POTENTIAL IMPACTS OF CLIMATE CHANGE ON BC HYDRO-MANAGED WATER RESOURCES

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BC hydro
FOR GENERATIONS

EXECUTIVE SUMMARY

Global climate change is upon us. Both natural cycles and anthropogenic greenhouse gas emissions influence climate in British Columbia and the river flows that supply the vast majority of power that BC Hydro generates. BC Hydro's climate action strategy addresses both the mitigation of climate change through reducing our greenhouse gas emissions, and adaptation to climate change by understanding the risks and magnitude of potential climatic changes to our business today and in the future.

As part of its climate change adaptation strategy, BC Hydro has undertaken internal studies and worked with some of the world's leading scientists in climatology, glaciology, and hydrology to determine how climate change affects water supply and the seasonal timing of reservoir inflows, and what we can expect in the future. While many questions remain unanswered, some trends are evident, which we will explore in this document.

WHAT WE HAVE SEEN SO FAR

- Over the last century, all regions of British Columbia became warmer by an average of about 1.2°C.
- Annual precipitation in British Columbia increased by about 20 per cent over the last century (across Canada the increases ranged from 5 to 35 per cent).
- For the period of inflow records (35 to 47 years, depending on the reservoir), there is some evidence of a modest historical increase in annual inflows into BC Hydro's reservoirs but trends are small and statistically not significant.
- Fall and winter inflows have shown an increase in almost all regions, and there is weaker evidence for a modest decline in late-summer flows for those basins driven primarily by melt of glacial ice and/or seasonal snowpack.
- The severity of year-to-year variation in annual reservoir inflow has not changed.

LOOKING INTO THE FUTURE

Projected changes in climate and hydrology are for the 2050s (unless stated otherwise) under different future emission scenarios.

- Projected warming in the 21st century shows a continuation of patterns similar to those observed in recent decades.
- All emission scenarios project increasing temperatures in all seasons in all regions of British Columbia.
- The amount of warming in the 21st century will very likely be larger than that of the 20th century.
- Precipitation in winter, spring, and fall will likely increase in all of BC Hydro's watersheds under all emission scenarios.
- BC Hydro will likely see a modest increase in annual water supply for hydroelectric generation.
- Most Upper Columbia watersheds will see an increase in water supply. The snowmelt will start earlier, spring and early-summer flows will be substantially higher, and late-summer and early-fall flows will be substantially lower.
- The Peace region will see an increased water supply. Inflows in late-fall and winter will increase; the snowmelt will begin earlier; and summer flows will be lower.
- The Campbell River area and likely most Coastal watersheds will see negligible changes to annual water supply.
- On the South Coast (Vancouver Island and Lower Mainland watersheds), more of the precipitation will fall as rain and snow will become less important. Fall and winter flows will increase; and spring and summer flows will decrease.

Hydrological impact studies are the first step in BC Hydro's climate change adaption strategy. In the next step, BC Hydro will evaluate how the projected hydrological changes may impact hydroelectric power generation.

INTRODUCTION

More than 90 per cent of the electricity in British Columbia comes from falling water. The amount of available water is directly affected by variations in climate. Land use, volcanic activity, ocean circulation, solar cycles, and the composition of the atmosphere all influence the global climate. An understanding of climate change, and its effect on the water cycle, along with information related to future economic activity and load growth, is critical to ensuring a reliable supply of hydroelectric power for generations to come.

Climate change is natural in both the short and long term (Figure 1). Among the most influential short-term events are ocean circulation patterns, such as the El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO), which fluctuate on yearly and multiyear timescales as they exchange heat between the oceans and the atmosphere. In the long term, changes in the Earth's orbit around the sun trigger ice ages every 100,000 years or so. Other cycles operate on the scale of millions of years.

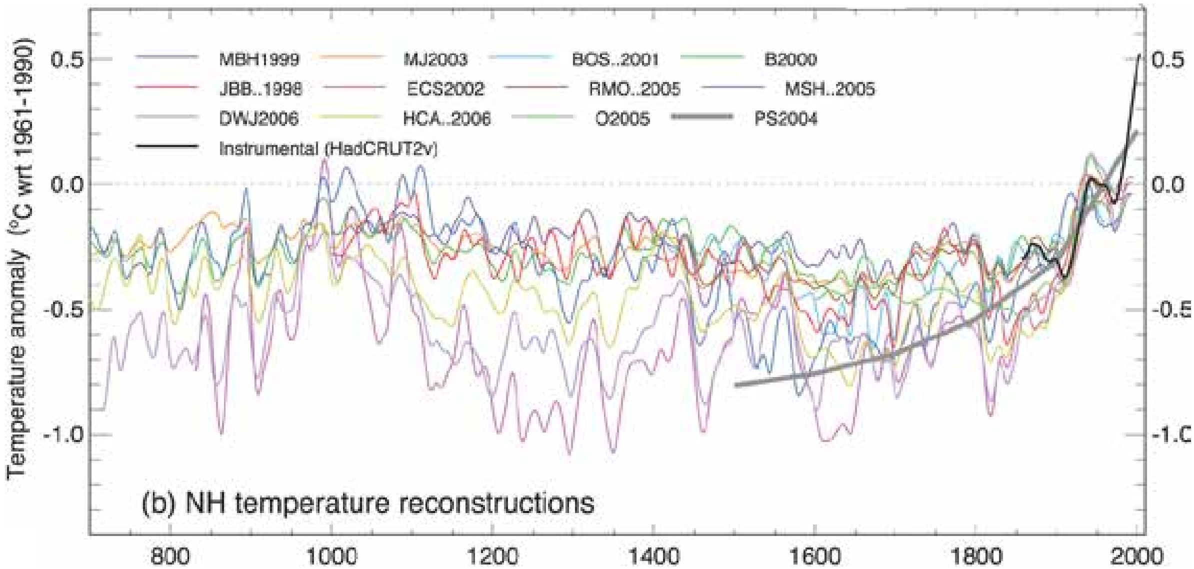


Figure 1: Northern Hemisphere warming based on a variety of reconstruction techniques (coloured lines) and instrumental record (black line). Source: IPCC 4AR: Climate Change 2007. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/figure-6-10.html

The recent warming trend associated with rising concentrations of greenhouse gases (GHG) that trap heat in the atmosphere is, however, taking place at an unprecedented rate. The scientific evidence that this trend is at least partially caused by the emissions produced by burning fossil fuels, and is likely to continue for many decades, is compelling. In its 2007 Fourth Assessment Report, the UN Intergovernmental Panel on Climate Change (IPCC) concluded that "most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations."

Since about A.D. 1860, temperature records from surface weather stations show an increase of about 1°C over the Northern Hemisphere. Although precipitation records are less reliable, climatologists agree that precipitation over North America has increased by about 10 per cent during the 20th century. Understanding the impact of these accelerated changes is crucial for planning adaptive strategies.

DESCRIBING UNCERTAINTY

Uncertainty in specific outcomes in the body of this report is assessed using expert judgments and expressed with the following probabilities of occurrence:

- very likely >90%
- likely >66%
- more likely than not >50%
- about as likely as not 33% to 66%
- unlikely <33%
- very unlikely 10%

DEFINING "CLIMATE CHANGE"

This document uses the U.N. Intergovernmental Panel on Climate Change definition of climate change, which is "a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity."

HOW CLIMATE AFFECTS WATER SUPPLY

Precipitation can fall as rain or snow. It can return to the atmosphere through evaporation, replenish groundwater aquifers, or run off into streams, rivers, and oceans. Higher temperatures increase evaporation, which in turn alters both precipitation and runoff. In humid regions, more precipitation will likely result in more runoff. In drier regions, extra precipitation tends to evaporate, causing only small changes in runoff. While the effects of a changing climate may reduce water supply in some regions, it could also increase supply elsewhere.

Thanks to the size and geography of the province, BC Hydro has a diverse portfolio of hydroelectric facilities in various climate zones. This, and the large storage capacity in the Peace and Columbia River reservoirs, offers some flexibility to adjust to changes in water supply and reservoir inflows. Still, a rapidly changing climate could challenge that ability to adapt.

BC HYDRO'S CLIMATE ACTION STRATEGY

As part of the province's target of cutting GHG emissions by a third from 2007 levels by 2020, BC Hydro has prepared a climate action strategy with two key objectives:

- » Maintain a low-carbon electricity supply for our customers; and
- » Leverage that supply to support provincial GHG reduction targets and policies for a low-carbon economy.

The strategy considers the potential effects of climate change in B.C., including increases in temperature, new precipitation patterns, and a greater frequency of floods, droughts, and wildfires. Changes in the timing and volume of spring runoff have implications for hydroelectricity generation. BC Hydro will incorporate these potential impacts, and adapt its infrastructure to accommodate the unavoidable.

