subscribe@yahoogroups.com .

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