BC HYDRO COLLABORATES WITH LEADING SCIENTISTS TO ASSESS IMPACTS OF CLIMATE CHANGE

As part of its climate change adaptation strategy, BC Hydro has undertaken internal studies and worked with some of the world's leading scientists in climatology, glaciology, and hydrology. BC Hydro teamed up with scientists from the Pacific Climate Impacts Consortium (PCIC) at the University of Victoria; the Western Canadian Cryospheric Network (WC2N), which consists of six Western Canadian and two Washington state universities; and the Climate Impacts Group (UW-CIG) at the University of Washington.

Hydrologists at BC Hydro conducted studies to investigate historic impacts of climate change on reservoir inflows. PCIC assessed historical and future trends in climate across British Columbia and projected future reservoir inflows in three distinct regions critical to BC Hydro's hydroelectric capacity: the Upper Columbia region, the Peace region, and the Campbell River region (Figure 2). The WC2N study quantified the magnitude and timing of glacier melt contributions to inflows into Kinbasket Reservoir (Mica basin) under a changing climate. The UW-CIG study assessed the hydrological impacts of climate change for the entire Columbia River basin in both Canada and the US (without accounting for effects of glaciers).

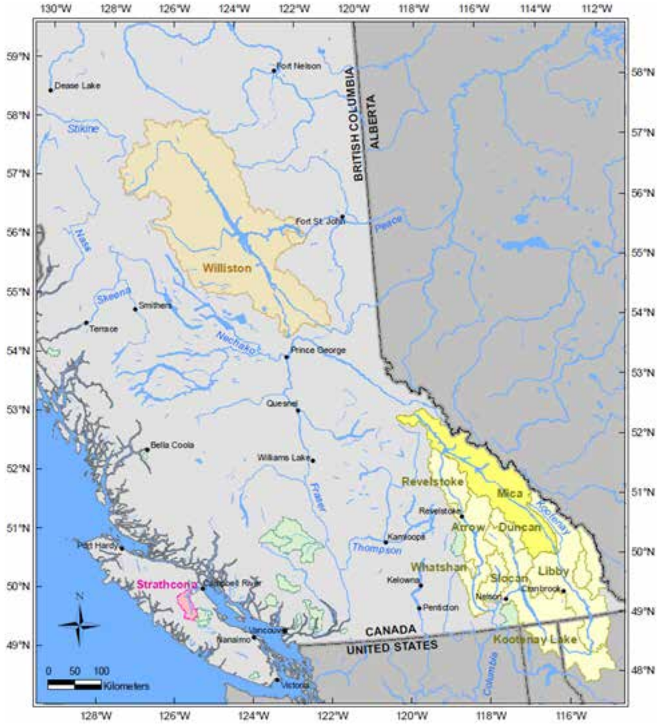


Figure 2: Regions with BC Hydro watersheds and representative watersheds for each region (Columbia basin with Mica highlighted=yellow, Campbell River at Strathcona=pink, Williston=brown, other BC Hydro basins=green).

ASSESSING CLIMATE CHANGE IMPACTS

Climate change impact assessments are largely based on scenarios—stories about how the future could look. Scenarios do not attempt to predict the future, but aim to better understand the uncertainties involved in making decisions, to accommodate a wide range of possible outcomes. They also help researchers and managers anticipate the consequences of those decisions.

The assessments that BC Hydro uses rely on numerical computer models that generate GHG emission scenarios, global climate models (GCMs) that resolve large-scale global weather patterns, statistical techniques that add regional detail to the GCMs, and hydrological models that convert climate scenarios into runoff scenarios (Figure 3).

EMISSION SCENARIOS

Projections of GHG emissions are based on storylines of demographic, social, economic, technological, and environmental developments. Future projections of climate and reservoir inflows were obtained by using three different IPCC emission scenarios. The so called B1, A1B, and A2 emission scenarios define futures with low, medium, and high increases in greenhouse gas concentrations, respectively When the IPCC scenarios were developed in the late 1990s, all were considered equally likely. However, the actual emissions growth rate since then is closer to or greater than the most fossil-fuel-intensive scenario.

GLOBAL CLIMATE MODELS

Global climate models represent physical processes in the atmosphere, in the oceans, and on land. They broadly reproduce historical climate at global scales, but are less successful at regional and local scales. The resolutions are such that any processes occurring on scales less than several hundred kilometres, such as the effects of mountain ranges and coastlines on cloud formation, are only roughly approximated. Statistical techniques bridge the gap between global climate and regional impacts, but at the price of higher levels of uncertainty.

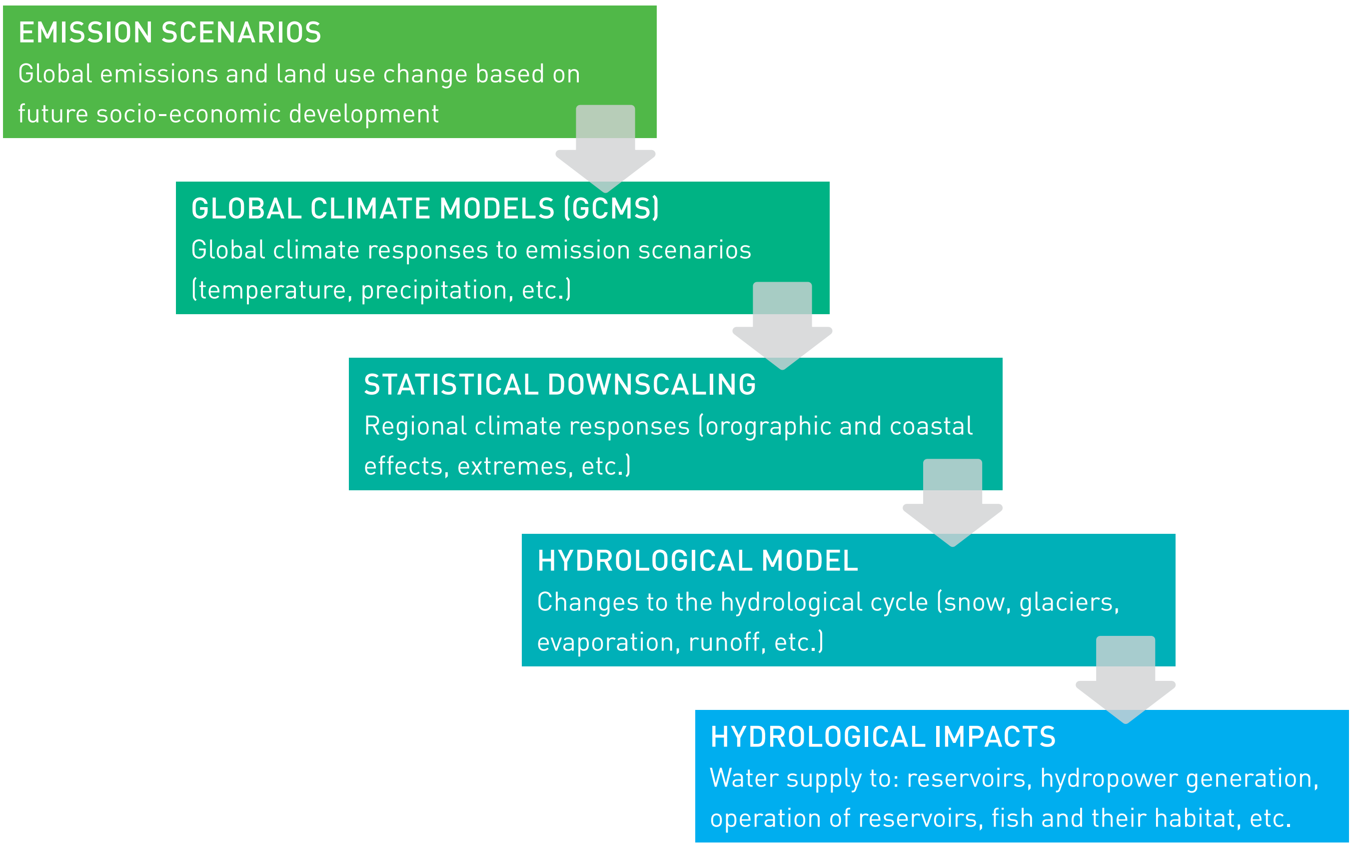


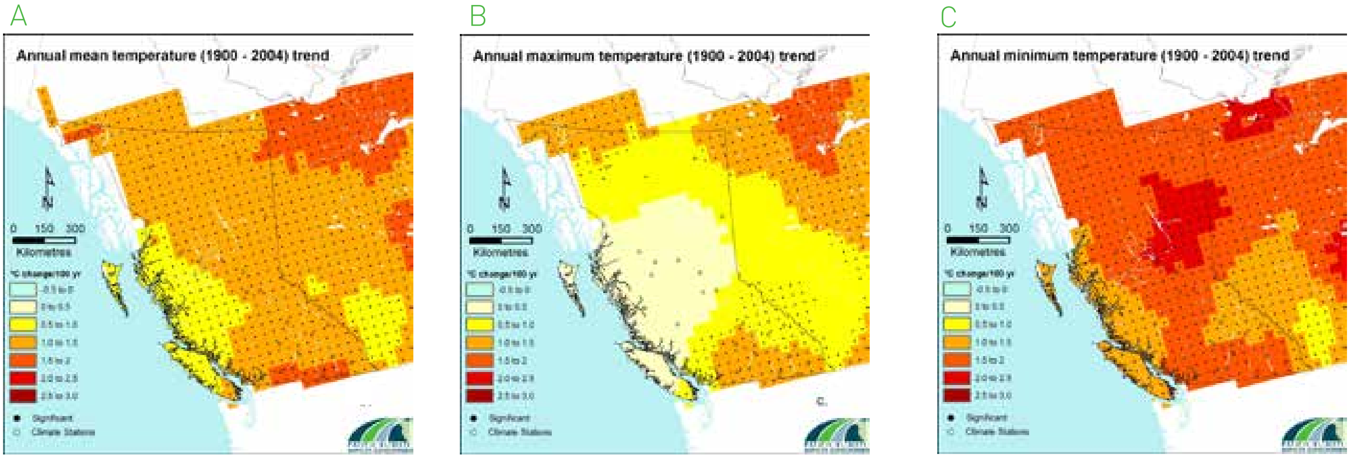
Figure 3: Method for quantifying hydrologic impacts under projected future climates.

OBSERVED TRENDS IN CLIMATE AND HYDROLOGY

HISTORICAL TRENDS IN TEMPERATURE AND PRECIPITATION

Between 1900 and 2004, B.C. saw wetter conditions and an increase in the average annual temperature of about 1.2°C. Most of the increase was a result of higher minimum temperatures (Figure 4).

Annual precipitation increased by about 20 per cent (Figure 4). Most of the precipitation increase occurred in fall, winter, and spring, with the highest increases in the northern interior and no change in the southwest (Figure 5).



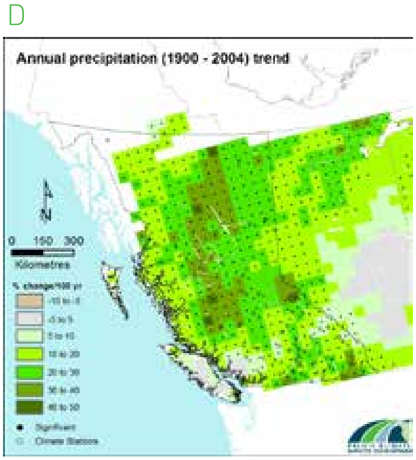


Figure 4: Annual mean temperature and precipitation trends for the 1900-2004 period (Rodenhuis et al. 2007)

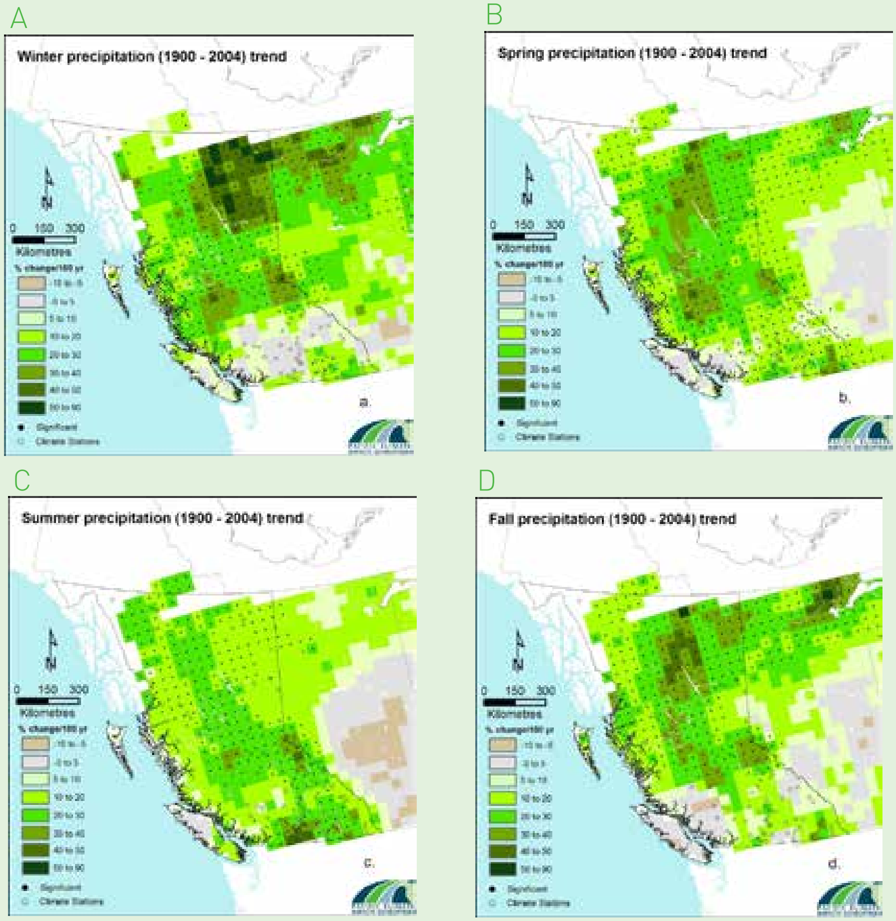


Figure 5: Seasonal precipitation trends for the 1900 to 2004 period (Rodenhuis et al. 2007).

CHANGES TO THE SNOWPACK

Precipitation that falls as snow is temporarily stored in seasonal snowpacks or glaciers. For many BC Hydro watersheds, basin-wide snow storage is larger than reservoir storage. A snowpack's water content is reported in millimetres of snow water equivalent (SWE). SWE on April 1 is often used as a proxy for the maximum snow accumulation of a year, although the timing of peak accumulation timing can vary at individual locations.

Records show a substantial reduction in peak winter snow accumulation over the past 50 years. On average across British Columbia, the peak SWE of 73 long term snow courses dropped by about 18 per cent. The Columbia region showed a 20 per cent reduction, the Kootenay fell by 23 per cent, and the South Coast and Vancouver Island dropped by 17 per cent. The Middle Fraser region experienced a 47 per cent reduction, while the Peace showed no notable changes and a few northerly locations recorded increases in SWE.

One-half to two-thirds of the reduction in peak SWE over the past 50 years is tied to natural ENSO and PDO cycles, with the PDO shift from a cold to a warm phase in 1976 having the most significant effect. After removing the effects of this natural climate variability, the province-wide SWE trends become very small, with a snowpack decline of just four per cent (Table 1). In some regions, adjusting for ENSO and PDO reverses the trend.

An important limitation of SWE analysis is that most of the observing sites are at mid elevations. Models suggest that the colder, highest elevations, which are less sensitive to warming, have seen an increase in peak SWE due to increases in precipitation.

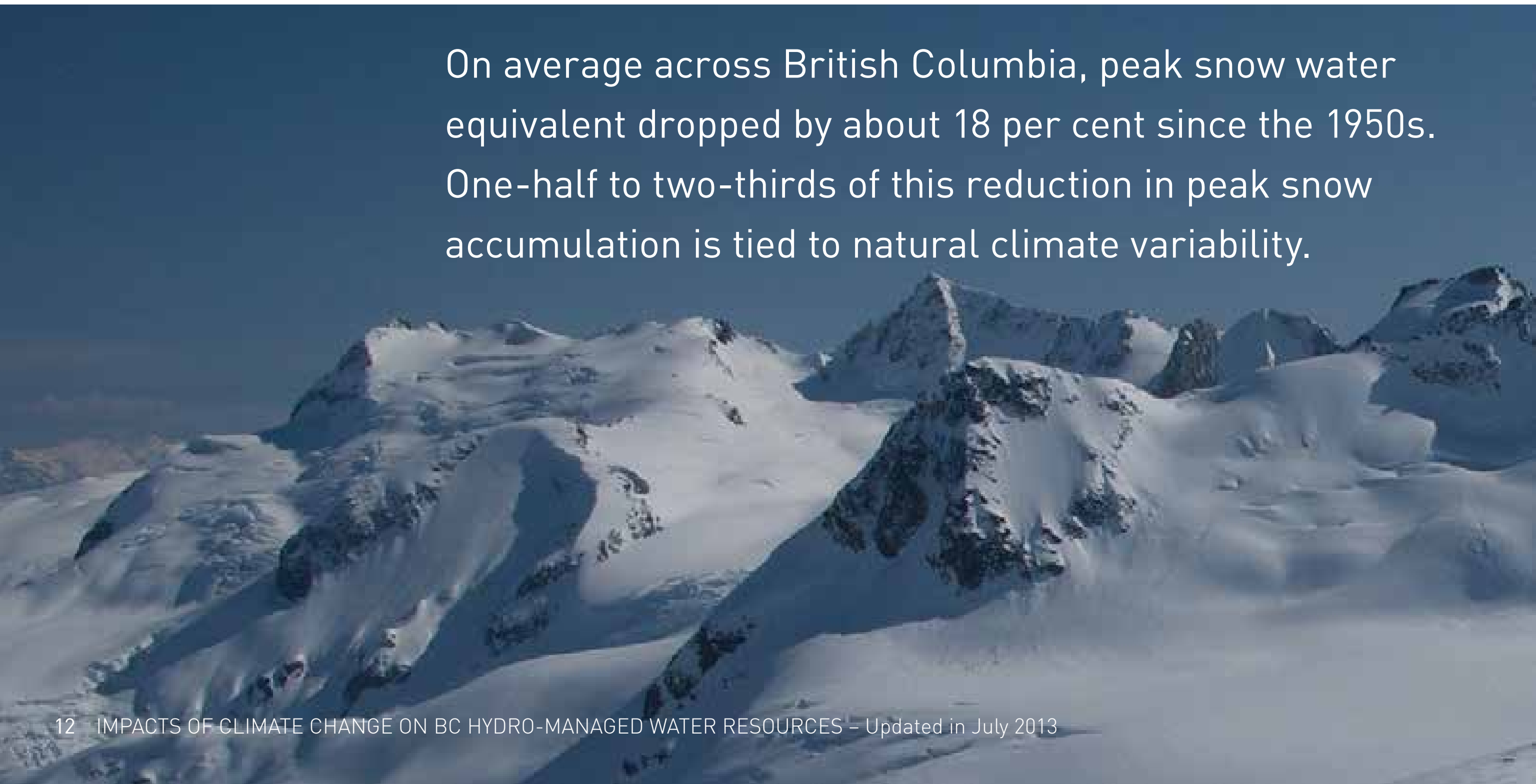


Table 1: Trends in April 1 Snow Water Equivalence at British Columbia long-term snow courses (1956-2005).
* Results are shown for unadjusted data and data with the effects of ENSO and PDO variability removed (Chapman, 2007).

	UNADJUSTED DATA			ADJUSTED DATA*	
BASIN / REGION	Mean [mm]	Change [mm]	Change (%)	Change [mm]	Change (%)
Peace	399	-8	-4	33	7
Columbia	646	-87	-20	7	-5
Kootenay	365	-91	-23	-21	-6
Middle Fraser	213	-82	-47	-31	-27
South Coast/ Vancouver Island	1202	-261	-17	-65	-4
British Columbia (overall)	474	-71	-18	0	-4

% Change Key: little or no change: -5% and 5% increase: > 5% decrease: < -5%

GLACIER CHANGE

A change in glacier cover provides visually compelling evidence of the effects of climate change on the water cycle. Glaciers across the province lost about 11 per cent of their area between 1985 and 2005. Coastal glaciers lost less area than interior glaciers, but absolute volume loss was larger in the Coast Mountains than in the Columbia region or the Rocky Mountains. In the Columbia River basin, glacier cover declined by about 16 per cent from 1986 to 2000. Glaciers thinned most at lower elevations. Figure 6 illustrates the retreat of the Illecillewaet Glacier at Roger's Pass between 1887 and 2000.

Glaciers cover approximately 25,000 km^2 of British Columbia which is just three per cent of the total surface area. At the scale of watersheds operated by BC Hydro, the impact of glacier melt on annual flow volumes is relatively minor. However, even a glacier cover of five per cent, such as in the Mica basin, can contribute significant flow in the late summer. During the warm and dry summer of 1998, for example, glacier melt contributed 35 per cent to the Mica basin's September streamflow. With a warming climate, those contributions will very likely decrease as glaciers retreat.

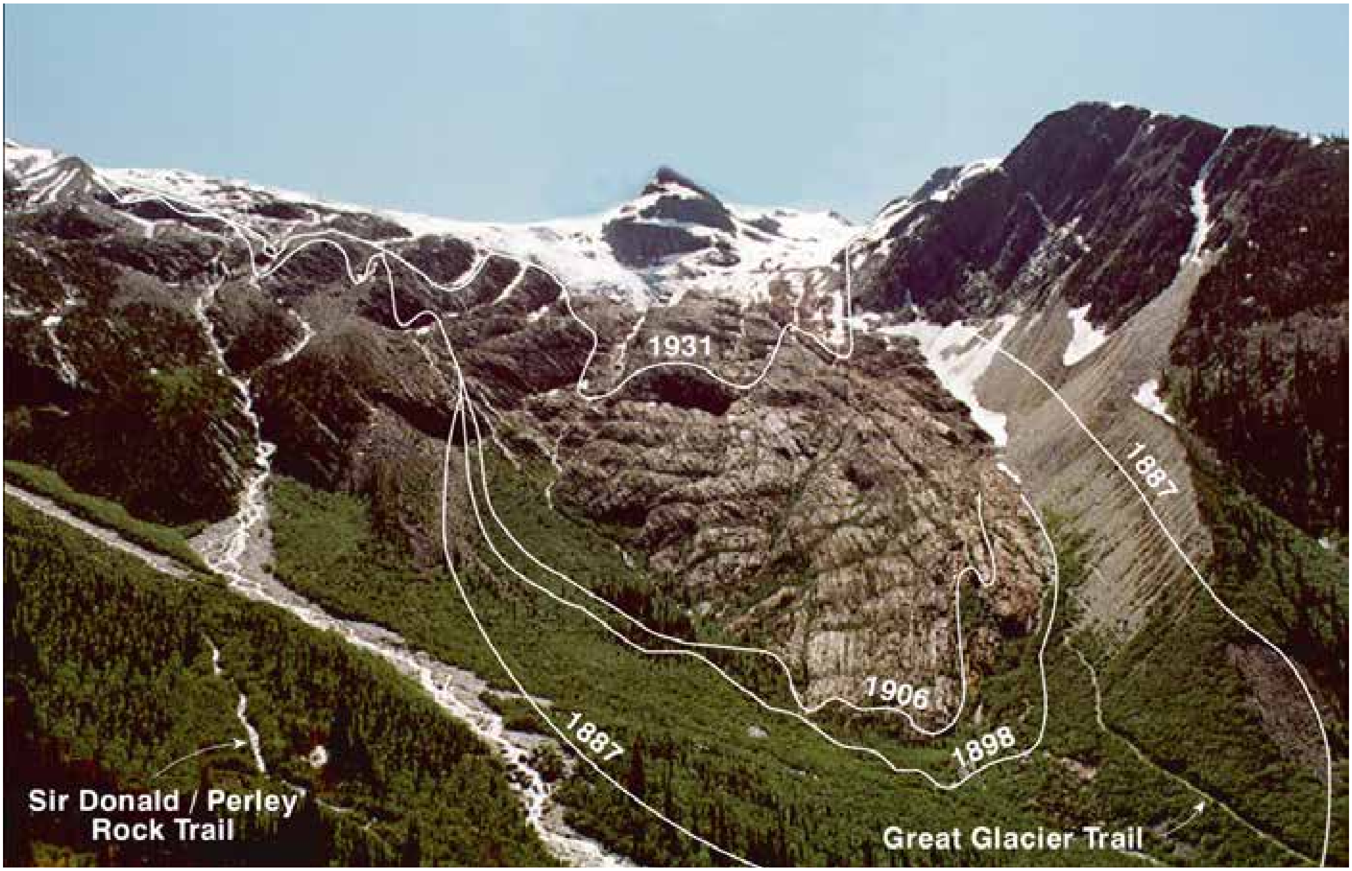
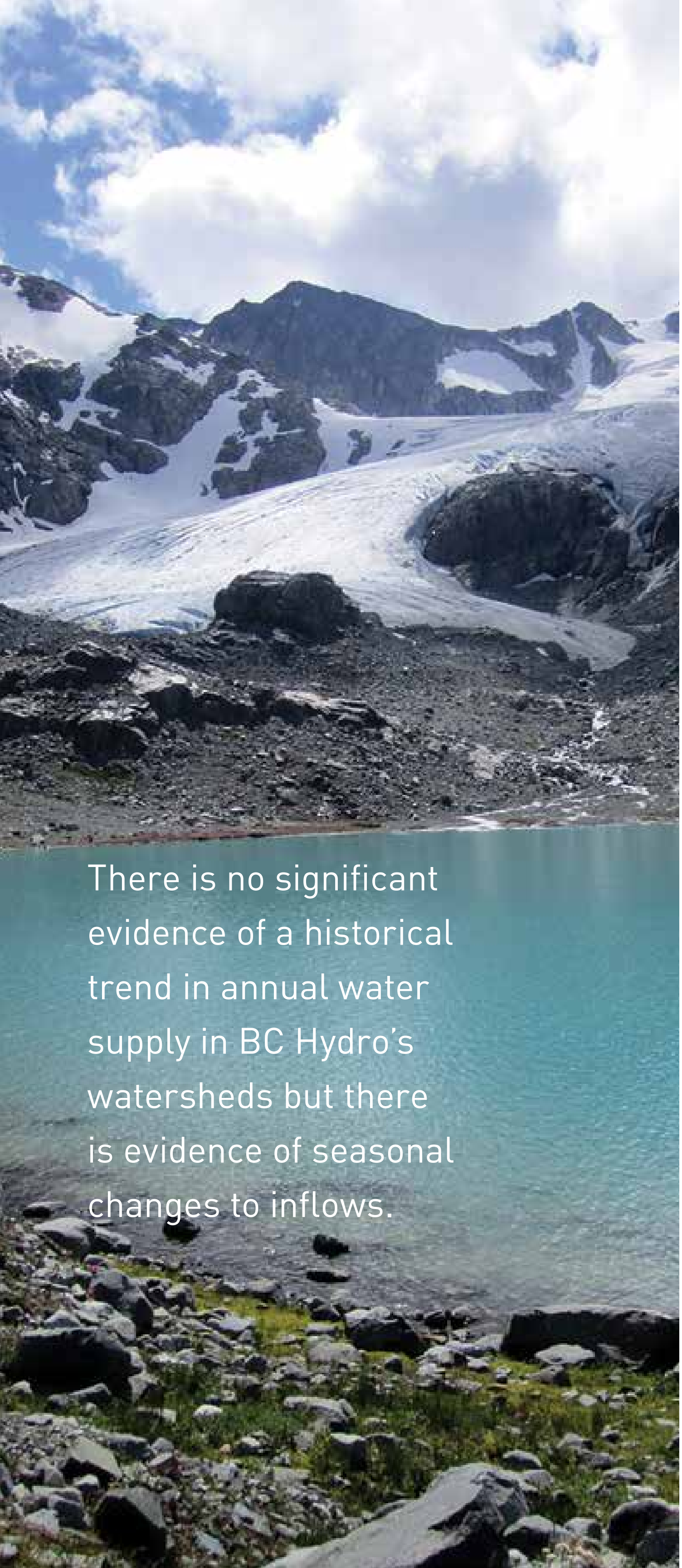


Figure 6: Extent of Illecillewaet Glacier at Roger's Pass (Selkirk Mountains) in the Arrow watershed in 2000, with lines indicating previous glacier extent. (Source: Dr. Dan McCarthy, Brock University & Mas Matsushita, Parks Canada.)



OBSERVED CHANGES IN RESERVOIR INFLOWS

Researchers have reconstructed streamflows for the Peace River at the Peace-Athabasca Delta using lake sediments, while others have used patterns of tree rings to establish long-term streamflow records for the Chilko River and its glacier-fed watershed in the Coast Mountains. Findings of these studies and of a similar study for the Columbia River at The Dalles indicate that over the past ~250 years both wetter and drier conditions than currently observed have persisted for decades under natural climate variability.

A detailed analysis of climate change signals in BC Hydro reservoir inflows found no significant trends of declining annual total water supply between 1984 and 2007. Rather, there is some evidence for a modest historical increase in streamflow in some basins. There is, however, clear evidence for changes in the seasonality of flow. Fall and winter flows have increased at most of BC Hydro’s watersheds. There is weaker evidence for a decline in late-summer flows in snowmelt dominated watersheds. The absence of detectable trends in annual water supply does not imply that there are none, however. Brief record length and poor data quality mean a genuine but weak climate change signal could be hidden by more dramatic year-to-year fluctuations.

FUTURE PROJECTIONS

Climate patterns for the 21st century are derived from model simulations based on different emission scenarios. Emissions are difficult to project because they depend on economic growth, population increase, and technological and land-use changes, all of which are impossible to anticipate accurately. The emissions scenarios are designed to reflect the range of these uncertainties. Unless stated otherwise, results for all future scenarios focus on projections for the 2050s.

TEMPERATURE AND PRECIPITATION PROJECTIONS

In general, trends observed during the past century in British Columbia will likely continue throughout the 21st century. By the 2050s, all parts of British Columbia will very likely get warmer in all four seasons. The mean annual temperature is projected to increase by 1.4 to 3.7ºC, which is greater than the range of historical variability. In the southeast, warming will be greatest in summer, while in the northeast, warming will be greatest in winter. In the Campbell River watershed and other parts of south coastal B.C., the warming will be more evenly distributed throughout the year.

Much of British Columbia will likely get modestly wetter (Figure 7) by 0 to 18 per cent. Contrary to temperature projections, however, the projected increase in precipitation is within the range of historical variability. Precipitation increases are projected to be greatest in fall, winter, and spring.

Precipitation increases are higher for the northern and northeastern parts of the province, where they are also more evenly distributed across all seasons. In summer, the southern portion of the province, and particularly the southwest, will likely become drier.

Median Precipitation Change Projected for the 2050s

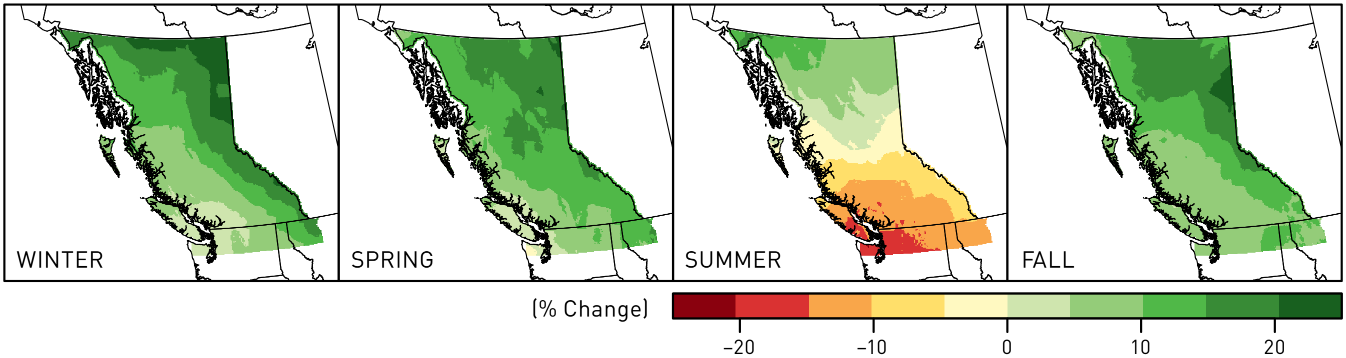


Figure 7: Seasonal mean precipitation change in the 2050s (2041-2070) relative to the 1961-1990 baseline period. (Source: Schnorbus et al. (2011)).

By 2050, the mean annual temperature in British Columbia is projected to increase by 1.4 to 3.7ºC, which is greater than the range of historical variability.

HYDROLOGICAL PROJECTIONS FOR THE UPPER COLUMBIA REGION

Mica Dam drains 20,742 km^2 of the Columbia River headwaters. Annual precipitation averages 1,075 millimetres with 70 per cent falling as snow. The average annual temperature is 1.9°C. In 1985, glaciers covered 1,268 km^2, representing 6.1 per cent of the basin. Between 1985 and 2005, the glacier area shrank by 181 km^2, reducing glacier cover to 5.2 per cent of the basin.

GLACIERS

Glaciers in the Columbia basin are shrinking and, even with no further warming, would likely continue to retreat for at least another decade. Future simulations project that glacial coverage in the Mica basin will decrease by at least 44 per cent and possibly as much as 100 per cent by 2100, with an average decrease of 85 per cent. Figure 8 visualizes the retreat of the Athabasca glacier in the 21st century.

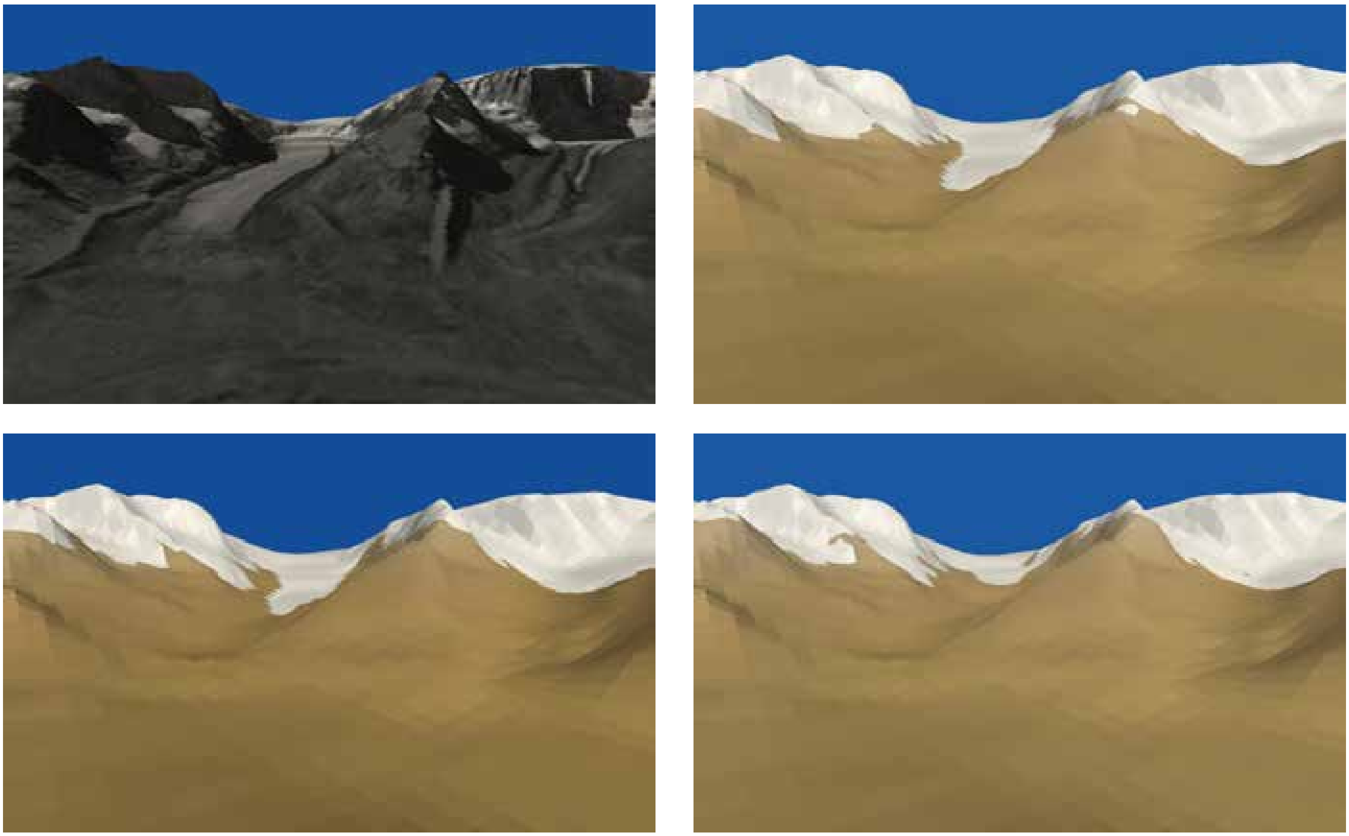


Figure 8: Athabasca Glacier coverage observed in 2001 (upper left, LandSat satellite photo) and projected for 2050, 2080 and 2100. GCM forced with the A1B emission scenario. Graphics: Glacier Modelling Group, Earth & Ocean Sciences, UBC.

STREAMFLOW PROJECTIONS

Streamflow projections for the Mica basin are available from three different studies (PCIC, WC2N, UW-CIG). While streamflow projections for the Mica basin come with high levels of uncertainty, all three studies agree that the mean annual flow will increase (Figure 9). Each foresees an earlier onset of spring melt and lower flows in late summer and early autumn (Figure 10), consistent with other studies of streamflow in snow-dominated catchments. The decrease in icemelt contributions to August streamflow exacerbates the low flows in late summer produced by an earlier snowmelt. The overlap between the different emission scenarios (Figure 9b) shows that the primary source of uncertainty comes from modeling climate and hydrology rather than from GHG emission scenarios.

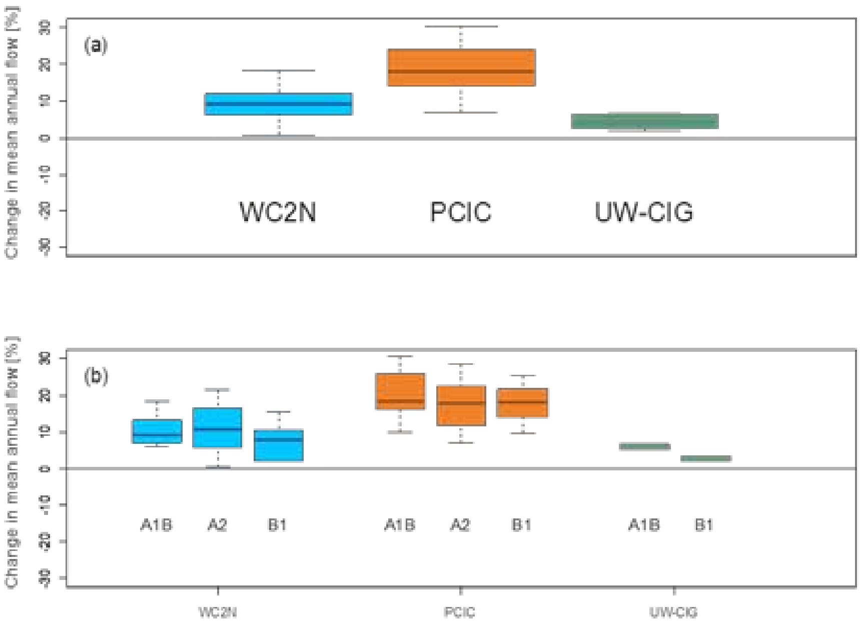


Figure 9: Projected changes in mean annual flow summarized for each study using (a) all studied emission scenarios and GCMs and (b) for each individual emission scenario.

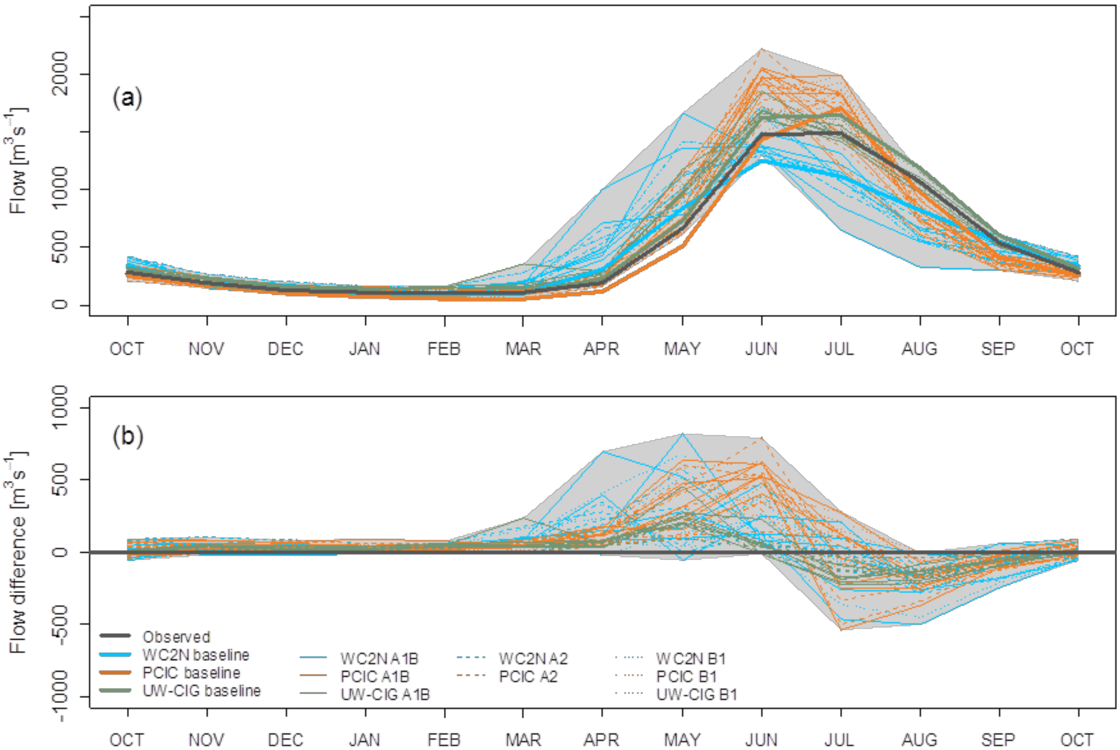


Figure 10: (a) Observed and future 2050s monthly Mica inflow and (b) flow anomalies relative to historical baseline for each study (bold lines) for all emission scenarios. Lines correspond to monthly medians for individual GCM runs under A1B, A2, or B1 emission scenarios. Flow anomalies (b) are plotted relative to the median of all historic runs for WC2N, PCIC and UW-CIG, respectively.

HYDROLOGICAL PROJECTIONS FOR THE PEACE REGION

The Williston basin in the northern Interior forms the headwaters of the Peace River. The region has a continental climate with frequent outbreaks of Arctic air. The mean annual precipitation is 838 millimetres, approximately 40 per cent in the form of snow. The average annual temperature is 0.2°C. A spring freshet is the dominant runoff event. Most precipitation falls as rain in the summer months, and glacier melt is negligible.

STREAMFLOW PROJECTIONS

Climate change scenarios for the Williston reservoir project an increase in inflow ranging between 11 per cent and 15 per cent by the 2050s, with streamflow increasing throughout most of the fall, winter and spring seasons (Figure 11). There is evidence for an earlier freshet onset and a shift in the peak flow from June to May. Summer flows are projected to decline, with the greatest decline in July.

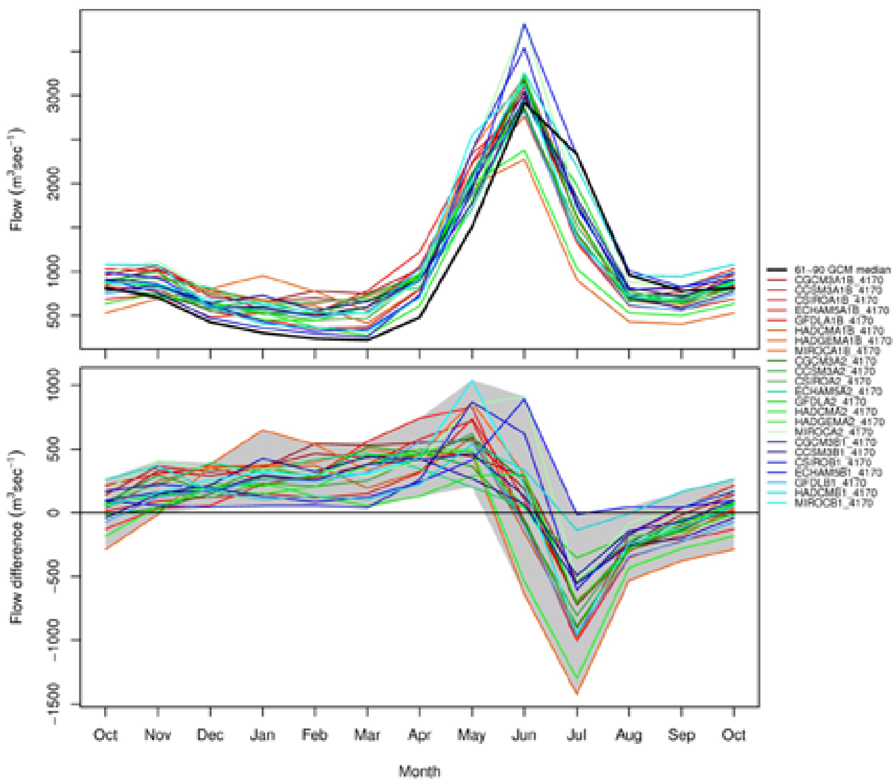


Figure 11: (a) Observed and future 2050s monthly Williston basin (GMS) inflow and (b) flow anomalies relative to historical baseline for each study (bold lines). The historic baseline is the median of all historic runs. Future streamflow is shown as the monthly median for each individual GCM/emission scenario combination. (Source: PCIC (Schnorbus et al. 2011)).

HYDROLOGICAL PROJECTIONS FOR VANCOUVER ISLAND, THE LOWER MAINLAND AND THE SOUTH COAST

Campbell River at Strathcona is a small coastal watershed that drains the central Vancouver Island mountains to the Strait of Georgia and impounds the Upper Campbell Lake and Buttle Lake Reservoirs. Annual precipitation in the study area is 2,960 millimetres, with 78 per cent falling from October to March. Inflows peak in the fall from rainfall and in spring from snowmelt, while glacier melt is negligible.

STREAMFLOW PROJECTIONS

By 2050, the Campbell River at Strathcona watershed is expected to change from a hybrid to a rainfall-dominated regime (Figure 12). Snowfall will decrease, and flows from October to April will increase, with a substantially reduced spring freshet. GCMs consistently predict the highest flow increases in January and the largest decreases in June. No significant changes to annual inflow volumes are projected.

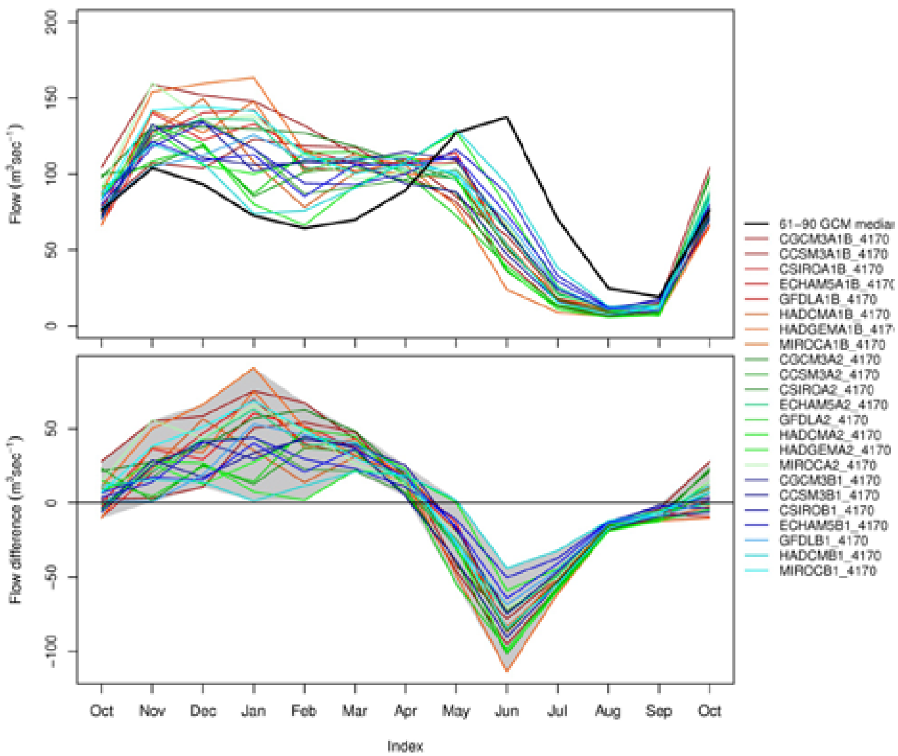


Figure 12: (a) Observed and future 2050s monthly inflow into Campbell River at Strathcona Dam and (b) flow anomalies relative to historical baseline for each study (bold lines). The historic baseline is the median of all historic runs. Future streamflow is shown as the monthly median for each individual GCM/emission scenario combination. (Source: PCIC (Schnorbus et al., 2011)).

SUMMARY OF CHANGES TO BC HYDRO'S WATER SUPPLY

ANNUAL CHANGES

Climate change projections for several of BC Hydro's watersheds suggest a likely small increase in water availability caused by a modest increase in future precipitation. Model uncertainties outweigh the relatively minor differences in projections among various emission scenarios.

There are regional differences in projections of future water availability. For the Mica basin, increases in overall water supply are likely, despite a decline in the glacier melt contribution, because increases in future precipitation more than offset the losses from shrinking glaciers (Table 2). Some models project an increase of only 10 per cent, others as much as 26 per cent. The Revelstoke and Arrow watersheds can also expect modest increases in annual flows. For the southern parts of the Columbia and Kootenay River basins (i.e., Whatshan, Kootenay Lake and Slocan) annual water supply is likely to slightly increase or remain unchanged. For the Williston basin, some GCMs see no change in water availability, while others predict increases of up to 15 per cent. The median projection is an increase of about 11 per cent. No significant changes to annual flows are projected for coastal watersheds.

All models have difficulties in simulating evaporation and the response of vegetation. However, potential and actual evaporation will likely increase due to higher temperatures, partly offsetting higher precipitation input. A notable exception is one model projected a decrease in evaporation for the Mica basin, which could further increase the annual water supply.

Table 2: Projected seasonal and annual inflow anomalies for select BC Hydro watersheds for the 2050s relative to 1961-1990 average under different emission scenarios. The anomalies refer to the median of the GCM ensemble for each emission scenario (Source: PCIC).

REGION	WATERSHED	EMISSION SCENARIO	WINTER	SPRING	SUMMER	FALL	YEAR
SOUTH COAST	Strathcona	A1B	51%	6%	-62%	11%	0%
		A2	43%	4%	-56%	7%	-2%
		B1	45%	9%	-47%	5%	4%
COLUMBIA	Mica	A1B	63%	79%	10%	11%	21%
		A2	75%	75%	9%	5%	17%
		B1	49%	53%	10%	7%	19%
	Revelstoke	A1B	107%	77%	-1%	10%	17%
		A2	124%	68%	-2%	1%	11%
		B1	77%	53%	5%	6%	15%
	Arrow	A1B	95%	61%	0%	-12%	10%
		A2	92%	61%	0%	-11%	4%
		B1	98%	57%	5%	-10%	10%
	Whatshan	A1B	117%	37%	-42%	5%	2%
		A2	114%	32%	-39%	-4%	-3%
		B1	84%	29%	-28%	6%	4%
KOOTENAYS	Duncan	A1B	49%	72%	7%	9%	16%
		A2	58%	73%	5%	5%	12%
		B1	43%	49%	10%	7%	15%
	Kootenay Lake	A1B	95%	44%	-17%	-5%	8%
		A2	84%	35%	-15%	-10%	3%
		B1	79%	32%	-5%	1%	10%
PEACE	Williston	A1B	84%	61%	-17%	8%	12%
		A2	64%	60%	-16%	5%	9%
		B1	56%	46%	-12%	5%	13%

Key: little or no change: -5% and 5% increase: > 5% decrease: < -5%

A modest increase in future annual water availability is likely for BC Hydro's integrated hydroelectric system.

SEASONAL CHANGES

Summer streamflow and hence water availability during summer will very likely decline across the province. Snowmelt will start earlier and flows will peak earlier. This has already been observed over the past few decades. Snowmelt-dominated watersheds in southeastern B.C., for example Arrow and Kootenay Lakes, will experience higher flows during winter and lower flows during late summer, but will very likely remain snowmelt-dominated. The Williston basin will remain a hybrid snowmelt- and rainfall-dominated watershed.

Glaciers are projected to continue retreating under all future climate scenarios. Under a warming climate, the contribution of glacier melt to streamflow initially increases but eventually declines as glaciers shrink. Evidence shows that B.C. glaciers are already shrinking and studies suggest that the glacier melt contribution to streamflow is already declining. In the Mica basin, approximately 60 per cent of glacier cover is projected to disappear by 2050 and 85 per cent by 2100. Some scenarios show a complete loss of glaciers in the region by 2100.

The biggest changes to seasonal flow regimes can be expected for coastal watersheds. There, rainfall-runoff processes will very likely become dominant over snowmelt. Hybrid rainfall- and snowmelt-dominated watersheds will turn into rainfall-dominated watersheds. With only marginal precipitation increases, the region will see a decline of basin-wide snowpack and consequently a reduction in spring runoff.

Summer streamflow and hence water availability during summer will very likely decline while streamflow during winter months will very likely increase across the province.

BC Hydro will evaluate how the projected hydrological changes will impact hydroelectric power generation.

NEXT STEPS

Climate change impact studies give a reasonably good understanding of future trends in water availability, but have only been undertaken for some BC Hydro watersheds. BC Hydro has renewed its partnership with the Pacific Climate Impacts Consortium to expand the hydrologic impact studies to other BC Hydro watersheds.

The next step for BC Hydro is to feed operational and planning models with projected inflow scenarios to assess how sensitive hydroelectric power generation is to climate change. For instance, it has not been determined how effectively reservoir storage will be able to buffer projected changes in seasonal runoff timing, such as lower summer inflows. Changes in the year-to-year variability of water supply, and hence changes to the frequency and severity of hydroelectric droughts will also need further research.

Water availability is but one of many climate-related factors affecting hydroelectric power generation. Just as important are the effects of a changing climate on heating and cooling demand, on infrastructure such as transmission and distribution lines, impacts to fisheries and habitat, as well as changes in demographics, socio-economics, and government policies and regulation. All these factors must be integrated to develop a useful and holistic vision of how best to adapt to a changing climate. To this end, BC Hydro continues to work with the Pacific Climate Impacts Consortium and others to expand our knowledge of climate change science. An Adaptation Working Group at BC Hydro continues to assess and address the risks of climate change, and to continue powering B.C. with clean, reliable electricity, for Generations.

SOURCES

Bolch, T., Menounos, B., Wheate, R., 2010. Landsat-based inventory of glaciers in western Canada, 1985-2005. Remote Sensing of Environment, 114(1): 127-137.

Chapman, A., 2007. Trend in April 1 Snow Water Equivalent at Long-Term British Columbia Snow Courses, in Relation to ENSO, PDO and Climate Warming.

Covey, C. et al., 2003. An overview of results from the Coupled Model Intercomparison Project. Global and Planetary Change, 37(1-2): 103-133.

Fleming, S.W., 2010. Climate Change Signal Detection in BC Hydro Reservoir Inflows. Unpublished BC Hydro Technical Report.

Gedalof, Z., Peterson, D.L., Mantua, N.J., 2004. Columbia River flow and drought since 1750. Journal of the American Water Resources Association, 40(6): 1579-1592.

Gobena, A., 2010. Teleconnections between Large-scale Climate Modes and the Hydroclimate of BC Hydro Watersheds. Unpublished BC Hydro Technical Report.

Haigh, J.D., Winning, A.R., Toumi, R., Harder, J.W., 2010. An influence of solar spectral variations on radiative forcing of climate. Nature, 467(7316): 696-699.

Hamlet, A.F., Lettenmaier, D.P., 1999. Effects of Climate Change on Hydrology and Water Resources in the Columbia River Basin. JAWRA Journal of the American Water Resources Association, 35(6): 1597-1623.

Hart, S.J., Smith, D.J., Clague, J.J., 2010. A multi-species dendroclimatic reconstruction of Chilko River streamflow, British Columbia, Canada. Hydrological Processes, 24(19): 2752-2761.

Jost, G., Moore, R. D., Menounos, B., Wheate, R., 2012. Quantifying the contribution of glacier runoff to streamflow in the upper Columbia River Basin, Canada. Hydrol. Earth Syst. Sci., 16, 849-860.

Meehl, G.A., Boer, G.J., Covey, C., Latif, M., Stouffer, R.J., 2000. The Coupled Model Intercomparison Project (CMIP). Bulletin of the American Meteorological Society, 81: 313-318.

Moore, R.D. et al., 2011. Glacier and Streamflow Response to Future Climate Scenarios, Mica Basin, British Columbia. Unpublished BC Hydro Technical Report.

Nakicenovic, N. et al., 2000. Special report on emissions scenarios: a special report of Working Group III of the Intergovernmental Panel on Climate Change, Pacific Northwest National Laboratory, Richland, WA (US), Environmental Molecular Sciences Laboratory (US).

Pederson, G.T. et al., 2011. The Unusual Nature of Recent Snowpack Declines in the North American Cordillera. Science, 333(6040): 332.

Raupach, M.R. et al., 2007. Global and regional drivers of accelerating CO2 emissions. Proceedings of the National Academy of Sciences, 104(24): 10288.

Rodenhuis, D., Bennett, K., Werner, A., Murdock, T., Bronaugh, D., 2007. Hydro-climatology and future climate impacts in British Columbia, Pacific Climate Impacts Consortium, Victoria, B.C..

Schiefer, E., Menounos, B., Wheate, R., 2007. Recent volume loss of British Columbian glaciers, Canada. Geophysical Research Letters, 34: 1-6.

Schnorbus, M.A., Bennett, K.E., Werner, A.T., Berland, A.J., 2011. Hydrologic Impacts of Climate Change in the Peace, Campbell and Columbia Watersheds, British Columbia, Canada. Pacific Climate Impacts Consortium, Victoria, B.C, pp. 157.

Service, R.F., 2004. As the west goes dry. Science, 303: 1124-1127.

Stahl, K., Moore, R.D., 2006. Influence of watershed glacier coverage on summer streamflow in British Columbia, Canada. The University of British Columbia, pp. 21.

Stahl, K., Moore, R.D., Shea, J.M., Hutchinson, D., Cannon, A.J., 2008. Coupled modelling of glacier and streamflow response to future climate scenarios. Water Resour. Res., 44.

UW-CIG, 2010. Hydrologic Climate Change Scenarios for the Pacific Northwest Columbia River Basin and Coastal drainages, http://www.hydro.washington.edu/2860/. University of Washington Climate Impacts Group.

Wolfe, B.B. et al., 2005. Impacts of climate and river flooding on the hydro-ecology of a floodplain basin, Peace-Athabasca Delta, Canada since AD 1700. Quaternary Research, 64(2): 147-162.

Wood, A.W., Leung, L.R., Sridhar, V., Lettenmaier, D.P., 2004. Hydrologic implications of dynamical and statistical approaches to downscaling climate model outputs. Climatic Change, 62(1): 189-216.

Zhang, X., Vincent, L.A., Hogg, W., Niitsoo, A., 2000. Temperature and precipitation trends in Canada during the 20th century. Atmosphere-Ocean, 38(3): 395-429.

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